Prevention of flight-related neck pain in military aircrew

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Citation for published version (APA):
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General Discussion
Chapter 9
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The main objective of this thesis was to study neck pain in military aircrew especially of the Royal Netherlands Air Force (RNLAF). The purpose of the studies performed in this thesis was to generate knowledge about the extent of the problem and identify associated factors concerning the work exposures and the aircrew’s capacity and to learn about aircrew’s experiences to identify feasible preventive measures. Based on the type of aircraft flown and the corresponding tasks to be performed, the aircrew was divided into the following three different occupational populations: the F-16 pilots, the helicopter pilots and the helicopter rear aircrew members. Aircrew members flying other fixed wing aircrafts of the RNLAF than the F-16 were excluded from this thesis. In this chapter, the main research findings of this thesis are presented by answering the research questions as formulated in Chapter 1 followed by the interpretations of these findings and methodological considerations. Recommendations for future research and practice are presented at the end of this chapter.

Main findings

1. What is the prevalence of flight-related neck pain in military aircrew?

F-16 pilots

The overall one-year prevalence of any neck pain in F-16 pilots of the Royal Netherlands Air Force and the Belgian Air Force was 42%, and a total of 19% of the participating F-16 pilots experienced more than two episodes of neck pain which lasted for at least one day in the previous year. Of this latter group 77% indicated their complaints were flight-related.

Helicopter pilots and rear aircrew

The one-year prevalence estimates of any neck pain of the helicopter aircrew population of the Dutch Defence Helicopter Command\(^1\) were 43% in the helicopter pilot population and 62% in the rear aircrew population. Regular or continuous neck pain was reported by 20% of the pilots and by 28% of the rear aircrew members (Chapter 4 and 5). Over 90% of the pilots and rear aircrew members reporting regular or continuous neck pain attributed their complaints to flying. Almost half of the pilots with neck pain related their complaints to the use of night vision goggles.

2. What aspects of the aircrew members’ capacity and which work factors are associated with flight-related neck pain?

F-16 pilots

The pilots who experienced more than two episodes of neck pain which lasted for at least one day in the previous year reported significantly more often that their work

\(^1\) The Defence Helicopter Command of the Royal Netherlands Air Force include all land and sea tasked helicopter units of the Defence Organisation
demanded high forces, that they hold their neck in a forward bent position and had to sit for a long time compared to the pilots without these complaints. The pilots with neck pain reported significantly more hours of computer work per day. Flying hours were not significantly associated with neck pain. Considering the responses to work exposures, being physically and mentally tired at the end of the workday were significantly more often reported by pilots with neck pain compared to their colleagues without neck pain (Chapter 2). Regarding the F-16 pilot’s capacity (Chapter 3), the physical abilities of the neck of the F-16 pilots were measured by assessing the cervical range of motion, the neck position sense and the neck muscle strength. The F-16 pilots reporting regular or continuous neck pain had a decreased cervical range of motion in the sagittal and transversal plane compared to their colleagues without such complaints.

Helicopter pilots and rear aircrew
The pilots reporting regular or continuous neck pain reported significantly more total flying hours and flying hours in the previous year compared to their colleagues without these complaints. The type of helicopter flown or the flight helmet used was a work factor significantly associated with having regular or continuous neck pain. Considering the worker’s characteristics, female gender and older age were significantly associated with neck pain. Furthermore a higher frequency of previous history of neck pain, a higher prevalence of shoulder and thoracic pain in the previous 12 months, and being physically fatigue at the end of the workday were significantly more often reported by the pilots with neck pain (Chapter 4). The experienced neck load during flight was significantly highly correlated with the experienced neck pain during flight (Chapter 8). Regarding the pilots’ and rear aircrew members’ capacity (Chapter 6), the physical abilities of the neck assessed as the cervical range of motion, the position sense and strength were not different, neither between the pilots and rear aircrew members nor between the pilots and rear aircrew members with neck pain compared to their colleagues without neck pain and no interaction effect between occupation (pilot/rear aircrew) and neck pain status (neck pain/no neck pain) was found.

3. Can an optimised helmet fit reduce the neck load and pain during flight in helicopter aircrew?
A common work factor of both helicopter pilots and rear aircrew members was the head equipment and often making dynamic movements with their necks (Chapter 5). Exploring the experiences of the helicopter pilots and rear aircrew members revealed that the stability of the head equipment, the fit of the helmet and the comfort of the helmet were related to the experienced neck load during flight (Chapter 7). Based on these results, an intervention was developed and tested that aimed to optimise the fit of the aircrew’s helmet and sought to improve the stability of the helmet while taking comfort into account (Chapter 8). The evaluation of applying an optimised helmet fit resulted in a significant decrease in the experienced neck load and a trend in decreased
neck pain during flight. In addition, the optimised helmet fit resulted in a significant decrease in helmet gliding (increase of helmet stability) and a decreased experience of pressure points, a trend in decreased experienced irritation/distraction and a significant increase in the experienced overall helmet comfort during flight.

**Interpretations of findings**

**Neck pain prevalence**

The estimates of the one-year prevalence of regular or continuous neck pain in F16-pilots, helicopter pilots and helicopter rear aircrew members were 19%, 20% and 28%, respectively. These estimates of the neck pain prevalence are similar to those of the Dutch non-flying working population [28]. This would suggest that military pilots and rear aircrew members are at no greater risk for developing neck pain than the non-flying working population. However, military aircrew of the RNLAF are a selected population; they have to meet medical and physical standards before entering flying school and undergo yearly medical examinations. They therefore are assumed to be a population in better physical condition than the average worker. From this perspective, a lower prevalence of neck pain would be expected, and these similar prevalence estimates could thus indicate a relatively higher risk for neck pain among military aircrew. An explanation for this higher risk may be sought in the specific work demands of military aircrew compared to the general working population. In the helicopter pilots population, this explanation was strengthened by the result that more flying hours were reported by the pilots with neck pain compared to their colleagues without regular or continuous neck pain. In addition to the health concern, in other studies, military pilots have reported that their neck pain interfered with their flying performance and duty, which makes neck pain not only a health concern but also a safety and operational concern [2;9;26]. Given the neck pain prevalence found, the perceived relationship of neck complaints to flying, and the consequences of pain on flying performance and duty reported in the literature, we consider neck pain in the military aircrew of the RNLAF to be a work-related complaint that should be prevented whenever possible.

**Towards prevention**

**Improving physical capacity?**

Initially, the strategy chosen towards the prevention of flight-related neck pain was to develop a physical training intervention program to improve the physical capacity. Interventions targeted at lowering the work exposures were believed to be infeasible because of the operational demands and regulations accompanying military flying. In addition, cockpit and cabin ergonomics in military aircrafts is unfortunately not very open to change, and many of the aircrafts will remain operational for many years in the future. The focus in preventing neck pain is therefore necessarily on the individual. To
develop a physical training intervention program as a preventive measure for flight-related neck pain, the possible impairments of the physical abilities of pilots and rear aircrew with neck pain should first be identified. We measured the active cervical range of motion, the position sense and maximum isometric muscle strength, which are three tests often used in the clinical setting to assess neck pain [21]. According to the literature, the high demands on muscle strength during flight and the pilots’ lack of muscular force of the cervical musculature could be the main risk factors causing neck pain [3;22]. As a consequence, neck strengthening exercises are often recommended in the prevention of neck complaints in fighter pilots [1;4;11;19]. However, in our study (Chapter 3) there were no significant differences between healthy pilots and those with neck pain concerning neck muscle strength. Furthermore, pilots who actually performed neck exercises were equally represented in the group with and without neck pain (Chapter 2). Additionally, Newman [20] could not show any differences in pain prevalence between pilots who performed neck strength exercises and those who did not. These results suggest neck strength training to reduce or prevent neck pain in F-16 pilots as suggested by others might not result in the desired effect. The F-16 pilots with neck pain had a smaller cervical range of motion in the sagittal and transverse plane. Smaller cervical range of motion in the sagittal and transverse plane have been reported in other populations with neck pain [6;10;14;25]. The reason for the smaller cervical range of motion in the neck pain group remains unknown. It has been suggested that a reduced active range of motion in subjects with ongoing neck pain could be expected to relate to fear avoidance, but Ang [4] did not find such relation in military pilots. Other suggestions for a smaller cervical range of motion may be that the decrease might be caused by shortened neck musculature or degenerative changes brought on by flying as in fighter pilots premature degeneration of the cervical spine has been described [23]. Based on our results, training programs to maintain a proper active cervical range of motion might reduce neck pain, but further studies should investigate the reason for a smaller cervical range of motion in fighter pilots and the effectiveness of this type of training program.

We did not find any significant differences in neck muscle strength, neck position sense, or active cervical range of motion between helicopter pilots and rear aircrew or between the pilots and rear aircrew with neck pain and their colleagues without neck pain. To the best of our knowledge, we were the first to compare physical abilities of the neck between pilots and rear aircrew. Our results are in line with a recently performed study by Harrison et al. [16], who did not find any differences in physical abilities between pilots and rear aircrew. Our results suggest that these physical abilities, as assessed in this study are not associated with neck pain in these occupational populations. Some caution is required, however, because the results for the neck strength variables and range of motion variables were always somewhat higher in the pilots and the rear aircrew without neck pain compared to their colleagues with neck pain. The rather small number of pilots and rear aircrew members in the neck pain group might also
have been insufficient to demonstrate significant differences (see methodological considerations). We used three measurements of physical abilities often used in the practice of civilian physiotherapy, and deficits in these abilities have been found in the non-flying population with non-specific neck pain. However, other muscle function mechanisms may play parts in the occurrence of flight-related neck pain. Muscle fatigue, for example was not assessed, although it might play an important role in flight-related neck pain in helicopter pilots, as suggested by others [3;17;18], especially because helicopter flights of 6 to 8 hours are no longer the exception in the RNLAF. It would be interesting to investigate which physical abilities are mainly applicable to in-flight abilities and test these abilities. Referring to the conceptual model of work-relatedness of musculoskeletal complaints (Chapter 1), the mismatch between the physical job requirements and the physical capacity of the worker could be a risk factor for developing work-related neck pain. To validate this hypothesis, the physical requirements of flying should first be assessed, and then they should be compared to the physical capacities of the aircrew members. Further research to measure the in-flight physical requirements of the neck by assessing the in-flight exposures through observations or direct measurements is highly recommended [24;29].

At the same time as the research was carried out for this thesis, Swedish researchers [5] were performing a clinical trial to investigate the preventive efficacy of a neck/shoulder exercise regimen in helicopter pilots on neck pain. The exercises emphasised neck/shoulder movement control and included endurance-strength exercises. The exercise group had a significant reduction in neck pain cases compared to controls at the 12-month follow-up, rated for the previous week and the previous 3 months. Neck training programs may thus be effective in the helicopter pilot population to reduce cases with neck pain. It would be interesting to study whether movement control and endurance-strength are key abilities during flight for helicopter pilots and rear aircrew members.

Our results showed good physical capacities among the helicopter aircrew as assessed in this study. Further research into the required in-flight abilities and the effectiveness of job specific physical training is recommended.

An optimised helmet fit

In addition to differences in work demands between helicopter pilots and rear aircrew, there are also common factors that might be risk factors of flight-induced neck pain. A potential common factor includes the head equipment that is worn and the exposure to dynamic neck movements during flight (Chapter 5). An intervention involving modifications to the flight helmet could therefore be beneficial to both pilots and rear aircrew members. We used the experiences of the pilots and rear aircrew by interviewing them following structured qualitative analyses [8;13] to identify the factors related to the experienced neck load during flight resulting from their head equipment. In line with what would have been expected from a biomechanical point
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of view [15;27], factors such as weight and weight distribution of the flight helmet with mounted equipment were identified as factors related to the aircrew's neck load. However, three other factors, namely the stability of the helmet, the helmet fit and the comfort of the helmet were also identified as factors related to the in-flight neck load and had, to the best of our knowledge, never before been taken into account in studies investigating neck load in military aircrew. Furthermore, the results from the qualitative study revealed the possible reasons for not achieving a stable and comfortable helmet, and based on these results, an intervention could be developed. The intervention of an optimised helmet fit that followed showed a decrease in the experienced neck load during flight. According to the conceptual model describing the work-relatedness of musculoskeletal complaints (Chapter 1), this short-term response indicates potential for this intervention to prevent flight-related neck pain in the longer term. Furthermore the optimised helmet fit resulted in increased comfort during flight and comfort was significantly negatively associated with irritation and distraction during the flight. Thus, in addition to the potential of the intervention to reduce flight-induced neck pain, the intervention of an optimised helmet fit seems to have positive effect on flying performance and duty.

Methodological considerations

In this section, methodological issues are addressed, as well as the strengths and weakness of the study designs, the study population and the outcome measures used. Concerning the study population, a strength of the studies as described in Chapters 2 to 6 is that the intention was to include the whole population of F-16 pilots, helicopter pilots and rear aircrew members who were on active flight status. Only pilots and rear aircrew members who were on military deployment, holiday or sick leave were not included during recruitment. The response rate of the pilots and rear aircrew present at the days the questionnaire and physical tests were administered, was nearly 100%. In total, 70-80% of the F-16 pilots and helicopter aircrew members were reached and participated. In terms of external validity, the main findings can be used in other air forces flying the same types of aircrafts and using the same head equipment. Demographics of personnel and total number of flying hours were similar to other international studies investigating military aircrew [2;16;26]. The main findings could also be of interest for other populations flying similar aircrafts and also using night vision goggles, e.g. the police forces.
In the questionnaire studies, univariate statistical methods were used, multiple outcome measures were tested and several significant outcomes were found. Some researchers argue that the finding of a significant outcome by chance is increased when multiple test are performed and that the p-value should be adjusted to reduce this chance. The need for adjusted p-values when multiple comparisons are made is debatable.
because while the p-value adjustments may reduce the chance of making type I errors, they increase the chance of making type II errors and thus still may lead to incorrect conclusions. Several strategies are suggested in literature to address this complex multiplicity problem [7;12]. For the questionnaire study of the F-16 pilots, we did not adjust the p-value and tested the complete questionnaire for differences in pilots with and without neck pain. This led to numerous significance tests and might be seen as a limitation of that study. However, for the questionnaire study of the helicopter pilots and for the other studies that followed and in which multiple testing was applied, we used the strategy to carefully select the outcome measures based on previous research and the hypothesis for each variable, and we discussed each significant outcome with respect to the other outcomes and possible confounding variables. Because there was a hypothesis for each outcome measure, a p-value for each test could be set and did not need to be adjusted [12]. Furthermore the focus of the different studies of this thesis was not solely on statistical significance, but on describing outcomes and discussing their relevance, which is seen as a strength of these studies.

The outcome measure in the studies described in Chapters 2 to 6 was self-reported neck pain in the previous year and was defined as any pain, including aches and discomfort with a diagram used to illustrate and define the specific neck area. Allocation to the neck pain group or the reference group was based on the responses of the neck pain question as follows: never, occasional, regular or continuous. The reference group in the studies described in Chapters 2 to 4 experienced never or occasionally neck pain in the previous year, while the neck pain group experienced regular or continuous neck pain. Many self-assessment questionnaires exist that address perceived pain and disability and overall self-reports of neck pain have been found to be reliable and valid [21]. We did not use other criteria to allocate the pilots and rear aircrew members into the neck pain group, such as severity of complaints or self-reports of functionality and disability. All participating aircrew members were on active flight status and thus fit to fly. Post hoc it was found that the great majority of the helicopter group reporting regular and continuous neck pain attributed their neck pain to flying compared to only a small proportion of the aircrew members reporting occasional neck pain. This strengthens our belief of having the true flight-related neck pain cases in the neck pain group for the purposes of this thesis, which was to study flight related neck pain for preventive purposes.

It still might be argued whether the contrast between the neck pain group and the reference group was distinctive enough. We considered the division into groups (neck pain versus reference) before the analyses and did not know what the distribution would be of the aircrew population on the four answer possibilities. With the knowledge of the questionnaire studies about this distribution, we decided for the study assessing the physical abilities in the helicopter population to exclude the aircrew members reporting only occasional neck pain to create as much contrast as possible between the groups. No significant differences were found although on average there was a trend
towards lower values in strength and cervical range of motion in the pilots and rear aircrew members with neck pain compared to their colleagues without neck pain. The number of participants in the neck pain group could have been too limited to reach statistical significance, or the contrast between the aircrew with and without neck pain was still too low. As mentioned before all aircrew were on active flight status and fit to fly. Differences in capacities might not have been detectable in this small population with this health status.

A strong study design to explore the experiences of both the pilots and rear aircrew members regarding factors related to the neck load resulting from their head equipment, was used in chapter 7, namely qualitative research methods. By using semi-structured interviews we were able to ask more in-depth questions about their experiences, compared to structured surveys or interviews. By using this method, we were able not only to identify the factors related to their experienced neck load but also to identify the reasons why a stable and comfortable helmet fit was not easily achieved. Using the aircrew’s input for the purpose of finding feasible preventive measures for flight-related neck pain is seen as a valuable strategy.

Several considerations led to the use of a within subject design in Chapter 8. The optimised helmet fit was developed for one helmet type, so only pilots and rear aircrew flying with this type were eligible to participate. This was approximately half of the total helicopter aircrew population. Pilots and rear aircrew were expected to fly at least nine flights using night vision goggles within a period of 3 months during October 2010-March 2011, and they had to be in the Netherlands as the executions of the optimised helmet fit could only take place in the Netherlands. These criteria were responsible for the number of eligible aircrew members, because of which a within-subject design was considered to be the most powerful. Furthermore, the extra value of including a control group in case more aircrew members would have been eligible to participate was rejected before recruitment started. Contamination effects would have been too serious of a risk because the pilots and rear aircrew members work at the same workplace, talk each other daily and regularly fly together.

Recommendations

Recommendations for research

The results of the qualitative study described in Chapter 7 revealed the following six factors that, according to the aircrew, were related to the experienced neck load during flight: the type of flight operation, the weight of the head equipment, the weight distribution of the head equipment, the stability of the helmet, the helmet fit and the comfort of the helmet. An intervention was developed based on these latter three factors. The results of this thesis show that an optimised helmet fit reduces the experienced neck load during night flights and that the experienced neck load is highly
associated with the experienced neck pain. Whether this short-term response may have a preventive effect on neck pain in the longer term was not investigated, and further research is needed to study this issue. There is also a need to further investigate the other three identified factors related to the experienced neck load. Counterweights are provided to aircrew to optimise the weight distribution of their head equipment, but the optimal weight and location of the counterweight on the helmet with respect to neck load is still unknown. There is a need for biomechanical studies that address this issue, and they should take the head and neck positions and movements during flight of both pilots and rear aircrew members into account. Therefore, there is also a need for the assessments of head and neck positions and movements during real flights. Furthermore, according to the results in this thesis, the different type of helicopter operations (e.g., navigation flight, slings and slopes) should be considered in these assessments, because rear aircrew members mentioned that their experienced neck load depended on the type of flight operation. These assessments could further provide important information about the physical abilities needed during flight and further studies could investigate whether these physical abilities meet the physical capacities of the pilots and rear aircrew members. The latter would contribute to a better understanding of the aetiology of flight-related neck pain.

**Recommendations for practice**

**Employees and employer**

An optimised helmet fit should be provided to all pilots and rear aircrew members. The protocol tested in this thesis was developed for one helmet type. Protocols to achieve an optimised helmet fit should be developed and applied for the other helmet types in use with the RNLAF. The flight equipment technicians who are responsible for the helmets fits need to be educated in how to perform these fits according to the protocol. Additionally, the pilots and rear aircrew members should be educated about the importance of an optimal helmet fit for both health and safety concerns and about the factors that determine an optimal fit. Pilots and rear aircrew members at the start of their career often do not know how and why their helmet is supposed to fit. They need to be informed when checks and adjustments of their helmets are needed.

As mentioned, the focus in preventing neck pain is necessarily on the individual, because cockpit and cabin ergonomics are not very open to change. However, in the long term, ergonomics in the military aircraft should receive more attention and the RNLAF should make ergonomic requirements important in their contracts with contractors for new aircrafts, aircraft interiors and flight equipment.

**Flight physician and ergonomist**

All pilots and rear aircrew members undergo medical examination on a yearly basis by flight physicians. Knowledge about the factors and symptoms that differ between aircrew members with and without neck pain is important to the flight physician. He
can recognise these factors and intervene as early as possible to prevent chronic work-related complaints.

Using semi-structured interviews to explore the experiences of the aircrew with respect to their experienced neck load during flight was considered to be a very valuable method in our search to preventive measures. This method is therefore recommended to other ergonomists in their search for other preventive interventions for work-related health complaints.

**Industry**

The flight helmet and night vision goggles in use by the RNLAF are two different systems made by different industries. A secondary aim of the qualitative study was to elucidate the factors contributing to an ideal flight helmet. Based on the results of that study, it is recommended that the industry consider the head equipment as one system in stead of separate systems. Furthermore, factors such as weight, weight distribution, helmet stability, helmet fit and comfort issues should be considered in head equipment designs and requirements. Depending on the helmet type and manufacturer, helmets come in a limited number of sizes. Every head is shaped differently, and the development of custom-made helmets is encouraged.
References


