Cross-Sectional Study of Neck Pain and Cervical Sagittal Alignment in Air Force Pilots

Bong Ju Moon; Kyong Ho Choi; Chul Yun; Yoon Ha

BACKGROUND: There is a high prevalence of neck pain in air force pilots; however, the causes are not clear and are considered work-related. Kyphotic changes in the cervical spine have been known to cause neck pain. In this study, we investigated the association between neck pain and cervical kyphosis in air force pilots.

METHODS: This is a cross-sectional study of 63 Republic of South Korea Air Force pilots. We examined the C2-7 absolute rotation angle (ARA) using the posterior tangent method and other radiologic parameters on whole spine lateral radiographs. We divided the participants into a neck pain group ($N = 32$) and no neck pain group ($N = 31$), and subsequently analyzed the difference in radiographic parameters and clinical data between the two groups.

RESULTS: There were no significant differences found in age, body mass index, total flight time, or aerobic or anaerobic exercise between the neck pain and control groups. The fighter pilots had higher 1-yr prevalence of neck pain than nonfighter pilots (84.4% vs. 15.6%). The lower C2-7 ARA (OR = 0.91, 95% CI 0.846, 0.979) and fighter type aircrafts (OR = 3.93, 95% CI 1.104, 13.989) were associated with neck pain.

CONCLUSIONS: Fighter pilots experienced neck pain more frequently than the nonfighter pilots. Those fighter pilots suffering from neck pain were shown to have more kyphotic changes in the cervical spine than control pilots through evaluation of whole spine lateral radiographs using the posterior tangent method. These key findings suggest that the forces involved in flying a fighter type aircraft may affect cervical alignment and neck pain.

KEYWORDS: neck pain, cervical kyphosis, pilot, spinal curvature.

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Neck pain is the most common symptom along with lower back pain among musculoskeletal symptoms in the general population, with a particular predilection in pilots. An epidemiological study reviewed literature from 1980 to 2006 and reported that the 1-yr prevalence of neck pain in the general population was between 30–50%.[15] In 2012, a survey showed that the 1-yr prevalence of lower back pain and neck pain among 5338 Chinese workers was 59.7% and 48.6%, respectively.[35]

Due to rapid changes in velocity and gravitational forces in the cockpit environment during tactical maneuvering, the physically demanding nature of their work puts pilots at high risk of musculoskeletal injury manifesting as neck pain. A previous study reported that the 1-yr prevalence of neck injury in F16 pilots was 56.6%.[1] Interestingly, 50.6% of 437 U.S. Air Force pilots experienced a 3-mo prevalence of acute neck injury during the study.[31] Out of 127 helicopter pilots, 57% experienced neck pain with a 3-mo prevalence and 32% of these pilots experienced neck pain frequently.[2]

Neck pain originates from various etiologies, including cervical spondylosis, sprain, fracture, cervical disc herniation, occipital neuralgia, anomalies of the craniocervical junction, and fibromyalgia syndrome. Kyphotic changes in cervical spine alignment also have been considered an important cause of neck pain, both preoperatively and postoperatively.[13,16,20] Neck extensor muscles of the cervical spine play an important role in maintaining neck strength and alignment.[18,24]

Air force pilots exposed to high G forces have lower maximal contraction strength of neck extensor muscles and experience neck pain.[3] Moreover, if neck extensor muscles are

From the Department of Neurosurgery, Yonsei University College of Medicine, Severance Hospital, Seoul, Korea.

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Address correspondence to: Professor Yoon Ha, M.D., Ph.D., Department of Neurosurgery, Spine and Spinal Cord Institute, Yonsei University College of Medicine, Severance Hospital, 50 Yonsei-ro, Seodaemun-gu, Seoul 120-752, South Korea; hayoon@yuhs.ac.

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stretched for a long time, they become weak, resulting in cervical kyphosis.[17] However, prevalence of cervical kyphosis in air force pilots has not been well investigated to date. In addition, the association between cervical kyphosis and neck pain in the working environment of the cockpit has not been clearly elucidated. Therefore, in order to identify the spinal alignment and its impact on neck pain, we investigated the association of neck pain to cervical kyphosis and work related variables in pilots.

METHODS

Subjects

A total of 63 subjects were randomly selected from Republic of South Korea Air Force pilots who underwent annual physical check-ups in December 2012. Subjects selected were all men because there are very few female pilots in the Republic of South Korea Air Force. All subjects signed informed consent and had institutional review board approval for the present study (ASMC-12-IRB-003). Active pilots with ages in their 20s and 30s were selected to exclude age-related degenerative kyphotic changes in the cervical spine. Those with pathological conditions such as rheumatoid arthritis, diabetes, other systemic diseases, and previous history of cervical spine trauma were excluded.

Clinical and demographic factors related to neck pain were collected from medical records, including gender, age, height, weight, and total flight time. Neck pain was assessed by questionnaire after obtaining informed consent. The questionnaire included age, aircraft type, total flight time, aerobic and anaerobic exercise, and body mass index (BMI). The questionnaire inquired about neck pain during the past 1 yr. Characteristics of neck pain such as frequency, duration, and referred pain were investigated along with the use of the visual analog scale to score pain. Pilots who answered the questionnaire were divided into a Neck Pain group and a No Neck Pain Control group.

All 63 participants took lateral cervical and whole spine radiographs. Cervical spine radiographs were taken when subjects were in the relaxed standing position facing forward. We evaluated the C2-7 absolute rotation angle (ARA) on whole spine lateral radiographs using the posterior tangent method.[13] The C2-7 ARA is caused by an intersection of two extension lines of the posterior margins of the C2 and C7 vertebral bodies (**Fig. 1A**). In the present study, the C2-7 ARA value was defined as positive when the C2 line was located on the right side of the C7 line (**Fig. 1B**). Conversely, the C2-7 ARA value was defined as negative when the C2 line was located on the left side of the C7 line.

A positive C2-7 ARA indicates a lordotic curvature of the cervical spine and a negative C2-7 ARA correlates to a kyphotic curvature of the cervical spine. In the cases where the C2-7 ARA is close to zero, a straight cervical spine alignment is considered.[13,20] Cervical spine alignment is based on Grob's criteria.[14] Cervical kyphosis was defined as a C2-7 ARA of less than −4°. A straight cervical spine was defined when the C2-7 ARA was from −4 to +4°, whereas a lordotic cervical spine was designated as a C2-7 ARA of more than +4°. We also examined the following parameters on whole spine lateral radiographs: C1-2 Cobb angle, C2-7 Cobb angle, C7 slope, external auditory meatus-C7 distance, C2-7 sagittal vertical axis, T5-T12 Cobb angle, L1-S1 Cobb angle, sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and C7 sagittal vertical axis (**Fig. 2**).[23]

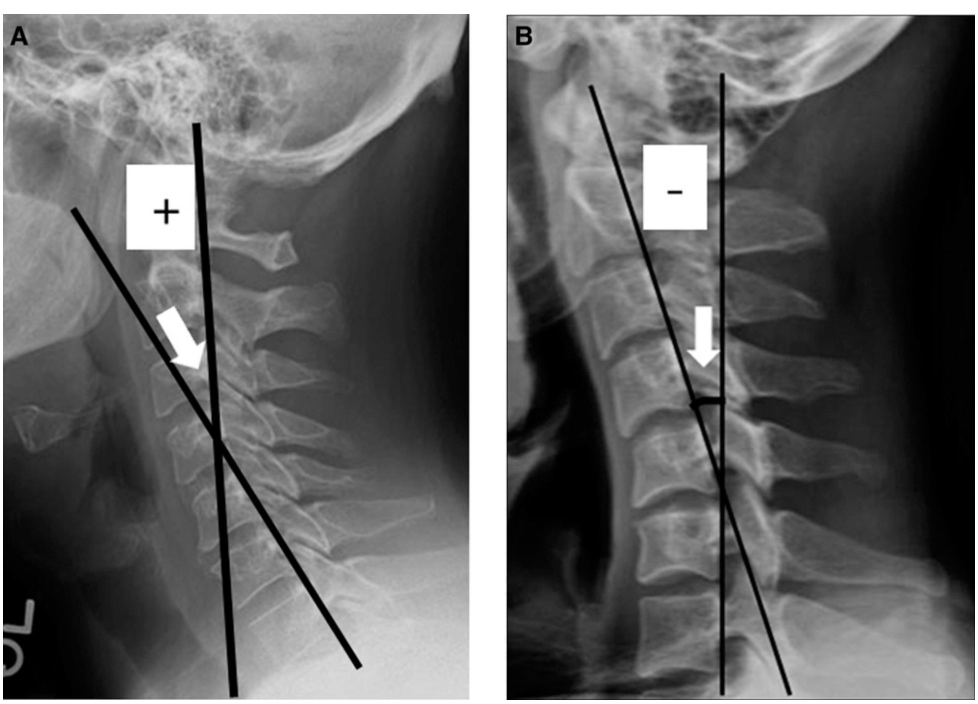

Fig. 1. The white arrow indicates absolute rotation angle (ARA) on lateral radiographs. A.) C2-7 ARA has a positive value when the C2 line is located on the right side of the C7 line. B.) C2-7 ARA is a negative value when the C2 line is located on the left side of the C7 line.

Statistical Analysis

All statistical analyses were performed using the SPSS version 18.0 software (SPSS Inc., Chicago, IL). P-values < 0.05 were considered statistically significant. Frequency distributions and summary statistics were calculated for demographic, clinical, and radiographic variables. For categorical variables, cross-tabulations were generated and Chi-square tests were used to compare distributions. For continuous variables, nonparametric t-tests were used to investigate differences between subsets of patients classified by neck pain and the control group. Logistic regression analysis was performed to provide adjusted assessment of risk factors for neck pain.

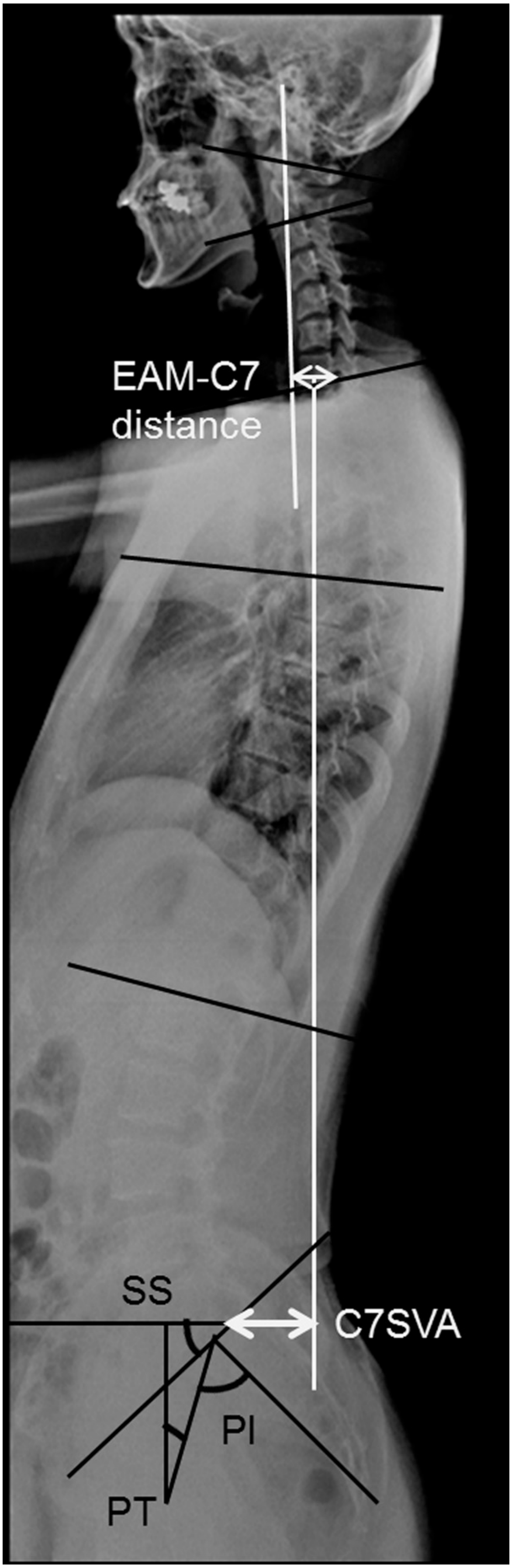

Fig. 2. Radiographic measurements performed using standard technique: C1-2 Cobb angle, C2-7 Cobb angle, C7 slope, external auditory meatus (EAM)-C7 distance, T5-T12 Cobb angle, L1-S1Cobb angle, sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and C7 SVA.

RESULTS

A total of 63 pilots were enrolled into the study with the mean age of the study population being 30 yr (range: 24 to 39 yr). The demographic data for the Neck Pain and the No Neck Pain Control groups are summarized in **Table I**. Of the 63 pilots, 32 (50.7%) experienced neck pain and 31 (49.3%) did not during the duration of the study. Therefore, the 1-yr prevalence of neck pain in our study population was 50.7%.

Age, BMI, total flight time, and aerobic and anaerobic exercise between the two groups were not statistically significant. Aircraft types and the C2-7 ARA showed a statistically significant difference. Additionally, the pilots were categorized according to fighter aircraft types and nonfighter aircraft types. The fighter types include the F-4, F-5, F-16, F-15, and the T-50 while the nonfighter types consisted of the CN235, C-130H, and helicopters. The Neck Pain group consisted of more fighter pilots (84.4% vs. 61.3%, $P = 0.039$). The mean C2-7 ARA was 2.72° (range: from −15.3 to 22.5°, SD: 8.55) in the Neck Pain group and 8.54° (range: from −5.6 to 25°, SD: 8.67) in the No Neck Pain group, respectively [$t(61) = -2.545$, $P = 0.011$].

Pain characteristics and other variables of neck pain are shown in **Table II**. The mean duration of neck pain was 5.5 d (SD: 5.47, range 1 to 21 d) and the visual analog scale for neck pain was on average 4.5 points (SD: 2.34). Of the 32 neck pain pilots, 24 (75%) experienced 1 or more events of neck pain during a 6-mo period. Pilots described the location of their pain to be either neck pain in 17 (53.1%), scapular pain in 14 (43.8%), or radiating pain in 1 (3.1%) pilot. Of the 32 pilots, 29 subjectively answered the circumstances in which they experienced neck pain. Among these 29 pilots, 15 (51.7%) stated that a sudden high G force that forcibly moved their heads during flying caused the onset of their neck pain and 4 (13.8%) had neck pain during long flights. Additionally, 10 (34.5%) pilots experienced neck pain during daily life.

The C2-7 ARA were classified into kyphosis (less than −4°), straight (−4° to 4°) and lordosis (more than 4°) denominations (**Table III**). A significantly higher number of pilots with kyphosis (82%) had neck pain ($P = 0.029$) compared to those in the No Neck Pain group. However, fewer pilots with the straight (50%) or lordosis (41.7%) classifications complained of neck pain when contrasted to their no neck pain counterparts.

Results of the spinopelvic parameters in both the Neck Pain and No Neck Pain groups are summarized in **Table IV**. All the radiographic parameters except the C2-7 ARA in lateral spine radiographs were similar between the two groups. The mean values for the pelvic parameters in both the No Neck Pain and Neck Pain groups were PI (45.21 ± 8.54 and 47.95 ± 9.40, respectively, $P = 0.341$), PT (14.92 ± 9.62 and 13.59 ± 8.78,

Table I. Data and Association of the Variables Between the Neck Pain and No Neck Pain Groups.

	NO NECK PAIN	NECK PAIN	*P*-VALUE
Pilots, N (%)	31(49.3%)	32(50.7%)	
Age, years (SD)	30.6(3.88)	29.4(3.85)	0.221
Body Mass Index (SD)	24.76(2.51)	24.93(3.57)	0.796
Total flight time, hours (SD)	875.7(706.6)	997.6(624.8)	0.470
Aircraft type			0.039*
Fighter type, N (%)	19(61.3%)	27(84.4%)	
Nonfighter type, N (%)	12(38.7%)	5(15.6%)	
Aerobic exercise			0.822
None, N (%)	7(22.6%)	8(25%)	
One or more times per week, N (%)	24(77.4%)	24(75%)	
Anaerobic exercise			0.716
None, N (%)	17(54.8%)	19(59.4%)	
One or more times per week, N (%)	14(45.2%)	13(40.6%)	

* Statistically significant ($P < 0.05$). Aircraft type had a significant difference between the two groups.

Table III. Distribution of Categorized C2-7 ARA Between the Neck Pain And No Neck Pain Groups.

CERVICAL CURVATURE	NO NECK PAIN	NECK PAIN
Kyphosis, N (%)	2 (18.2%)	9(81.8%)
Straight, N (%)	8 (50%)	8(50%)
Lordosis, N (%)	21(58.3%)	15(41.7%)

Kyphosis (C2-7 ARA: less than −4°); straight (C2-7 ARA: −4° to 4°); lordosis (C2-7 ARA: more than 4°). $P = 0.029$ analyzed by the Chi-square test; ARA: absolute rotation angle.

respectively, $P = 0.652$) and SS (30.93 ± 8.19 and 35.17 ± 8.32, respectively, $P = 0.052$).

Significant correlations were found between the parameters of adjacent anatomical regions (**Fig. 3**) in both the Neck Pain and No Neck Pain groups. PI regulated the sagittal sacro-pelvic orientations (SS and PT). The SS corresponded with the shape of the lumbar spine. Adjacent anatomical regions of the spine and pelvis were interdependent, which resulted in a stable and compensated posture. However, these relationships were not distinguished between the thoracic and cervical spine. Of note, stronger correlations were not found between the thoracic morphology and cervical morphology (C7 slope and C2-7 ARA) in both the Neck Pain ($r = 0.169$, $P = 0.373$) and No Neck Pain groups ($r = 0.196$, $P = 0.299$).

Binary logistic regression analysis using the backward conditional method revealed risk factors of neck pain among age, BMI, total flight time, aircraft type, and C2-7 ARA (**Table V**). Aircraft type (fighter) and cervical alignment (kyphosis) were significantly associated with neck pain in pilots. The statistical value of aircraft type and ARA in regards to the odds ratio (OR) are 3.930 (95% CI = 1.104∼13.989, $P = 0.035$) and 0.910 (95% CI = 0.846∼0.979, $P = 0.012$), respectively.

DISCUSSION

Air force pilots work in a strenuous physical environment in the cockpit. In this study, we found that neck pain in air force pilots was associated with fighter type aircraft and cervical kyphosis. Different studies have investigated the role of physical and psychosocial factors correlating to neck pain in air force pilots.[11,29,30] Nevertheless, few studies have demonstrated the differences in variables significantly associated with neck pain.[1,2,25]

In this cross-sectional study, we found high prevalence of this musculoskeletal condition where 50.7% of the respondents reported prominent neck pain. The prevalence of neck pain in this report is in agreement with results from other studies.[2,10,21] However, few studies of air force pilots have reported a lower prevalence of neck pain.[11] The differences in prevalence between studies are possibly due to disagreement in populations studied, time periods used in period prevalence calculations, or criteria used for defining pain and its symptoms.

Holding the neck in a forward bent posture for prolonged periods and working in the same position for extended periods of time have been significantly associated with neck pain.[6,32] Although not statistically significant, it has been suggested that there is a positive correlation between neck flexion and neck pain, suggesting an increased risk of neck pain for those who spend long working hours with their necks in the flexed position.[5,6]

Table II. The Characteristics of Pain in Pilots Suffering Neck Pain.

VARIABLES	MEAN (SD) OR N (%)
Duration of pain (days)	5.5(5.47)
Pain scale (Visual Analog Scale)	4.5(0.41)
Frequency of pain	
Once/1 yr	8/32 (12.7%)
Once/6 mo	8/32 (12.7%)
Once/3-6 mo	7/32 (11.1%)
Once/1-2 mo	8/32 (12.7%)
Always	1/32 (1.6%)
Referred pain	
Only neck pain	17/32 (27%)
With radiating pain	1/32 (1.6%)
With scapular pain	14/32 (22.2%)
Situation when pain developed	
Exposure of high G force	15/29 (23.8%)
Long flight length	4/29 (6.3%)
Daily life	10/29 (15.9%)

Table IV. Spinopelvic Profiles in Both the No Neck Pain and Neck Pain Groups.

	NO NECK PAIN ($N = 31$)	NECK PAIN ($N = 32$)	*P*-VALUE
C1-2 Cobb angle° (SD)	21.82(7.53)	23.53(6.59)	0.355
C2-7 Cobb angle° (SD)	8.97(6.71)	6.46(5.81)	0.128
C2-7 ARA° (SD)	8.54(8.67)	2.72(8.55)	0.011*
C7 slope° (SD)	15.65(5.04)	13.35(6.03)	0.113
EAM-C7 distance, mm (SD)	17.77(18.38)	19.33(14.15)	0.713
C2-7 SVA, mm (SD)	17.81(12.53)	18.70(10.64)	0.770
T5-12 Cobb angle° (SD)	22.78(5.94)	22.27(5.55)	0.731
L1-S1 Cobb angle° (SD)	50.98(7.37)	51.85(8.78)	0.680
C7 SVA, mm (SD)	47.66(36.53)	30.34(42.45)	0.096
Sacral slope° (SD)	30.93(8.19)	35.17(8.32)	0.052
Pelvic tilt° (SD)	14.92(9.62)	13.59(8.78)	0.652
Pelvic incidence° (SD)	45.21(8.54)	47.95(9.40)	0.341

* Statistically significant ($P < 0.05$). ARA = absolute rotation angle; EAM = external auditory meatus; SVA = sagittal vertical axis.

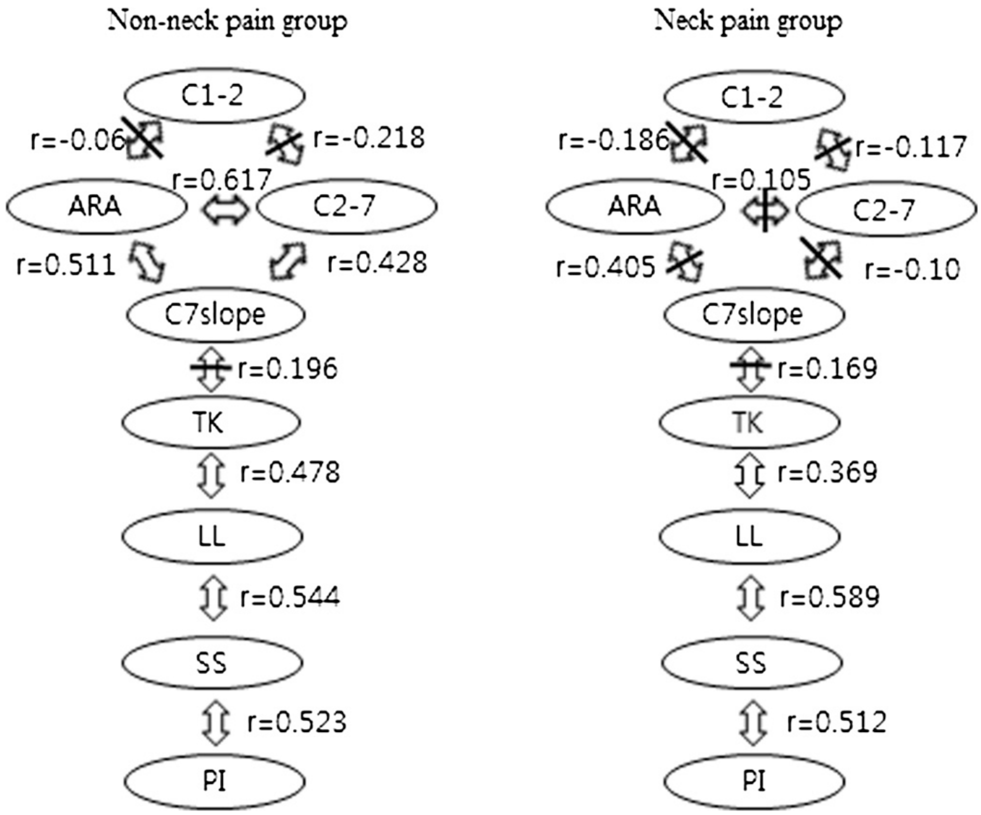

Fig. 3. Pearson's correlation of radiological parameters as the sagittal alignment in the No Neck Pain and Neck Pain groups. Arrows are the correlation with two radiological parameters of adjacent spinal segments. Arrows with a line through them means no correlation with two radiological parameters. "r" is Pearson's correlation coefficient.

Performing repetitive movements per minute has also been associated with neck pain. When working with the hands and fingers, the muscles in the neck and shoulder region must act as stabilizers. Static contraction of the trapezius and other shoulder muscles are needed to keep the arms at right angles, a necessary posture when controlling the handle.[6] This contraction is accentuated when rotation or bending of the neck occurs when a pilot moves and angles their head to maneuver their aircraft in a different direction.

In a Finnish military study, at the onset of acute neck injury, the position of the head was twisted in 98% of cases.[28] Acute in-flight neck injuries (pain) have not been recorded to occur below 4 G (g forces). In the present study, a higher prevalence of neck pain was found in fighter aircraft pilots compared to low G non-fighter aircraft pilots. The effects of sustained G and head movements on cervical erector spinal muscle strain have been investigated.[28,33] Muscular strain was found to rise in neck extensor muscles with higher G and corresponding head motions. There was a 5.9-fold increase in muscular strain (i.e., 37.9% maximal voluntary contraction, % MVC) at 7 G in comparison to 1 G. Thus, fighter pilots are most susceptible to acute in-flight neck injury when the strength of the neck muscles is insufficient to support the head during high G forces.

Research has also identified certain neck movements of rotation, lateral bending, extension, and flexion in high G force conditions as high risk for neck pain. Since these actions require maximal neck rotation and maximal recruitment of muscle motor units, they create significant stress from the substantial forces that are supporting the tissues to stabilize the head and neck. Yet, the neck rotator muscles generate the least isometric force of all the neck muscles.[9] Rotational motions are often accompanied by the pilot's neck being in flexion, extension, or lateral bending. A combination of the various motions often leads to acute neck injuries.[8] The seat angle of fighter aircraft coupled with high G forces has been reported to have an effect of subjective discomfort and neck pain in those pilots. One study found that differences in cervical spine biomechanics in the F-16 aircraft with a 30° reclined seat required an additional 15° forward flexion of the neck to maintain adequate direction of pilot vision.[8] This maintained posture may explain the higher prevalence of cervical kyphosis in air force pilots.

The association between helmet weight and G forces on neck muscle strain has likewise been described.[4,27] The reports indicated the possibility of lighter flight helmets causing less strain on neck structures. The positive effect of less helmet weight was seen only under high G forces. Switching from a heavy (1940 g) to a lighter (1310 g) helmet reduced the mean muscular strain from 9.5 to 8.8% maximum voluntary contraction (MVC) under 4 G and from 20.2 to 17.1% MVC under 7 G.[4,27] Therefore only some acute in-flight neck injuries can be avoided by using lighter flight helmets. However, in an aircraft capable of higher Gs, this helmet effect may be more pronounced. Although our study does not clearly examine the effect of helmet weight on neck pain and cervical kyphosis, its

Table V. The Risk Factors of Neck Pain.[†]

	B SLOPE	*P*-VALUE	ODDS RATIO (95% C.I.)
Age	0.094	0.212	1.099(0.948∼1.273)
Body mass index	0.014	0.906	1.014(0.807∼1.273)
Total flight time	0	0.88	1(0.999∼1.001)
Fighter type	1.379	0.035*	3.930(1.104∼13.989)
C2-7 ARA	1.901	0.012*	0.910(0.846∼0.979)

* Statistically significant ($P < 0.05$).

† The risk factors for neck pain were analyzed by binary logistic regression analysis using the backward conditional method. Fighter type aircraft was a risk factor for neck pain (OR = 3.930). An increased C2-7 ARA value decreased the risk for neck pain (OR = 0.910). ARA = absolute rotation angle.

significance cannot be ignored and we suggest further investigations on the effect of helmet weight on the cervical spine in order to prevent acute neck injury.

Whole body vibration (WBV) is defined as "the mechanical vibration that, when transmitted to the whole body, entails risk to the health and safety of workers, in particular lower-back morbidity and trauma of the spine."[7] WBV is experienced by the pilot (primarily from the seat) and by the crew with variable intensities depending on their position in an aircraft. Studies designed to quantify the effects of WBV have found that a vibration frequency as low as 5 Hz can increase helmet and head displacement exponentially when vibrations are transferred from the buttocks to the head in the seated position.[19,34] In contrast, another study[26] found that WBV for most helicopter crew did not exceed thresholds for health risks according to international guidelines[22] and did not cause muscular fatigue in pilots.[12] This research suggests that WBV, in addition to posture, might increase the risk for low back pain and potentially neck pain as well. It should be made known that every mission has varying vibration levels depending on the aircraft type and duration of flight.

In the present study, the mean ARA of neck pain pilots was 2.80°. In the general population, those with neck pain have been found to have varying mean ARAs with figures in the ranges of 9.6, 12.4, and 4.2°.[13,16,20] These results coincide with the mean ARA of pilots in the No Neck Pain group and thus we can assume that the ARA in pilots is lower than that of the general population.

We acknowledge that this study has some limitations. Since the cause of neck pain between pilots of fighter type aircrafts, cargo planes, and helicopters is different, we believe that the forces and changes to the curvature of the cervical spine may be different for each aircraft.[3,11] However, because of the small sample size, a significant difference of cervical spine curvature between each aircraft did not exist and we suggest further study into specific aircraft types. The ARA for the cervical spine curvature of pilots suffering from neck pain will be the therapeutic index for exercise therapy of the cervical spine.

In conclusion, fighter pilots experienced neck pain more frequently than the non-fighter pilots. Those suffering from neck pain were shown to have more kyphotic changes in the cervical spine than control pilots through evaluation of whole spine lateral radiographs using the posterior tangent method. These key findings suggest that the forces involved in flying a fighter type aircraft may affect cervical alignment and neck pain.

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Authors and affiliations: Bong Ju Moon, M.D., Department of Neurosurgery, Chonnam National University Hospital and Medical School, Gwangju, Korea; Yoon Ha, M.D., Ph.D., Department of Neurosurgery, Yonsei University College of Medicine, Severance Hospital, Seoul, Korea; Kyong Ho Choi, University of Sydney College of Medicine, Sydney, Australia; and Chul Yun, M.S., Aerospace Medical Center, Republic of Korea Air Force, Cheongwongun, Chungcheongbukdo, Republic of Korea.

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