Prevention of flight-related neck pain in military aircrew
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The effect of an optimised helmet fit on neck load and neck pain during military helicopter flights

Chapter 8
Abstract

The main purpose of this study was to improve the helmet fit of military helicopter aircrew members and evaluate its effect on the experienced helmet stability (helmet gliding), neck load, neck pain, 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 two consecutive interventions of optimising the fit of the aircrew’s helmets: 1) a new helmet fit using a renewed protocol and 2) replacement of a thermoplastic inner liner with a viscoelastic foam inner liner. A total of 18 pilots and loadmasters rated the outcome measures using the Visual Analogue Scales immediately after their night flights, for three night flights in total per measurement period.

The optimised helmet fit resulted in a significant decrease in the experienced helmet gliding, neck load and pressure points, a decrease trend in the experienced neck pain and irritation/distraction, and a significant increase in the experienced overall helmet comfort 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.
Introduction

Neck pain in military helicopter aircrews is a recognised aeromedical problem [2;19]. It has been suggested that neck pain may interfere with flying performance [16], and therefore, neck pain should be prevented not only for health but also safety reasons. Several factors have been associated with the prevalence of flight-related neck pain including awkward flight postures and wearing heavy head equipment [1;8;18]. Helicopter pilots are forced to sit in a slouched posture with a slight twist of the body to the left to control the helicopter because the cockpit is designed with the collective pitch lever on the left side of the pilot’s seat and the cyclic stick between the pilot’s legs [15]. The main tasks of the loadmasters, the aircrew working at the back of the helicopter, are troop management, material handling, surveillance, and clearance tasks, which often require extreme body and head postures [13]. Military helicopter pilots and loadmasters wear helmets and Head Up Displays (HUD) and use Night Vision Goggles (NVG) during night operations. The design requirements of the flight helmet maintain that the centre of gravity of the helmet should be close to the head’s centre of gravity to increase stability and minimise the load moments that impact the cervical spine. However, NVGs and HUDs not only increase the weight the head must bear but also alter the centre of mass forward and upward in relation to the motion axis of the cervical spine [10]. Most pilots and loadmasters counteract this misbalance by using a counterweight situated posteriorly at the base of their helmets (photo 1). It is the aircrew’s choice to use counterweights, and the weight used varies individually from 50 to 400 grams. These reported risk factors suggest a biomechanical basis to flight-related neck pain in helicopter aircrews with a positive relationship between neck load and neck pain. The reported effects of counterweights when flying with NVGs, however, have been equivocal. Harrison et al. [11] reported beneficial metabolic effects of counterweight use, whereas Knight and Barber [14] reported increased muscle activity when a frontal load on a helmet was counterbalanced.
Helicopter aircrews have a dynamic job, and the demands of the mission determine the postures adopted, the helmet configurations used, the flight duration, and their interactions and consequences on neck load. The experience of the helicopter aircrew is therefore of considerable value in identifying the important factors related to optimising helmet use and adjustments with respect to neck load. Therefore, we recently interviewed our helicopter aircrew and performed a qualitative study[20]. The flight demands, the weight of the head equipment worn and the weight distribution were identified as factors directly related to the neck load experienced by the helicopter aircrew. However, three other factors were mentioned by the aircrew that might impact their experienced neck load: helmet stability, helmet fit and comfort (Figure 1). Helmet stability was identified as a factor that impacts weight distribution and thus as a factor indirectly related to the neck load experienced. If the helmet is not stable, it might glide over the head and consequently change the weight distribution compared to the centre of gravity of the head during flight. Helmet fit was related to stability and comfort because a good fit increased comfort and decreased gliding of the helmet (increase stability). It became clear from the interviews that while the fit of the helmet was important to the aircrew, an optimal fit was not easily achieved. One of the reasons was that some specific helmet adjustments, such as the type of inner liner used, the size of the helmet and the tightness of the straps, were mentioned by the aircrew to impact more than just one factor. For example, a smaller helmet with a specific inner liner and extremely tightened straps could increase the stability of the helmet but would lead to feelings of discomfort such as hot spots (pressure points). Our aircrew mentioned that discomfort during flying might cause them to be irritated and distracted, indicating the importance of not only a stable helmet but also a comfortable helmet fit. Although
comfort is not synonymous with the absence of discomfort [5], we believe that the absence of hot spots will increase overall helmet comfort. The results of our qualitative study suggest the need for a critical evaluation of the fitting procedures currently used by the Royal Netherlands Air Force (RNlAF) and a renewed helmet-fitting protocol. This renewed protocol should result in better helmet fits for the aircrew and greater helmet stability, taking issues of comfort into account.

Figure 1. Factors contributing to the neck load experienced during flights.

The purposes of this study were twofold: the first aim was to improve the helmet fit and evaluate its effect on the experienced helmet stability, neck load, neck pain, hot spots, irritation/distraction, and overall helmet comfort during flight; the second aim was to explore the assumed relations between helmet stability and neck load, between neck load and neck pain, between hot spots and comfort, and between hotspots, comfort, and irritation/distraction experienced during flight.

**Methods**

**Design**
A within-subjects design was used that consisted of two consecutive interventions of optimising the fit of the aircrew's helmet and three measurements: before intervention, after the first intervention and after the second intervention.

**Subjects**
Participants were helicopter pilots and loadmasters from two squadrons from the Royal Netherlands Air Force who flew the Cougar or Chinook helicopter. All pilots and loadmasters of these squadrons who were on active flight status and were expected to fly at least nine night flights using NVGs within a period of 3 months during October 2010-March 2011 were eligible to participate. Participation was voluntary, and the participants gave their informed consent. Ethical approval was not requested, because the current study did not meet the criteria of the Medical Research with Human Subjects Act [22]. The study involved no medical research, the measures involved normal job
Interventions

The optimisation of helmet fit consisted of two parts. The first intervention involved a new helmet fit using a renewed protocol. This renewed protocol was the result of reorganizing the relevant chapters of the helmet’s operating instructions, results of our qualitative study [20] and the knowledge and experience of the helmet technicians of the flight equipment department. This resulted in a stepwise checklist divided in 4 main topics and illustrated with clear drawings. The first topic involved the determination of the helmet size, including several steps of measuring the head and selecting the correct size. The second topic involved the helmet preparation, including all steps from unpacking the new helmet from the box till inspecting all parts of the helmet and their correct positions. The third topic involved the instructions to correctly put on the helmet, an activity that has to be carried out several times during the fitting procedure. The fourth topic involved all steps needed to actually fit the helmet and was subdivided in the following items: fitting the inner liner and relieving hot spots, positioning of the ear cups and adjustment of the ear cushion pressure, adjustment of the chinstrap and the neck strap, adjustment of the visors, mounting the NVG, and checking the stability and fit of the helmet with NVG. The main changes compared to the previous fitting procedure were that in the renewed protocol all steps necessary to fit a helmet were pooled, instead of spread throughout the helmet’s operating instructions; additional warnings were inserted at crucial steps within the protocol where mistakes could easily and unnoticeable be made; and skilful tricks and tools were provided to aid the technicians during certain steps. To fit the helmet according to this protocol, all aircrew received a new thermoplastic inner liner fitted in their helmet and adapted according to the protocol to achieve the best fit. The thermoplastic inner liner is the standard inner liner provided with the flight helmet by the helmet manufacturer. It is comprised of four layers of thermoplastic sheets covered with a washable cloth cover. Individual fitting is accomplished by removing layers or parts of layers of the thermoplastic sheets. If further individual fitting is needed, the liner can be heated, the thermoplastic layers become pliable and the individual puts on the helmet with the heated liner until the sheets have cooled. At least one familiarisation flight was included to acclimate the aircrew to the new fit, and further adaptations to the fit were made after this familiarisation flight, if necessary. This procedure was described in and part of the renewed fitting protocol.

The second intervention involved a new type of inner liner. The thermoplastic inner liner was replaced with an inner liner made of viscoelastic foam. This liner is a commercially released liner and is comprised of sections of viscoelastic foam sewn into a washable cloth outer covering. The viscoelastic foam compresses under the weight
of the helmet and conforms to the contours of wearer’s head, providing a custom fit. Impact protection tests performed by the U.S. Army Aeromedical Research Laboratory have shown that the use of this new type of liner in the helmet does not affect the impact protection of the helmet [4]. The helmet fit was rechecked with this new inner liner and adapted if necessary.

Both interventions took place at the building of the flight equipment department located on the same base as the two participating squadrons. Before the start of the study, both interventions were practiced with two fitting experts of the flight equipment department by two ergonomists (YS and MO).

**Procedures**

The chief operating officers of both squadrons selected all eligible aircrew. The study was explained to the selected aircrew in an oral briefing, and written information was also provided. Immediately after every night flight, aircrew filled in a form that contained several questions about the past flight and rated their perceived helmet stability, neck load and neck pain, hot spots, distraction/irritation, and comfort during the past flight for this fit. It took less than five minutes to complete the form. The aircrew placed the completed form in an envelope and dropped it in a box. To ensure the forms were filled in immediately after the flight, the researcher (MO) sent reminder e-mails on the day of the flight and the envelopes were counted the next day before the aircrew arrived at the squadron.

The time line of this study is illustrated in Figure 2. During the baseline, participants flew their night flights with their current helmet fit, including their current inner liner, NVG and optional counter weights. After an individual aircrew member had flown and evaluated three night flights, an appointment was made to fit their helmet according to the renewed protocol (intervention 1). After three further night flights were flown and evaluated following intervention 1 (excluding the familiarisation flight), the

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**Figure 2.** Time line of the study. NF = night flight
thermoplastic inner liner of the helmet was replaced with the viscoelastic foam inner liner, and the helmet fit was rechecked (intervention 2). After flying and evaluating another three night flights, the individual aircrew member had completed the study. All interventions in this study were performed by two trained fitting experts of the flight equipment department and one ergonomist (YS). Another ergonomist (MO) was always present to supervise the proceedings.

**Outcome measures**

The dependent variables were the following: experienced helmet stability (helmet gliding), hot spots (pressure points), neck load, neck pain, irritation/distraction, and overall helmet comfort during flight. These were rated using separate Visual Analogue Scales (VASs). Each VAS consisted of 100 mm lines bounded by two short vertical lines and another short vertical line at 50 mm to indicate the middle of the line. The verbal anchors for experienced helmet gliding, pressure points and irritation/distraction during flight were “no suffering from helmet gliding/pressure points/irritation or distraction at all” on the left side of the scale and “extreme suffering from helmet gliding/pressure points/irritation or distraction at all” on the right side of the scale. For experienced neck load during flight, the verbal anchors were “hardly any neck load” on the left side of the scale and “extreme neck load” on the right. For experienced neck pain during flight, the verbal anchors were “no pain or aches at all” on the left side of the scale and “extreme pain or aches” on the right. For experienced overall helmet comfort, the extremes were “very little comfortable” on the left side of the scale and “very comfortable” on the right. In addition to the VASs, the aircrew answered several questions about the current flight, such as flight duration, tasks performed during flight (only the loadmasters), counterweight (CW) use and amount, and current inner liner type.

**Analyses**

Statistical analyses were performed using the SPSS 16.0 software package (SPSS Inc, Chicago, IL). Means for each dependent variable were obtained by calculating the mean VAS score of a minimum of two flights for base line (T1), T2 and T3. The means of each dependent variable and flight duration were compared within subjects using ANOVA-repeated measures. If there were significant differences, Bonferroni post hoc tests were performed. For the second aim, the relation between experienced helmet stability (helmet gliding) and neck load, between neck load and neck pain, between hot spots (pressure points) and comfort, and between hot spots (pressure points), comfort and irritation/distraction were measured at T3 using Pearson’s correlation coefficients. For all outcome measures, a statistical significance was defined as p<0.05.
Results

Participants and flight information
A total of 18 helicopter aircrew members, 9 pilots and 9 loadmasters, 10 flying the cougar helicopter and 8 flying the Chinook helicopter, completed the study in the study period. Their average age, height and weight (±SD) were 31 yr (± 10), 183 cm (± 8) and 80 kg (± 8). In terms of flying experience, their average total flying hours were 1192 hours (±1085), and average hours flown with NVG were 215 hours (± 259). All but two crewmembers evaluated three night flights after both interventions; two loadmasters completed two evaluations after the second intervention.
Mean flight duration was 2.4 hours (± 0.7) at T1, 2.1 hours (± 0.5) at T2 and 2.7 hours (±0.6) at T3. Post hoc analyses showed a significance difference in flight duration between T2 and T3. Counterweights varied from 150 grams to 400 grams between individuals; mean counterweights did not differ within subjects between T1, T2 and T3.

Effect of an optimised helmet fit (first aim)
The optimised helmet fit showed a significantly decrease in the experienced helmet gliding (p<0.000), neck load (p=0.02) and pressure points (p=0.001), a nearly significant decrease in the experienced neck pain (p=0.058) and irritation/distraction (p=0.057), and a significant increase in the experienced overall comfort (p<0.000) during flight (Figures 3 and 4).
The mean VAS scores for each outcome measure are shown in Table I.
Neck pain experienced during flight was reduced after the helmet was refitted and was further reduced with the viscoelastic foam inner liner. The aircrew reported no change in irritation/distraction after the new helmet fit, but they were less irritated or distracted after the viscoelastic foam inner liner was fitted in their helmets.

Table I. VAS scores for the different outcome measures at baseline (T1), after a refitted helmet (T2) and after the implementation of a viscoelastic foam liner (T3).

<table>
<thead>
<tr>
<th>Outcome Measure</th>
<th>T1 Mean (± SD)</th>
<th>T2 Mean (± SD)</th>
<th>T3 Mean (± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helmet gliding</td>
<td>60 (16)</td>
<td>27 (21)*</td>
<td>25 (23)*</td>
</tr>
<tr>
<td>Neck load</td>
<td>42 (22)</td>
<td>32 (21)</td>
<td>30 (23)*</td>
</tr>
<tr>
<td>Neck pain</td>
<td>39 (24)</td>
<td>33 (23)</td>
<td>26 (21)</td>
</tr>
<tr>
<td>Pressure points</td>
<td>52 (22)</td>
<td>53 (27)</td>
<td>27 (21)* †</td>
</tr>
<tr>
<td>Distraction</td>
<td>46 (22)</td>
<td>46 (29)</td>
<td>30 (23)</td>
</tr>
<tr>
<td>Comfort</td>
<td>40 (15)</td>
<td>49 (24)</td>
<td>66 (20)* †</td>
</tr>
</tbody>
</table>

Post hoc analyses were performed for helmet gliding, neck load, pressure points and comfort.
* p < 0.05 compared to T1, † p < 0.05 compared to T2
Figure 3. Mean experienced helmet gliding, neck load and neck pain during night flights at baseline (T1), after a refitted helmet (T2) and after the implementation of a viscoelastic foam inner liner (T3).

Figure 4. Mean experienced hot spots, irritation/distraction, and overall helmet comfort during night flights at baseline (T1), after a refitted helmet (T2) and after the implementation of a viscoelastic foam inner liner (T3).
Post-hoc analyses were performed for the following outcome measures: helmet gliding, neck load, pressure points and comfort. These analyses revealed a significant decrease in helmet gliding during the night flights after the helmet was refitted followed by a small non-significant decrease after the implementation of the viscoelastic foam inner liner. The effect of the optimised helmet fit on the experienced neck load during night flights was achieved by a reduction in neck load after the aircrew’s helmets were refitted, followed by a further smaller reduction after the viscoelastic foam inner liner was fitted in the helmets of the aircrew members.

The occurrence of pressure points were slightly higher after the new helmet fit but decreased significantly after the viscoelastic foam inner liner was fitted.

A non-significant higher overall comfort in the fit of the helmet during the night flights was experienced by the aircrew after the first intervention followed by a further significant increase in overall comfort with the viscoelastic foam inner liner fitted in the helmet.

**Associations between variables (second aim)**

The results for the associations between the experienced helmet stability (helmet gliding) and neck load, between neck load and neck pain, between hot spots (pressure points) and overall comfort, and between both hot spots and comfort and irritation/distraction are shown in Figure 5. There was a significant positive correlation between:

- Helmet fit and stability (helmet gliding)
- Stability (helmet gliding) and neck load
- Neck load and neck pain
- Neck load and irritation/distraction
- Neck pain and comfort
- Comfort and irritation/distraction
- Hot spots (pressure points) and comfort
- Hot spots (pressure points) and irritation/distraction

**Figure 5.** Correlations between helmet gliding and neck load; between neck load and neck pain; between hot spots and comfort; between hot spots and distraction/irritation; and between comfort and distraction/irritation. **Correlation is significant at the 0.01 level.
helmet stability (helmet gliding) and neck load, \( r=0.70 \) (\( p<0.01 \)), with higher perceived neck load during flights associated with higher suffering from helmet gliding. Neck load was significantly positively correlated with neck pain, \( r=0.80 \) (\( p<0.01 \)). There was a significant strong correlation between hot spots and overall comfort, \( r=-0.79 \) (\( p<0.01 \)), with higher comfort levels associated with lower suffering from hot spots during the night flights. Both suffering from hotspots and overall comfort were significantly correlated with irritation/distraction, \( r=0.78 \) and \( r=-0.82 \), respectively, (\( p<0.01 \)), with higher suffering from hot spots and lower overall comfort associated with higher irritation/distraction.

**Discussion**

**Main results**

With an optimised helmet fit, helicopter aircrew members experienced less neck load, greater helmet stability, fewer hot spots and more comfort. Furthermore, a decrease trend was observed in experienced neck pain and irritation/distraction during their night flights.

The second aim of the study was to explore assumed relations between specific variables. Significant positive associations were found between helmet gliding and neck load, between neck load and neck pain, and between hot spots and irritation/distraction experienced during flight. Significant negative associations were found between hot spots and overall helmet comfort and between comfort and irritation/distraction experienced during flight.

**Helmet stability, neck load and neck pain**

To prevent flight-related neck pain in military helicopter aircrews, ergonomic improvements must be made to the equipment used. As a first step, we previously explored the in-flight experiences of pilots and loadmasters concerning their helmet configuration in relation to their experienced neck load [20]. Factors identified in that study, such as helmet fit, helmet stability and helmet comfort, were the focus in the present study because they could be indirectly related to neck load during flight. Taking the learned discomfort issues into account, we hypothesised that optimising helmet fit would increase helmet stability and decrease neck load during flight. The results of the present study confirm our hypothesis: the experienced helmet gliding and neck load during flight decreased significantly after the helmet was refitted and were highly associated with each other. These results suggest that a significant improvement in helmet stability can be achieved by refitting the helmets of aircrew that are on active duty and results in less neck load during flight. It should be stressed that optimising an aircrew member’s helmet fit does not merely involve following the manual of the helmet provider but requires professional skill and should not be underestimated.
Because the effect of an optimised helmet fit on neck pain was nearly significant ($p=0.058$), we decided post hoc to perform Bonferroni post hoc tests for this outcome measure as well. These analyses revealed a significant difference in neck pain between T1 and T3 ($p=0.04$). Considering the relatively small number of participants and the post hoc analyses, we believe that an optimised helmet fit might result in a decrease in neck pain during flight.

When planning these kinds of interventions in practice, one would like to predict what proportion of workers would benefit from the intervention. Therefore, we calculated the individual differences for helmet stability, neck load and neck pain between the time measurement periods, which revealed significant differences in the post-hoc analyses. Based on the values reported by others, who consider a difference of 9 to 13 mm using VAS scales as relevant [6;12;21], we agreed on 11 mm as a relevant difference. After the new helmet fit (the first intervention), 16 out of 18 participants showed a decrease in helmet gliding of more than 11 mm on the VAS scale, and after the viscoelastic foam innerliner was fitted (the second intervention), 17 out of 18 pilots showed a difference of more than 11 mm compared to baseline measurements. For neck load and neck pain, 10 out of 18 pilots and loadmasters showed a decrease of 11 mm on the VAS scale when the helmet was refitted and the viscoelastic foam inner liner inserted (T3) compared to baseline (T1).

By taking measurements immediately after flights and within a period of three months, we measured the short-term effects of the interventions. Hamberg-van Reenen et al. [9] evaluated localised musculoskeletal discomfort in workers during the working day using a 10-point scale. They found a relative risk of 2.6 for future neck pain (regular or prolonged pain in the past 12 months after a pain-free episode of 12 months) when discomfort ratings of at least 2 in the neck area were reported during a workday. The results of that study suggest that the short-term effects found in the current study of an optimised helmet fit on neck load and neck pain might result in a decrease in regular and prolonged neck pain in helicopter aircrew members in the long term.

**Hot spots, comfort and distraction**

Increasing the helmet stability would not be that difficult if comfort issues did not play a part. Helmet stability could be maximised simply by fitting the helmet as fixed and tight as possible, allowing no movement of the helmet in any direction. However, this would cause enormous discomfort and is therefore not desirable because of feelings of discomfort and safety concerns. Indeed, our results showed a high association between perceived hot spots and lower ratings of comfort and higher ratings of irritation/distraction during flight. Whereas the refitting of the helmet was intended to take comfort issues into account and certainly not decrease comfort to an unbearable level, it was hypothesised that particularly the viscoelastic foam inner liner would contribute to the perception of less hot spots and higher comfort. Above expectations, the renewed helmet fit alone as a first intervention did not worsen the perception of hotspots, and
the comfort ratings even increased. However, after the viscoelastic foam inner liner was fitted into the helmet as a second intervention, feelings of hot spots decreased significantly, and comfort ratings increased significantly. Furthermore, the positive effect of the first intervention on helmet stability and neck load did not change or even increased slightly after the viscoelastic foam inner liner was fitted into the new fitted helmets of the aircrew members.

The results of the post hoc analyses suggest that a significant improvement in helmet stability and decrease in neck load can be achieved by refitting the helmets. Furthermore, the viscoelastic foam inner liners appear to decrease the perceived hot spots and increase the level of comfort.

The high association between comfort and irritation/distraction during flight further suggests the importance of a comfortable helmet fit for safety concerns.

Because the main analyses showed a nearly significant ($p=0.057$) effect of an optimised helmet fit on irritation/distraction, we decided to perform Bonferroni post hoc analyses, which revealed a significant difference after the second intervention, between T2 and T3 ($p=0.03$).

As mentioned above, for practitioners who consider these kinds of interventions, it is interesting to evaluate the proportion of aircrew members who benefitted from the interventions. For hot spots, irritation/distraction and comfort, we therefore calculated individual differences between the measurement periods. Assuming a relevant difference to be at least 11 mm on the VAS scales, the difference in VAS score in irritation/distraction between T2 and T3 was at least 11 mm for 9 of the 18 aircrew members. For the perceived hot spots, there was a relevant difference in 12 out of the 18 aircrew members between T2 and T3 and in 13 out of the 18 aircrew members between T1 and T3. For comfort, 11 of the 18 aircrew members showed a relevant increase in comfort after the viscoelastic foam inner liner was fitted (T3) compared to only the new helmet fit (T2), and 13 out of 18 aircrew members showed a relevant increase in comfort compared to baseline (T1).

**Further implications**

Two risk factors often associated with neck pain in military helicopter pilots are awkward flight postures and heavy head equipment [17]. The optimised helmet fit in the current study resulted in a more stable helmet, and helmet stability might influence neck postures during flight. Forde et al. [7] investigated neck loads and neck postures in the Canadian Forces helicopter pilots during routine simulator day and night flights. They reported significantly greater percentages of time spent in mild and severe neck postures during night flights compared to day flights. They reasoned that the reduction in peripheral vision caused by NVGs required the pilot to flex and rotate his head more than during day flights. In addition to this explanation, our helicopter aircrew reported that an unstable helmet can also force them to modify their neck posture to keep the NVG aligned with their eyes[20]. Therefore, an optimised helmet fit that increases the
stability of the flight helmet might affect the in-flight postures of helicopter aircrew because they do not need to change their neck postures to keep their eyes aligned with the NVG. This explanation is only a hypothesis because we did not observe or measure the postures of the aircrew members. Nevertheless, we believe that future studies investigating flight head postures and movements of helicopter crews should confirm a good and stable helmet fit.

Strengths and limitations of the study
Neck pain in military helicopter pilots and rear aircrew is a recognised problem, and several studies have investigated this issue [3;7;11]. The effect of ergonomic improvements in a real working situation, however, is seldom studied. To the best of our knowledge, this is the first study to evaluate an ergonomic intervention in real airborne flights. However, the strength of the current study, taking measurements immediately after real airborne flights, might at the same time have been the limitation of the study. We could not control for the type and duration of the flight, which might have affected the outcomes. We tried to equalise this variation within subjects between T1, T2 and T3 by taking the means of several flights per condition. The optimum number of flights is debatable; however, we had to consider the practical fulfilment of the study as well. Post hoc within-subject analyses revealed that the flight duration did not differ between T1 and T2, but average flight duration was found to be significantly longer at T3. However, because the assumption would be that longer flight duration is associated with higher neck load, and no change or a decrease in neck load, pain and discomfort was reported at T3, we believe that the higher flight duration at T3 might have suppressed the effects of the interventions rather than the opposite.

Conclusions
This study suggests that an optimised helmet fit increases helmet stability, reduces neck load and hot spots and increases overall helmet comfort during real airborne helicopter flights. The neck pain perceived with an optimised helmet fit is highly associated with the neck load experienced during flight. During night flights, less hotspots and higher overall helmet comfort are perceived, and both are highly associated with irritations / distractions 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.
Prevention of flight-related neck pain in military aircrew

References


