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DEGENERATIVE CHANGES OF THE SPINE OF PILOTS OF THE RNLAF

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The results of this study have been previously published in "Cervial spinal injury from repeated exposures to sustained acceleration. RTO Technical Report 4, 1999", and will also be published in Aviation, Space and Environmental Medicine.

Summary

Introduction: During air combat maneuvering under high $+G_z$ forces, the spine is frequently exposed to heavy loads. Therefore, acute in-flight neck injury is a common complaint among pilots flying high performance aircraft. However, not only sudden incapacitation is caused by high performance flying. The frequent and extreme loading of the spine over the years also constitutes a "chronic" strain, which can possibly lead to degenerative changes. In the "normal" population, the prevalence of spinal degeneration is associated with increasing age. However, this deterioration with age may be accelerated by regular exposure to high $+G_z$ forces. The aim of this study was to examine whether F-16 pilots are at an increased risk of (cervical) spine degeneration. **Methods:** Retrospectively, all pilots of the Royal Netherlands Air Force (RNLAF) that were systematically radiographed (at least twice) in the period between 1982 and 1994, were examined. In total 316 pilots were evaluated, 188 F-16 pilots (mean age 28.5 years at initial X-ray) and 128 pilots in the control group (mean age 24.2 years at initial X-ray). The control group consisted of 64 helicopter pilots, 63 NF-5 pilots and 1 F-27 pilot. None of this group of pilots had more than 150 hours flying experience with a F-16. Two radiologists, who were blinded as to whether the X-ray films were of F-16 pilots or control group, examined these X-rays separately. In both groups, the time between the two X-rays was on average 6 years. In these years the control group had a significantly higher mean number of flying hours compared to the F-16 group (resp. 922 versus 690 hrs). **Results:** Though the inter-rater agreement of the X-rays was rather low, both radiologists found comparable statistical significant differences between the two groups, on several levels of the cervical spine. In the F-16 group, an increased osteophytic spurring was found at levels C_4-C_5 and C_6-C_7, and increased arthrosis deformans was found in the cervical spine. Further analysis of the data of a selection of the total group of pilots, whereby the difference in age between both groups was minimized, showed that the higher mean age of the F-16 pilots was possibly correlated with the increased degeneration in this group. No consistent relationship was found between spinal degeneration and initial radiological status. Also, a clear relationship between spinal degeneration and flying hours could not be demonstrated. **Conclusion:** These findings suggest that frequent exposure to high $+G_z$ forces might cause premature degeneration of the spine of F-16 pilots. Future research has to demonstrate to what extent age, mission, and number of flying hours have influenced the results. An uniform international classification and coding system in combination with establishing an international data-base is recommended in order to more fully understand the relationship between exposure to high $+G_z$ forces and spinal degeneration.

Introduction

During air combat maneuvering under high $+G_z$ forces, the spine is frequently exposed to heavy loads. Above all, the harmful factor is the acceleration of the high performance aircraft. Together with twisted and extreme positions of the head, while wearing a flight helmet and oxygen mask with hose, the high $+G_z$ forces place an increased stress, especially on the cervical spine.

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Other aggravating factors are the poor sitting position of the pilot on the ejection seat and the vibrations of the aircraft, which are particularly marked in certain phases of the flight (taxi-ing, take-off, low-level flight, turbulence and landing).

A review of the literature has revealed numerous cervical spine injuries associated with high in-flight $+G_z$ forces, such as compression fractures, ligament tears and bulging of the intervertebral discs (1, 3, 8, 26). Acute in-flight neck injury is a common complaint among pilots flying high performance aircraft (17, 18, 21, 28). Not only sudden incapacitation is caused by high performance flying, the frequent and extreme loading of the spine over the years also constitutes a "chronic" strain (due to repeated instances of minor insult), which can possibly lead to degenerative changes (6). However, not much information is available on the long-term effects of exposure to high $+G_z$ forces on the spine.

In the "normal" population, the prevalence of spinal degeneration is associated with increasing age, already beginning in the third decade (4). However, this deterioration with age may be accelerated by regular exposure to high $+G_z$ forces (1). With the introduction of the F-16 in the Royal Netherlands Air Force (RNLAF), an increase in spinal column disorders was anticipated. Therefore, a systematical radiological examination of the whole spine was instituted in the medical screening since December 1982 (27).

The purpose of this study was to assess the effects of flying F-16 on spinal degeneration in RNLAF pilots, by using these X-rays, and to possibly relate spinal degeneration to initial radiological status. Also, the relation between total F-16 flying hours and severity of degeneration will be investigated.

Methods

Subjects

All subjects were pilots of the RNLAF, who were systematically radiographed at least twice in the period between 1982 and 1994. Between the two X-rays at least two years should have been passed. Both candidate student pilots and qualified pilots, designated to fly the F-16 since December 1982, took part in this study. Only those student pilots, who had no severe abnormalities at their first X-ray, entered the study population. This pre-selection did not occur in the older qualified pilots, because almost all of them were approved to be converted to the F-16, in spite of eventual deviations.

The F-16 group consisted of pilots having more than 150 flying hours in a F-16 between the two X-rays. Those pilots who had none or less than 150 hours flying experience with a F-16, entered the control group (64 helicopter pilots, 63 NF-5 pilots and 1 F-27 pilot). In total 316 pilots were evaluated; 188 F-16 pilots (mean age 28.5 years at initial X-ray) and 128 pilots in the control group (mean age 24.2 years at initial X-ray). These, and some other characteristics of the participants are summarized in Table 1.

Table 1 Subject characteristics

	F-16 pilots	control group	Significant difference
Number (no. females)	188 (1 female)	128 (7 females)	
Height (cm)	181 (167 - 193)	181 (161 - 191)	-
Weight (kg)	75.7 (60 - 98)	74.8 (48 - 100)	-
Age at initial X-ray (yrs)	28.5 (17 - 49)	24.2 (16 - 48)	**

values are mean and range in parenthesis,
* : significant at $p < .05$,
** : significant at $p < .01$,
- : not significant

Because of the higher mean age at the initial X-ray of the F-16 group, which can possibly interfere with the results, statistical analyses were also performed on a subgroup of the total population. A statistical equal mean age was obtained in the subgroup with an initial age between 20 and 30 years. This resulted in a group of 101 F-16 pilots and 67 pilots in the control group (mean age at initial X-ray resp. 24.2 years and 23.9 years).

Radiological examination

Two spine X-rays of every pilot were examined in this study, one initial and a second X-ray a few years later. Each X-ray consisted of 12 small films (circa 8 by 8 cm), which represented frontal and lateral views of the spine taken in standing

Table 2 Classification of disorders

	Disorder	Levels
General :	Osteo-arthrosis / Spondylosis / Arthrosis Deformans	Cervical, thoracic, lumbar
	Scoliosis	Cervical, thoracic, lumbar
	Abnormal alignment	Cervical, lumbar
	Scheuermann's disease / Enchondrosis	Thoracic, lumbar
Specific :	Degenerative changes in the intervertebral disc / Discopathy	Cervical, thoracic, lumbar
	Presence of Osteophyte's / Osteophytic Spurring	Cervical, thoracic, lumbar
	Presence of Osteophyte's posterior in spinal canal	Cervical, thoracic, lumbar

position. The X-rays were made with a 14 inch image intensifier, to reduce the radiation exposure to the candidate to 10-25% of that produced by conventional radiography.

Two radiologists of the Central Military Hospital, who were blinded as to whether the X-ray films were of F-16 pilots or control group, examined these X-rays separately. Both X-rays were examined in order of time, using the classification as mentioned in Table 2. The severity of the disorder was given on a 7 point scale (Table 3).

Table 3 Severity scores

Code 0	no abnormalities
Code 1	minor
Code 2	modest
Code 3	moderate
Code 4	rather severe
Code 5	severe
Code 6	very severe

Data analysis

The data were analysed using SPSS 7.5 and SYSTAT 7.0. Significancy was set at $p < .05$ (*) or at $p < .01$ (**). Statistic analysis was performed on the severity scores as well as on the difference scores, which reflect changes in severity scores in time. An overview of the statistical tests used in the data analyses is given in Table 4.

Table 4 Data analysis

Test for :	Statistical test :
1. Initial difference between the two groups	
- population characteristics	Student's *t* - test
- radiographical data	Somers' *d*
2. Significant change in time, for each group separately	McNemar's symmetry □ ^{2}
3. Significant difference between the two groups concerning changes in severity scores in time	Cochran's linear trend
4. Inter-rater agreement	Cohen's kappa

Student's *t* - test was used to study if there was a difference in population characteristics (i.e. age, height, weight) between F-16 pilots and the control group at the start of the study. To test whether a difference existed in severity of disorders between F-16 pilots and the control group at the start of the study, Somers' *d* was calculated. This is a measure of association for ordinal variables (r x c table), which has a column variable that is considered to be the dependent variable (in this study the severity score of the disorders is the dependent variable). A value of 0.0 means no association and 1.0 is indicating a perfect positive association (29).

McNemar symmetry Chi-square test was performed to determine the changes in the severity of disorders in the period between the two X-rays, for each group separately. For conclusions about differences between the two groups concerning changes in severity scores in time, Cochran's linear trend was used. Finally, Cohen's kappa was computed to study the degree of agreement between the two radiologists (inter-rater agreement). Values of kappa greater than 0.61 indicate good to very good agreement, between 0.21 and 0.60 means fair to moderate, and below 0.20 the strength of the agreement is poor (2).

Results

General results

Initially, the films of 346 pilots were examined. Because of unacceptable quality, it was not possible to judge the X-rays of 11 pilots. In 19 cases vital data were missing, so eventually the films of 316 pilots were used for statistical analysis. The removal of these 30 subjects was executed before classifying them in F-16 or control group.

None or only minor changes were observed at levels C_7-Th_1 and Th_{12}-L_1 and no further tests

Table 5 Subject characteristics

	F-16 pilots	Control group	Significant difference
Time between two X-rays (yrs)	6.13 (2 - 12)	5.77 (2 - 11)	-
Flying hours in this period (hrs)	690 (160 - 1900)	922 (200 - 2460)	**

values are mean and range in parenthesis,
* : significant at $p <.05$,
** : significant at $p <.01$,
- : not significant

were done on these levels. In this report no data will be presented for Scoliosis, Abnormal Alignment and Enchondrosis / Scheuermann's disease, because a significant relationship between these disorders and high $+G_z$ forces was not expected.

There was no difference between the two groups as far as the time between the two X-rays was concerned (on average 6 years), but during this period the control group had a significantly higher number of flying hours (resp. 922 against 690 hrs, Table 5).

Radiological results

The results of the test for initial difference, the tests for degenerative changes in time of the F-16 group (F-16) and the control group (C), and the final conclusions are summarized in Table 6. Only those levels are presented, demonstrating a significant difference between F-16 group and control group.

At most levels, there is a significant difference in severity scores between the F-16 and the control group at the first X-ray (third and fourth column). In all cases where an initial difference exists between both groups, higher severity scores are seen relatively more frequent in the F-16 group than in the control group.

In some cases, not only a significant change in time is found in the F-16 group, but also in the control group. In the last columns the final conclusions are presented. In most cases that a significant change in time was found in both groups, it was significantly larger in the F-16 group, and in these cases it is concluded that the degree of degeneration was higher in the F-16 group (degeneration F-16 > C).

In contrast to Radiologist II, Radiologist I not only found significant changes at cervical level, but also at lumbar level. At thoracic level only Radiologists II found Arthrosis Deformans. Agreement exists between both radiologists on levels C_4-C_5 and C_6-C_7 concerning Osteophytic Spurring and on general cervical level, concerning Arthrosis Deformans.

In Table 7, the frequency of changes in severity scores between the initial and the second X-ray are described for each radiologists separately, for those levels of the spine where both radiologists found significant degenerative changes. Absolute numbers as well as percentages are included in this table.

It can be seen that the frequency scores of Radiologist I are almost always higher than those of Radiologist II, except for Arthosis Deformans at cervical level. An arrow is marking those levels where agreement exists between both radiologists.

Selected group

As can be seen in Table 1, the F-16 group had a statistical significant higher age than the control group. In order to minimize a possible confounding effect of the age of the F-16 group, a second analysis was done on groups matched for age. By removing a relatively large number of pilots above age 30 out of the F-16 group, and a relatively large number of pilots below the age of 20 out of the control group, a comparable mean age was achieved in both groups. As a result, the mean age at initial X-ray of this selected group was 24.2 years for the F-16 pilots (n=101) and 23.9 years for the control group (n=67), which was not significantly different.

Table 6 Statistical results of the radiological disorders according to Radiologist I (Rad I) and Radiologist II (Rad II)

		Initial difference F-16 and C		*Degenerative change in time*				*Conclusion*	
				F-16		*C*			
		Rad I	Rad II	Rad I	Rad II	Rad I	Rad II	Rad I	Rad II
C_4-C_5	Osteophytic Spurring	F-16 > C	F-16 = C	**	**	-	-	degeneration F-16	degeneration F-16
C_5-C_6	Discopathy	F-16 > C	F-16 > C	**	**	**	**	degeneration F-16 > C	-
	Osteophytic Spurring	F-16 > C	F-16 > C	**	**	*	*	degeneration F-16 > C	-
	Osteophyte's Posterior	F-16 > C	F-16 > C	**	**	**	-	-	degeneration F-16
C_6-C_7	Osteophytic Spurring	F-16 = C	F-16 = C	**	**	-	-	degeneration F-16	degeneration F-16
C	Arthrosis Deformans	F-16 > C	F-16 > C	**	**	-	**	degeneration F-16	degeneration F-16 > C
T	Arthrosis Deformans	F-16 > C	F-16 > C	**	**	*	-	-	degeneration F-16
L_3-L_4	Osteophytic Spurring	F-16 = C	F-16 = C	**	-	-	-	degeneration F-16	-
L_5-S_1	Discopathy	F-16 = C	F-16 = C	*	-	-	-	degeneration F-16	-

> : significantly higher (p <.05), = : no difference, * : significant at p <.05, ** : significant at p <.01, - : not significant

Table 7 The number of pilots (absolute number and percentages) demonstrating an increase in severity scores in the period between both X-rays

	Radiologist I		*Radiologist II*		
	F-16 (%)	C (%)	F-16 (%)	C (%)	
C_4-C_5					
□ Discopathy	48 (26)	18 (16)	17 (9)	9 (7)	
□ Osteophytic Spurring	27 (14)	3 (3)	20 (11)	4 (3)	□
□ Osteophyte's Posterior	55 (29)	29 (25)	8 (4)	3 (2)	
C_5-C_6					
□ Discopathy	56 (30)	20 (17)	34 (18)	15 (12)	
□ Osteophytic Spurring	38 (20)	11 (10)	36 (19)	10 (8)	
□ Osteophyte's Posterior	61 (33)	27 (23)	23 (12)	4 (3)	
C_6-C_7					
□ Discopathy	22 (12)	12 (10)	17 (9)	4 (3)	
□ Osteophytic Spurring	32 (17)	4 (3)	18 (10)	4 (3)	□
□ Osteophyte's Posterior	23 (12)	13 (11)	8 (4)	2 (2)	
C					
□ Arthrosis Deformans	23 (12)	3 (3)	77 (41)	31 (26)	□

□ : change in time, values are numbers and percentages in parenthesis, □ : statistical agreement between both radiologists

In Table 8 the radiological results are summarized of both the total group as well as the selected group. Only those levels of the cervical spine are presented, at which significant differences were found between the F-16 pilots and the control group in the total group.

The initial differences between the F-16 pilots and the control group disappeared at almost all levels. In Radiologist I, it remained intact for Osteophytic Spurring at C_4-C_5 and C_5-C_6 and for Arthrosis Deformans on general cervical level. The results of Radiologist II showed no initial differences at all in the selected group. The conclusion of the results of Radiologist I is that the F-16 pilots show a significant higher degree of Osteophytic Spurring at C_4-C_5 level than the control group. This is not in agreement with Radiologist II, who found a significant higher degree of Arthrosis Deformans on general cervical level in the F-16 group compared to the control group.

Associations between variables

In order to evaluate the consistency of the radiological interpretations, the inter-rater agreement was computed for those levels, at which both radiologists found significant degenerative changes. The range of Cohen's kappa was 0.06 - 0.29 for the initial X-ray and 0.01 - 0.30 for the radiological changes in time, which means a poor to fair agreement between both radiologists. However, expressed as percentages, the range of agreement was 61 - 91 % for the initial X-ray, and 65 - 85 % for the change in severity scores.

In the F-16 pilots as well as in the control group, the number of flying hours between both X-rays decreased significantly with increasing age at initial X-ray, indicating a decreasing number of flying hours with increasing age of the pilot. However, the correlation was relatively low in both groups, respectively -0.20 in the F-16 group and -0.30 in the control group (Figure 1).

At almost all levels in the F-16 group, a higher age at initial X-ray was correlated with increasing degeneration in the cervical spine (Table 9). The values of the correlation coefficient's, at which significant relationships were found, varied between 0.16 and 0.35 in Radiologist I and between 0.19 and 0.36 for Radiologist II. In the control group, only in the data of Radiologist II significant correlations were found at some levels.

No consistent relationship was found between the changes in severity scores in time and the initial radiological status. Only at level C_4-C_5 both radiologists found a significant correlation for Osteophytic Spurring in the control group, and Discopathy at level C_6-C_7 in the F-16 pilots. At several other cervical levels significant correlations were found, but these correlations were low and there was no agreement between both radiologists.

Finally, no significant correlation could be found between the amount of flying hours in the time between both X-rays and cervical degeneration in this period.

Discussion and Conclusion

The results achieved in this study are in line with those expected. Previous studies have reported that high $+G_z$ forces might promote degeneration of cervical spine structures in addition to the effects of aging (1). Most of these studies, however, were not longitudinal, but merely compared F-16 pilots and a control group at a certain moment in time. Also, the limited number of subjects studied and the type of control group (e.g. unknown or non-pilots) restricts the impact of these studies.

Gillen and Raymond (12) demonstrated a significant deterioration in young pilot groups compared to a control group, in terms of Osteophytic Spurring at C_5-C_6 and disc space narrowing at C_4-C_5 and C_5-C_6. According to these authors, the $+G_z$ environment appears to play a role in an accelerated rate of cervical Osteoarthritis in high performance pilots, starting at a surprisingly young age (20 years and older). They hypothesize that the pilots, while remaining relatively asymptomatic during their flying career, may be at greater risk for symptomatic cervical disease later in life.

In a study of Hämäläinen (13), who used magnetic resonance images (MRI), disc degeneration among fighter pilots frequently exposed to high $+G_z$ forces was greater than among a non-exposed control group (age-matched ground personnel of the Finnish Air Force), the difference being the most remarkable for the C_3-C_4 disc.

Table 8 Statistical results of the radiological disorders according to Radiologist I (Rad I) and Radiologist II (Rad II), for the whole group (n=316) compared to the selected 'age-matched' group (n=168)

		Initial difference F-16 and C				*Conclusion*			
		Whole group		*Selected group*		*Whole group*		*Selected group*	
		Rad I	Rad II	Rad I	Rad II	Rad I	Rad II	Rad I	Rad II
C_4-C_5	Osteophytic Spurring	F-16 > C	F-16 = C	F-16 > C	F-16 = C	degeneration F-16	degeneration F-16	degeneration F-16	-
C_5-C_6	Discopathy	F-16 > C	F-16 > C	F-16 = C	F-16 = C	degeneration F-16	-	-	-
	Osteophytic Spurring	F-16 > C	F-16 > C	F-16 > C	F-16 = C	degeneration F-16	-	-	-
	Osteophyte's Posterior	F-16 > C	F-16 > C	F-16 = C	F-16 = C	-	degeneration F-16	-	-
C_6-C_7	Osteophytic Spurring	F-16 = C	F-16 = C	F-16 = C	F-16 = C	degeneration F-16	degeneration F-16	-	-
C	Arthrosis Deformans	F-16 > C	F-16 > C	F-16 = C	F-16 = C	degeneration F-16	degeneration F-16	-	degeneration F-16

> : significantly higher (p <.05), = : no difference, - : not significant

Table 9 Correlation between age at initial X-ray and the amount of degeneration of the cervical spine

	Radiologist I		*Radiologist II*	
	F-16	C	F-16	C
C_4-C_5				
□ Discopathy	.08	- .13	.19 **	.04
□ Osteophytic Spurring	.27 **	.13	.24 **	.04
□ Osteophyte's Posterior	- .01	- .04	.20 **	.20 *
C_5-C_6				
□ Discopathy	.32 **	.06	.36 **	.15
□ Osteophytic Spurring	.29 **	- .04	.36 **	.15
□ Osteophyte's Posterior	.22 **	- .16	.25 **	.09
C_6-C_7				
□ Discopathy	.35 **	.10	.27 **	.27 **
□ Osteophytic Spurring	.32 **	- .07	.32 **	.27 **
□ Osteophyte's Posterior	.16 *	.10	.22 **	.21 *
C				
□ Arthrosis Deformans	.33 **	.06	.36 **	.04

□ : change in time, values are correlation coefficient's, * : significant at p <.05, ** : significant at p <.01

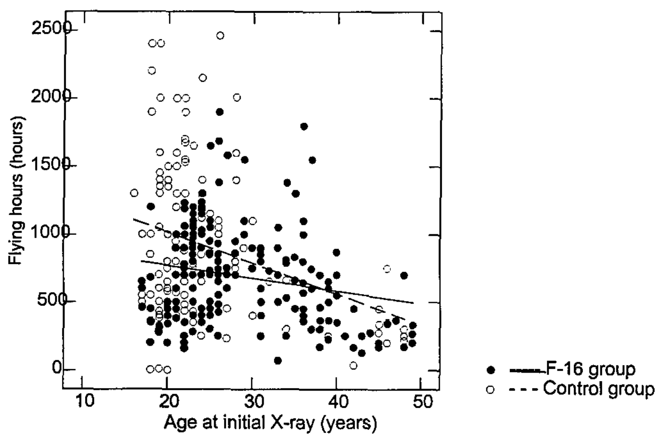

Figure 1 Correlation between age at initial X-ray and number of flying hours in the period between both X-rays

Petren-Mallmin and Linder (23) also found that military high performance flying might increase the risk for degenerative changes in the cervical spine. A significantly higher degree of disc protrusions per pilot was found and the mean sum of Osteophytes on the posterior border of the vertebral bodies also differed significantly from the control group. However, it was not mentioned whether the control group, who were sex- and age matched subjects, were also pilots.

One study found no significant difference between the MRIs of 22 asymptomatic male acceleration panel members and those of 19 age-matched control panel of asymptomatic male subjects (7). However, the power of the test was low because of the small sample size. Moreover, their confidence in the MRI interpretation was also low because of the high inter- and intra-rater variability.

In summary, there is some evidence that repeated exposure to high $+G_z$ forces might cause premature cervical disc degeneration (14). The repeated minor neck injuries may expose pilots to cumulative trauma and causing their spines, especially their cervical spines, to degenerate more rapidly than individuals not exposed to high $+G_z$ forces (1).

Moreover, there is a reasonable consensus about the most commonly involved site of cervical disc degeneration. In the general population, the frequency of cervical spine degeneration is greatest at C_5, followed by C_6 and C_4 (20). In studies of fighter pilots, the intervertebral disc at C_5-C_6, followed by C_6-C_7 were the most frequently affected sides (6, 9). Osteophytic Spurring was found most frequently at C_5-C_6 and disc space narrowing at C_4-C_5 and C_5-C_6 (12). The lower cervical spine appears to be most vulnerable to injury (7), which was also demonstrated in our study.

These findings suggest that frequent exposure to high $+G_z$ forces might cause accelerated degeneration of the cervical spine. However, the following considerations have to be made.

First of all, there are inconsistencies in the reading of radiographical data. Not only because of the lack of a uniform classification and coding system of disorders, but also because of the high subjectivity of the interpretation. This often leads to disagreements when different individuals report on the same films (1). A low inter-rater agreement is a common problem in radiography, and such was also the case in our study, although the agreement expressed in percentages in our study was reasonable high (61 - 91% for the initial X-ray, and 65 - 85% for the difference score). However, it must be mentioned that these numbers are flattered due to the high number of pilots having no radiological abnormalities. Cohen's kappa gives a better indication of the inter-rater agreement. The values found in this study were all below 0.40, which means a poor to fair strength of agreement (2).

Secondly, some methodological aspects may have influenced the results. Such as the fixed sequence of the films presented to the reviewer (always the initial films followed by the second), together with the fact that both radiologists were well aware of the purpose for which the examination was performed. Also, the assignment of the pilots to the F-16 or control group was based on the number of F-16 flying hours. The criterium of 150 flying hours or more was subjectively chosen, disregarding the nature of the flying missions and the experience of the pilot. Moreover, ideally the control group should have no fighter time at all.

A third, and very important item, is the overall radiographic degeneration of the spine with age. It is well known that cervical osteoarthritic changes occur with increasing frequency with increasing age in symptomatic and asymptomatic populations (12). These age-related degenerative changes possibly interfere in our study, because of the higher mean initial age of the F-16 pilots compared to the control group. This probably explains the initial difference between the X-ray scores at several levels of the spine, in favour of the control group. The results of the analysis of the 'age-matched' group confirm this hypothesis, because almost all initial differences between F-16 pilots and control group disappeared in this selected group, where the difference in mean initial age is minimized.

Although there are indications that a relationship exists between age and disc degeneration, there is no consensus about the nature of this relationship (10, 12, 16, 19, 25). Several studies demonstrate a roughly linear relationship, but it is also possible that, with increasing age, an acceleration of degeneration takes place which indicates that the relationship between age and disc degeneration is exponential.

Finally, several studies conclude that there is little correlation between radiographic findings and clinical symptoms of spinal disorders (1, 9, 15). According to Delahaye et al. (9) disc degeneration, even with very severe Osteophytosis, is often totally asymptomatic. The high incidence of spinal disc abnormalities in asymptomatic subjects has been well documented (7). So, when spinal films are used as a diagnostic tool, without correlating abnormal findings with specific symptoms, the radiological evidence has to be interpreted with great caution (3).

There was a small, but significant decrease in the number of flying hours in the period between both X-rays with increasing age at initial X-ray. This might be expected, because at higher age less flying hours will be made. However, especially in the F-16 pilots, a higher initial age is also related to increased cervical degeneration in the years between the two X-rays. As a consequence, no final conclusion can be drawn about the influence of the number of flying hours on spinal degeneration. Finally, a clear relationship between spinal degeneration and initial radiological status could not be demonstrated in this study, partly because of the low inter-rater agreement.

It can be concluded that, though the inter-rater agreement of the X-rays was rather low, statistical significant effects of F-16 flying were found. Increased Osteophytic Spurring was found at levels C_4-C_5 and C_6-C_7. Also, evidence for increased Arthrosis Deformans was found in the cervical spine. These findings suggest that F-16 pilots might have an increased risk of cervical spine degeneration. The results of an age-matched analysis are less striking, but differences between F-16 and control group are still present at some levels of the cervical spine. The results achieved here are in line with those from previous studies.

Recommendations

In the different member countries of the NATO, there is no consensus on the advisability of conducting systematic radiological examination of the spine at the time of acceptance or during the following years. Only a limited number of the NATO air forces carry out routine radiography of the spine (22), and the Royal Netherlands Air Force is one of them.

The results of our study suggest that it is recommendable to continue spine evaluations by means of radiography. Although the evidence is not strong, due to the low inter-rater agreement, there is some support that cervical spine degeneration can occur as a result of F-16 flying. Until more research has been done, it is advisable to continue the present procedure. The consequence of including radiographic examination in the initial screening of pilots is probably a higher rejection rate of candidate pilots. For example, in the period between November 1982 and January 1985, 20% of the Candidate Student Pilots of the RNLAF were rejected because of radiographically visualised spinal disorders, whether they had symptoms or not (27).

Instead of radiography, Magnetic Resonance Images (MRI) can be used. An advantage of MRI is that it does not involve exposure to X-rays, so radiation exposure will be minimized. Besides, the detection of disc degeneration using X-rays is difficult until quite severe (4). MRI is a far more sensitive imaging technique, which permits a definition of the earlier stages of degeneration (11). Unfortunately, the interpretation of MR images is much more difficult (1). It is excellent for delineating soft-tissue structures, such as the intervertebral discs, but the technique is less sensitive in defining osseous structures (5). Further, still let alone the costs, MRI being a fairly new and very sensitive diagnostic technique, it needs some time to establish reliable and reproducible interpretation criteria (7). To date, population-based statistics are not available for the entire spine using MRI (11).

So, despite the fact that MRI has a higher sensitivity and is less hazardous, plain X-rays might be more feasible for use in any definitive study (1). When using the image intensification method, as emphasised by Van Dalen & Van den Biggelaar (27), the radiation exposure will be greatly reduced.

To facilitate comparisons between the data from study to study, and country to country, it is advisable to standardize the format and description of anomalies. We propose to classify the results into categories of mild, moderate and severe disc degeneration, in order to improve the inter-rater agreement. Alternatively, the International Classification of Diseases Clinical Modification

(ICD 9 CM) could be used. This classification uses the terms mild, moderate and prominent (24).

Our results suggest to focus on the cervical spine, however, the cervical spine should not remain the exclusive focus of investigations of the effect of high $+G_z$ forces on the spine. High $+G_z$ forces may accelerate the normal degeneration process at all levels. For example at lumbar level, because more weight is put on this part of the spine as well. One of the problems in investigating the lumbar region is that back problems are extremely common in the general population (1).

For the prevention of injuries and also to increase the tolerance for high $+G_z$-forces, physical training is advised. Special physical training regimes for improving G-duration tolerance have been developed, and a subset of these training regimes consist of neck muscle exercise. The importance of these exercises should be emphasized (1).

In conclusion, more research is needed in order to establish the effects of frequent exposure to high $+G_z$-forces on the cervical spines of fighter pilots (21).

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