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Increase in Neck and Back Pain in Fighter Pilots After the Introduction of the F-35 Platform

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- INTRODUCTION:** Fighter pilots face unique occupational challenges, including exposure to high G-forces in suboptimal seating postures and wearing heavy equipment around neck and head. These factors contribute to a high prevalence of neck and back complaints, which can impair flight performance and prevent deployment of pilots.
- METHODS:** A cross-sectional survey was performed on the self-reported prevalence of neck and back pain among F-16 and F-35 pilots in the Royal Netherlands Air Force. Of the 121 pilots who were invited to participate, 50% (N = 61) were included. The questionnaire was based on prior research and adapted for military pilots. Differences between F-16 and F-35 pilots were analyzed.
- RESULTS:** The subjects were 36 yr (IQR 30.0–46.0) of age and had 1900 flight hours (IQR 1000–2800). We observed a statistically significant higher prevalence of back pain among F-35 pilots compared to F-16 pilots (46% vs. 8%), whereas neck pain was higher but not statistically significant among F-35 pilots (51% vs. 38%). Contributing factors included seat angle, heavy (helmet-mounted) equipment, and specific flight maneuvers. A majority (83%) reported a negative impact on flight performance, with 38% stating it affected flight safety. Suggested preventive strategies include a multidisciplinary approach as well as adjustments of equipment.
- DISCUSSION:** This study represents the first investigation into neck and back pain among F-35 pilots and shows a higher rate of both back and neck pain compared to F-16 pilots. Equipment and seat angle appear to be the main contributing factors. Targeted interventions are needed to prevent structural injuries, improve performance, and increase deployability.
- KEYWORDS:** aerospace medicine, aviation, G-force, occupational medicine, preventive medicine.

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Flying jet aircraft requires substantial physiological adaptations from pilots. Fighter pilots are regularly exposed to high G-forces, operate while wearing heavy equipment around their neck and shoulders and having suboptimal seating postures for support during actions, and perform under significant stress.¹ Neck and back pain are prevalent occupational problems among fighter pilots, arising from the demanding activities during their profession, which exert more than normal biomechanical and physiological stress to the body.² These vertebral column issues can negatively impact not only the immediate deployability of these fighter pilots, but also the long-term employability of this highly trained personnel, diminishing overall operational effectiveness.³ Mitigating these extraordinary biomechanical and physiological stresses to the body is likely to prevent structural damage to the body and improve fighter pilots' effectiveness, thus improving overall economic efficiency.

The existing literature highlights the significant impact of neck and back pain on pilot performance and productivity. Surveys conducted in 2007 and 2015 among Belgian and Dutch Air Force F-16 pilots showed an increasing trend in the occurrence of these problems.^{4,5} In the Royal Australian Air Force, neck pain related to flying was estimated to result in a loss of up to 7 man-years of productivity annually.¹ Danish pilots reported

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that their ability to perform high-G maneuvers was compromised, negatively affecting their performance in Basic Fighter Maneuvers and Air Combat Maneuvering missions.⁶ A 2019 meta-analysis found a pooled prevalence of neck pain at 51%, of which 39% of fighter pilots lost flight time due to sick leave, grounding, or skipping flights.²

The F-35, which was introduced in the Royal Netherlands Air Force (RNLAF) in 2019, also has differences in ergonomic features for pilots. This topic deserves dedicated publications, but to give some context, we would like to highlight some differences. The inclination of the seat in the F-16 was 30°, while it is 18° in the F-35. Additionally, lumbar support cushions in the F-16 have been used for many years, which seemed to reduce lower back complaints when introduced, but these measures are not (yet) available for the F-35 seats. Lastly, pilots in the F-35 are more restricted in their upper torso movements compared to the F-16, which may put additional stress on the neck when operating the aircraft. However, helmet-mounted systems like the joint helmet-mounted cueing system—or its replacement, the Gen 3 helmet (reducing the weight from 2.69 kg to 2.32 kg, respectively)—are still necessary and may further exacerbate the strain on pilots' spines during high G-force activities.^{4,6} As aircraft platforms and wearable equipment continue to advance, ongoing monitoring of their impact on fighter pilots' spinal health remains crucial, both from an occupational medicine and military operational perspective.⁷

The introduction of a new platform, along with its updated wearable equipment and different seating configurations, presents a new range of challenges to the human interface for the fighter pilot of these highly technically advanced aircrafts which can exert different stresses to the human biomechanical and physiological system. Therefore, renewed studies into the incidence of back and neck complaints are needed to show the necessity, as well as the effectiveness, of interventions aimed at mitigating or even preventing pilot complaints. The aim of this study was to evaluate the incidence of neck and lower back problems in fighter pilots of F-16 and F-35 and compare them with earlier studies. We hypothesize, based in part on the feedback from flight surgeons during consultations, that the incidence of back and neck problems has increased compared to earlier studies.

METHODS

A cross-sectional questionnaire study was performed among F-16 and F-35 pilots of the RNLAF on self-reported presence of neck and back pain. Ethical approval was obtained from the Medical Ethics Committee of the Leiden University Medical Center (ref N24.007), as well as from the Dutch Surgeon General (ref DGO20240403111). The online survey was emailed to the jet fighter pilot community. Pilots were eligible for inclusion if they had flown an F-16 or F-35 in the last 12 mo. Participation was voluntary. Reminders were sent after 13 and 20 d. After 23 d, the survey was closed, and data were extracted. All data were handled according to internal regulations and

adhered to European GDPR and national privacy legislation, as well as the guidelines set forth by the Association of Universities in the Netherlands.

Materials

To ensure comparison of data, the questionnaire was adapted from a similar study which was published in 2015.⁴ The questionnaire was based on the validated Dutch Musculoskeletal Questionnaire and modified according to the recommendations of the NATO research group.^{7,8} The questionnaire consisted of 95 questions and included the following sections: demographics, flight hours per aircraft type, physical activity, prevalence of neck and back pain with their respective characteristics, impact on performance and safety, medical diagnoses, self-reported causes and preventive strategies, influence of the transition from F-16 to F-35 platforms, evaluation of earlier interventions, proposed future preventive measures, and evaluation of medical support from the RNLAF.

Statistical Analysis

All data were extracted from the RNLAF questionnaire and transferred to a separate (encrypted) database. Numerical data were tested using *t*-tests or Mann-Whitney *U*-tests based on their normality, which was determined using Kolmogorov-Smirnov's test. Binary data was tested using Chi-squared or Fisher Exact tests where appropriate. Statistical analyses were performed using SPSS Statistics for Windows software (IBM Corp; Armonk, NY: 2021, version 29.0), with *P* < 0.05 defined as statistically significant.

RESULTS

Questionnaires were sent to the fighter pilot community of the RNLAF (*N* = 121), of which 72 (60%) responded. For seven pilots only the baseline characteristics data was available, and four pilots did not log any flying hours in the last 12 mo (only simulated flights), resulting in a net response rate of 50.4% (*N* = 61). Demographics are shown in **Table I**. Notably, 10 pilots, 9 of whom were F-35 pilots, reported both neck and back pain and were included in both groups for analysis. Additionally, of the 47 F-35 pilots, 7 had never flown an F-16 (i.e., the other 40 pilots made the conversion from F-16 to the F-35 platform). As detailed in **Table I**, the F-35 pilots were statistically significantly younger, taller, had recorded fewer flying hours, and had a higher prevalence of back pain (46.3% vs. 8.3%, (χ^2 , *df* = 1, *P* = 0.001) than the F-16 pilots. The self-reported incidence of neck pain was 37.5% for the F-16 and 51.1% for the F-35, but did not reach significance (χ^2 , *df* = 1, *P* = 0.278).

Table II shows the frequency of factors in pilots reporting on back or neck complaints. Pilots could choose up to five factors they thought would attribute to the development of their neck or back complaints. Of our respondents, 24 pilots (39%) did not report any back or neck complaints.

In F-35 pilots with neck complaints, the Life Preserver Unit (LPU) was mentioned most frequently (88%) as a contributing

Table I. Demographics.

PARAMETER	TOTAL (N = 71)	F-16 (N = 24)	F-35 (N = 47)	P-VALUE (TEST STATISTIC)
Age, yr	36 (30.0–46.0)	46 (36.5–51.0)	33 (30.0–42.0)	<0.001* (Z = -3.378)
Height, cm (mean, SD)	183 (5.8)	181 (6.3)	184 (5.2)	0.019* (t = -2.395, df = 69)
Weight, kg (median, IQR)	80 (76.0–88.0)	81 (73.3–89.8)	80 (76.0–88.0)	0.752 (Z = -0.317)
Body mass index (median, IQR)	24 (23.0–26.2)	25 (22.6–26.5)	24 (23.1–26.0)	0.447 (Z = -0.760)
Flying hours (median, IQR) [range]	1900 (1000–2800)	2600 (1600–3000) [500–4800]	1700 (700–2500) [120–5000]	0.015* (Z = -2.433)
History of neck and back pain, % (N)	18 (13)	21 (5)	17 (8)	0.694 (χ^2 , df = 1)
Neck pain, % (N)	47 (33)	38 (9)	51 (24)	0.278 (χ^2 , df = 1)
Back pain, % (N)	34 (24)	8 (2)	47 (22)	0.001* (χ^2 , df = 1)

All numeric data, except for height, were not normally distributed and, accordingly, median with IQR are shown and were tested using a Mann-Whitney *U*-test. For height, this is mean with SD and tested using an independent samples *t*-test. Binary data, the bottom 3 of this table, are tested using a Chi-Square or Fisher Exact test were appropriate. Statistically significant tests are marked with an asterisk (*).

factor, followed by the seat angle (75%) and the “check-six maneuver” (63%). For the F-16 pilots, the most frequently mentioned contributing factors were the “check-six maneuvers” (100%), high G-forces (100%), and the joint helmet-mounted cueing system (66.7%). In F-35 pilots with back complaints, the three most mentioned factors were the seat angle (82%), a long flight duration (68%), and the LPU (64%). For F-16 pilots, only the seat angle was mentioned in both neck and low back complaints.

All subjects, with or without back or neck complaints, were asked to suggest up to three preventatives or countermeasures for neck and back complaints. Results are shown in **Table III**. The “Fit for Flight” program at the squadron includes a multidisciplinary approach with support of a flight surgeon, physiotherapist, and fitness instructor for a tailored fitness program available at the squadron during working hours. This program, or some elements thereof, were most frequently thought to be of value to prevent neck and back complaints. In the F-35 group, adjustments to the LPU and seat, including lumbar support, were frequently mentioned, while the F-16 group did not mention any need for adjustments to the equipment or seat.

Among the 33 pilots with neck pain, 7 (21%) experienced complaints during nearly every flight and 4 (12%) reported continuous pain. For back pain, 11 (46%) indicated intermittent discomfort. The majority of the pilots (83%) reported that their neck and/or back complaints had a negative impact on

in-flight performance, and 38% reported that it impacted flight safety. With regards to loss of productivity over the last year, 26 pilots (37%) had to skip one or more scheduled flights as a result of neck and/or back complaints, of which 10 (18%) reported a duty not including flying (DNIF) restriction and 4 (7%) were on sick leave for one or more days. A total of 13 pilots (23%) were at least one time unable to perform flying duties because they were put on DNIF, were on sick leave, or skipped a flight due to neck and back pain. Each pilot who experienced any of the following—DNIF, sick leave, or skipping a flight—was counted only once, thus overestimating the pilots’ productivity or underestimating the impact on the pilots’ sick leave. Even if a pilot experienced more than one of these (e.g., both DNIF and sick leave), they were counted as a single case in this calculation.

DISCUSSION

The results of this study showed a high prevalence of significant flight-related neck and back pain in the RNLAf fighter pilots of 47% and 34%, respectively. There are differences between F-16 and F-35 pilots regarding neck and back complaints, which are more prominent in F-35 pilots. These are attributed to the physical demands of the pilots’ work, such as: the “check-6 maneuver” or high G-forces; ergonomic features like seating position (in the F-35) or headrest position; and equipment, such as the

Table II. Self-Reported Contributing Factors for Neck or Back Pain.

CONTRIBUTING FACTOR	PILOTS WITH NECK PAIN			PILOTS WITH BACK PAIN		
	TOTAL (N = 33)	F-16 (N = 9)	F-35 (N = 24)	TOTAL (N = 24)	F-16 (N = 2)	F-35 (N = 22)
Check 6 maneuver	24 (73%)	9	15	8 (33%)		8
High G-forces	20 (86%)	9	11	11 (46%)		11
Life preserving unit	22 (67%)	1	21	14 (58%)		14
Seat angle	19 (58%)	1	18	20 (83%)	2	18
Head rest	12 (36%)		12	3 (13%)		3
Cable on backside of helmet	11 (33%)		11	2 (8%)		2
Third-generation helmet	9 (27%)		9	6 (25%)		6
Joint helmet-mounted cueing system	8 (24%)	6	2	2 (8%)		2
Night vision goggles	5 (15%)	4	1			
Combination of many flying hours with short rest intervals	5 (15%)	3	2	6 (25%)		6
Long duration of flight	4 (12%)	1	3	15 (63%)		15
Seat straps	4 (12%)		4	10 (42%)		10

Table III. Interventions Chosen for the Mitigation and Prevention of Flight-Related Neck and Back Pain.

INTERVENTION	NECK PAIN			BACK PAIN		
	TOTAL (N = 68)	F-16 (N = 22)	F-35 (N = 46)	TOTAL (N = 66)	F-16 (N = 22)	F-35 (N = 44)
Fit for Flight Program	39 (57%)	14	25	35 (53%)	11	24
Physiotherapy	32 (47%)	11	21	36 (55%)	14	22
Life preserving unit adjustment	28 (41%)		28	13 (20%)		13
Exercise program	24 (35%)	14	10	21 (32%)	12	9
Scheduled time for physical exercise	16 (24%)	7	9	16 (24%)	7	9
Seat adjustment	15 (22%)		15	16 (24%)		16
Helmet adjustment	11 (16%)		11	3 (5%)		3
Education (on correct head posture)	11 (16%)	6	5	6 (9%)	4	2
Medical support	8 (12%)	4	4	13 (20%)	6	7
Other	8 (12%)	4	4	7 (11%)	4	3
Longer periods of rest				1 (2%)	1	
Lumbar support				21 (32%)		21

weight of the LPU unit and helmet-mounted instruments. The most frequently mentioned preventative measures reported by the fighter pilots include a multidisciplinary approach of the flight surgeon, physiotherapist, and options to exercise in the gym during working hours. Lastly, a substantial number of pilots mention neck and back complaints affect flight performance, threaten flight safety, or can lead to skipping flights.

To our knowledge, this is the first study to report on neck and back complaints among F-35 pilots. The results of this study suggest a high prevalence of significant flight-related neck and back pain in the RNLAf fighter pilots of 46.5% and 33.8%, respectively.

The 1-yr prevalence in this study is higher than in earlier studies published by the RNLAf.^{4,5} Additionally, other countries are reporting similar or even higher incidences.^{1,6}

Although more research is needed to confirm these findings in other populations, we feel it is safe to conclude that the prevalence of neck and back complaints has not decreased since the introduction of the F-35 platform. A large number of pilots (72%) mentioned that the “check 6 maneuver” has a possible relation with neck complaints. This does not imply that this maneuver has the highest impact on developing neck complaints: it simply describes that a large majority of the pilots attribute this factor to the development of neck complaints. This study suggests that aspects of the working environment of the fighter pilot, such as the LPU, seat angle, headrest, or stiff cables attached to the helmet contribute to the development of these complaints. This is supported by a recent systematic review on the incidence of neck complaints in military personnel, which attributes the high incidence of these complaints to working with helmets and other headgear.⁹ These are possible factors that may be altered to optimize the interaction and integration between man and machine.

In our population, the majority of F-35 pilots were previously F-16 pilots. We feel this could have affected the results, both positively and negatively. On the one hand, it could have induced a selection bias due to “vulnerable” pilots (or pilots with complaints) not making the conversion to the F-35 and choosing another career path. This phenomenon is academically known as “the healthy worker effect.” Conversely, younger pilots—as is the case in our F-35 population—are less likely to experience

back and neck complaints than older pilots.¹⁰ We feel the statistical difference in career total flight hours is not the explanatory factor here, as previous studies have failed to demonstrate a strong relationship between complaints and career total flight time.¹¹ Keeping the aforementioned in mind, it is striking that the F-35 community reported a higher prevalence of back pain and 9 out of 10 pilots had both neck and back pain, while only 1 F-16 pilot reported both neck and back pain. For neck pain alone, this difference was not statistically significant. This could have been attributed to the small sample size, which results in a post hoc power of 19%. To accept the null-hypothesis (that a difference exists for neck complaints between F-16 and F-35 fighter pilots) with more than 80% power, a sample size of at least 400 subjects is needed, which is more fighter pilots than the RNLAf employs. Therefore, we cannot conclude with sufficient statistical certainty that the F-35 pilots have a higher prevalence of neck pain compared to the F-16 community. However, our data do suggest that the F-35 platform may be more taxing for the lower back than the F-16, so an analysis of this in a larger cohort is warranted and may provide data for prevention.

Regarding the preventative measures, both communities express the need for a medical support system such as the earlier mentioned “Fit for Flight” program, which is a multidisciplinary approach and has been shown to reduce neck pain.¹² However, organizational interventions, such as enabling a pilot to exercise during working hours, could also benefit the fighter pilots.³ These organizational interventions are perhaps easier to deploy than altering the seat angle or having a highly specialized medical staff available. Altering a seat may seem a ubiquitous workplace adjustment, but it requires careful coordination when it concerns a jet fighter. Many parties, ranging from the manufacturer to the government when it considers (inter) national legislation, are involved. Additionally, one of the respondents expressed, at the end of the questionnaire (in the free text box, therefore not shown in the analyses above), the need to consult “off the record” with a medical professional, as he was aware that it could affect his flight status. This seems similar to earlier studies in military aviation, where contextual factors affect the pilots’ health-seeking behavior, and perhaps should be further explored. When considering all results, we feel preventative measurements for back and neck complaints

in fighter pilots should encompass a palette of various interventions, which could optimize the pilots' availability for duty or flying and increase productivity.

This study provides the first data on the prevalence of neck and back complaints among F-35 fighter pilots. Additionally, with the suggestions made by the subjects, alterations to the platform or working environment of the pilot can be made that could benefit flying performance and productivity for several decades.

However, we wish to address a few limitations of the current study. Firstly, this study lacks objective endpoints and presents subjective data based on questionnaires. While objective data would improve the validity of this study (by overcoming recall bias or selective reporting), gathering objective data in this group can be challenging. As mentioned in the discussion, the health-seeking behavior of pilots can be influenced by the context. The present study allowed for anonymous response, which may have overcome some of this limitation.

Secondly, we cannot be certain that these results can be generalized. For instance, as the average height of the Dutch population is higher than in many other countries, this could have affected the incidence of spinal complaints. Also, there are currently no females flying the F-16 or F-35 in the Netherlands. So, this study is limited to male data only. Additionally, with a response of just over 50% of our active jet fighter community, there is a possibility that the results may not reflect the community as a whole. Therefore, we have chosen not to utilize complex statistical modeling, as the risk for overfitting due to relatively low numbers of datapoints is significant. Moreover, correcting for biases—such as the significant difference between age and flight time in the F-35 and F-16 group—would very likely increase the differences found in the present study, as back and neck complaints are more likely to be found with increasing age and more exposure to the working conditions of a jet fighter.

Lastly, the prevalence of neck and back complaints in our study is slightly higher than earlier studies. While this could be attributed to the different platform, this may also have been caused by a slightly different definition of back and neck complaints. We have used the definition which was introduced by the aforementioned NATO working group – which was not available when earlier studies were conducted, which we recommend to use in similar studies in the future.⁸ However, while this may have masked the “true” incidence of neck and back complaints, which is very interesting from an academic perspective, we feel the most valuable results from our study are the suggestions made to reduce the complaints, as these directly affect productivity and flight performance.

Neck and back pain are common among RNLAF fighter pilots, predominantly those flying on the F-35 platform. While the increased incidence of neck and back complaints could have been a result from several factors, including flight hours or type of sorties, the increased incidence warrants further research whether these ailments are the result of the changed ergonomics of the F-35 platform or other factors. These complaints have led to decreased flight performance, flight safety, and productivity (i.e., flight time). The pilots attribute the development of these complaints to specific maneuvers and

equipment. These results may be used to improve flight gear, the cockpit environment, and preventative fitness programs, which may lead to reduction of these complaints and increase operational deployability.

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