Neck Proprioception, Strength, Flexibility, and Posture in Pilots With and Without Neck Pain History

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Introduction: Neck pain (NP) is common among military helicopter pilots. Older age and more flight-hours have been associated with pilots with a history of NP. However, modifiable neuromuscular and musculoskeletal characteristics such as neck proprioception, strength, flexibility, and posture have rarely been investigated in military helicopter pilots with a history of NP. The purpose of the study was to compare demographics, flight characteristics, physical fitness information, neck proprioception, strength, flexibility, and posture between helicopter pilots with and without a history of NP. ***Methods:*** A total of 27 Army helicopter pilots with NP in the past 12 mo (pain group) were matched based on age with pilots without a history of NP (nonpain group). All pilots had flown at least 100 h in the past 12 mo and were cleared for flight and physical training. All pilots completed a battery of laboratory testing: neck proprioception, neck and scapular muscular strength, neck active range-of-motion (ROM), forward head and shoulder posture, and pectoralis minor length. Paired *t*-tests or Wilcoxon tests were used to compare differences between groups. ***Results:*** The pain group had significantly less cervical extension (63.7 ± 8.5°) and rotation ROM (R rotation: 67.7 ± 8.8°; L rotation: 67.4 ± 9.0°) when compared to the nonpain group (extension: 68.3 ± 7.4°; R rotation: 73.4 ± 7.4°; L rotation: 72.9 ± 6.8°). No significant differences were found for other variables. ***Conclusion:*** The results demonstrate less neck active ROM in pilots with a history of NP. Operating a helicopter with limited neck ROM or NP may negatively impact flight safety and force readiness. Continued research is warranted.

Keywords: neck pain, helicopter pilots, neuromuscular and musculoskeletal factors.

NECK PAIN (NP) is one of the most common musculoskeletal conditions in military helicopter pilots (22). Van den Oord et al. (23) reported that 43% of helicopter pilots experienced NP in the past year, of which approximately 20% experienced regular or continuous NP. Neck pain can result in medical leave from military duty, interfere with flying duty and leisure activities, and influence force readiness for aviation units (1). Neck pain that is not properly monitored or treated may result in long-term consequences for the health and operational readiness of military pilots (5).

Previous studies have investigated pilots' demographics, flight characteristics, and physical fitness information in pilots with NP. Van den Oord et al. (23) reported that helicopter pilots with a history of NP had significantly greater total flight-hours than pilots without a history of NP. Ang et al. (1) reported that frequent use of night-vision goggles (NVG) and a history of NP were identified as risk factors for NP. Interestingly, the authors also report that pilots who engaged in strength training for more than one hour per week had significantly lower relative risk of NP, suggesting that muscular strength might be an important factor preventing NP (1).

Neuromuscular and musculoskeletal characteristics (e.g., neck proprioception, strength, flexibility, and posture) have been studied in the past in individuals with NP. Neck pain can affect cervical afferent input, resulting in altered neck proprioception (12,17). Individuals with NP may also exhibit reductions in neck strength and flexibility when compared to individuals without NP. Lecompte et al. (14) reported a reduction in neck lateral flexion isometric strength in fighter jet pilots with a history of NP when compared to the fighter jet pilots without a history of NP. De Loose et al. (7) reported reduced cervical range-of-motion (ROM) in fighter jet pilots with a history of NP when compared to fighter jet pilots without a history of NP. Other contributors such as the upper quadrant posture and scapular muscle weakness have been discussed in the past (22). Poor sitting posture in the helicopter cockpit has been suggested as a contributor of NP (8). Weak trapezius muscles could compromise the integrity of the glenohumeral and scapulothoracic joint and might be associated with individuals with NP (19). Therefore, it was of our interest to examine head and shoulder posture and scapular muscle weakness in helicopter pilots.

Previous studies have collectively increased our knowledge of NP in civilian and military populations. However, to our knowledge, there have been few studies that have evaluated multiple neuromuscular and

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musculoskeletal characteristics such as those discussed here. Therefore, the purpose of the current investigation was to compare demographics, flight characteristics, physical fitness information [Army Physical Fitness Test (APFT) score; hours per week of resistance/cardiovascular training], neck proprioception, neck/scapular muscular strength, neck active ROM, forward head posture, forward shoulder posture, and pectoralis minor length between helicopter pilots with a history of NP (pain group) and age-matched helicopter pilots without a history of NP (nonpain group). First, it was hypothesized that there would be no significant group difference for demographics and flight characteristics, largely due to age-matching. Second, it was hypothesized that the pain group would be less fit (based on lower APFT score) and spend less time in physical training when compared to the nonpain group. Third, it was hypothesized that the pain group would exhibit significantly impaired neck proprioception, neck/scapular strength, neck active ROM, and posture when compared to the nonpain group. The current investigation is clinically significant because the results would establish the status of selected neuromuscular and musculoskeletal characteristics in military helicopter pilots with and without a history of NP. In turn, helicopter pilots, unit leaders, and medical providers could utilize the current study's results to develop and validate aviator-specific intervention programs aimed at reducing the incidence and severity of NP.

METHODS

Subjects

Human subjects' approval was obtained from the Eisenhower Army Medical Center and the University of Pittsburgh. Active-duty helicopter pilots from the 101st Combat Aviation Brigade within the 101st Airborne Division (Air Assault) were recruited and participated in the study. Inclusion criteria were: male gender; age 18 to 55 yr; no history of concussion or mild head injury in the past 12 mo; no other past neurological or balance disorders; and no current spinal, upper limb, or lower limb impairment that could affect test performance. All pilots were pain-free at the time of testing, had passed their annual medical examination, and had no restriction of physical fitness. In order to qualify for this study, pilots had flown at least 100 h in the past 12 mo. Exclusion criteria were cardiovascular, pulmonary, or metabolic disorder, or skin allergy to adhesive tape.

As a part of comprehensive injury prevention and performance optimization research initiatives with the University of Pittsburgh and the 101st Airborne Division (Air Assault), a total of 123 pilots were tested on the current protocol over a period of one year. Of those pilots, 27 pilots (Aircraft: AH64 Apache = 7, UH60 Black Hawk = 6, CH47 Chinook = 1, OH58 Kiowa = 13) with a history of NP and over 100 flight-hours in the past 12 mo were matched based on age (± 5 yr) with pilots (Aircraft: AH64 Apache = 9, UH60 Black Hawk = 6, CH47 Chinook = 3, OH58 Kiowa = 9) without a history of NP and over 100 flight-hours in the past 12 mo. For the NP group, episodes of NP in the past 12 mo were verbally self-reported during a standardized history-taking performed by the researchers. Neck pain was defined as any pain, aches, and/or discomfort in the neck region (23). For pilots with a history of NP pain intensity by the Numerical Pain Rating Scale (NPRS: 0 as no pain and 10 as worst pain imaginable) (6), pain duration (days), and disability level by the Neck Disability Index (NDI) (26) were reported for the worst episode of NP in the past 12 mo. Demographics, flight characteristics, and physical fitness information are presented (**Table I**).

Equipment

Height and mass were measured using a standard stadiometer and scale (Seca North America, East Hanover, MD). Conscious neck proprioception was measured by active joint position sense error using the Vicon Nexus motion capture system synchronized with six wall-mounted MX13 infrared cameras (capturing frequency

TABLE I. DEMOGRAPHICS, FLIGHT CHARACTERISTICS, AND PHYSICAL FITNESS INFORMATION.

Dependent Variables	Pain Group	No-Pain Group	*P*-Value
Demographics			
Age (yr)	34.5 ± 6.4	34.3 ± 6.1	0.453
Height (cm)	176.9 ± 7.1	177.3 ± 8.5	0.948
Mass (kg)	84.8 ± 11.2	83.0 ± 12.0	0.542
BMI (kg/m^2)	27.0 ± 2.9	26.4 ± 3.6	0.399
Flight Characteristics			
Flight Experience (yr)	8.5 ± 6.0	9.0 ± 6.1	0.452
Total Flight-Hour	1800.9 ± 1460.7	1907.0 ± 1365.4	0.053
Total NVG Fight-Hour	446.7 ± 438.9	448.0 ± 426.3	0.819
12-mo Flight-Hour	216.5 ± 156.7	258.6 ± 188.5	0.190
Physical Fitness Information			
APFT Push-ups (repetitions)	64.0 ± 17.5	67.5 ± 13.8	0.319
APFT Sit-ups (repetitions)	66.9 ± 13.5	70.0 ± 12.9	0.371
APFT 2-Mile Run (min:sec)	15:06 ± 1:24	14:54 ± 1:36	0.557
APFT Score (points)	259.7 ± 30.3	269.3 ± 25.8	0.232
Cardiorespiratory Training (hr/wk)	3.4 ± 2.2	2.9 ± 1.6	0.344
Resistance Training (hr/wk)	3.6 ± 2.3	3.9 ± 2.3	0.710

BMI = body mass index; NVG = night vision goggles; APFT = Army physical fitness test.

at 200 Hz) (Vicon Motion Systems, Centennial, CO). Isometric cervical muscle strength (flexion, extension, right/left lateral flexion, and right/left rotation) and scapular muscle strength (middle and lower trapezius) was measured using a Lafayette handheld dynamometer (HHD) with large curved stirrup (Lafayette Instruments, Lafayette, IN). Prone cervical extension muscle strength was facilitated using a Tumble Forms 2 prone pillow (Sammons Preston, Bolingbrook, IL). Isokinetic upper trapezius muscle strength (shoulder shrug) was measured with the BIODEX System 3 PRO dynamometer (BIODEX, Shirley, NY). Neck active ROM (flexion, extension, right/left lateral flexion, right/left rotation) was measured using the CROM 3 (Performance Attainment Associates, Lindstrom, MN). Cervical rotation ROM testing was facilitated using a SKIL 8201-CL self-leveling cross-line laser (Robert Bosch Tool Corporation, Prospect, IL). Forward head posture was measured with the CROM 3. Forward shoulder posture and pectoralis minor length were measured with a modified 16 inch Swanson combination square (Swanson Tool Co., Frankfort, IL).

Procedures

Pilots reported to the University of Pittsburgh Warrior Human Performance Research Center at Fort Campbell, KY, for a 2-h testing session. An informed consent was completed by each pilot, followed by pain description (pain group), detailed inquiry regarding flight characteristics (total flight-years, total flight-hours, total NVG-hours, and 12-mo flight-hours), physical fitness information (the most recent APFT score: push-ups, sit-ups, 2-mile run time, and a combined score) and time (hours per week) spent in cardiorespiratory and resistance training. Height and mass were measured, and body mass index (BMI) calculated. Laboratory testing consisted of neck proprioception, neck strength, scapular strength, neck active ROM, and posture. Both directions (right and left) were tested for neck proprioception, strength, and ROM testing. Both arms and shoulders were tested for scapular muscular strength and posture testing. Reliability and precision of all laboratory testing procedures (neck proprioception, neck/scapular strength, cervical spine ROM, and posture testing) were established previously in our laboratory (**Table II**).

For the neck proprioception testing, pilots were blindfolded, seated on a wooden chair with hips and knees at approximately 90° flexion and feet hip-width apart. The elbows and forearms were supported by cushions on top of the chair. Pilots wore a 5-cm wide black athletic headband aligned parallel with the Frankfort Plane (16) and the lower edge aligned with the upper margin of the orbit. Retro-reflective markers were placed over the midline of the sphenoid bone (temple) and the most posterior aspect of the parietal bone on both sides of the head in line with the longitudinal midline of the headband (four head markers), and over the C7 and T10 spinous processes, the jugular notch, and the xiphoid process. A static capture trial was performed to create a

TABLE II. INTRARATER RELIABILITY AND PRECISION FOR NECK PROPRIOCEPTION, STRENGTH, ROM, AND POSTURE.

	ICC (2.1)	SEM
JPS Absolute Error (°)		
R30° Target	0.52	1.3 (°)
R60° Target	0.44	1.0 (°)
L30° Target	0.81	0.6 (°)
L60° Target	0.76	0.6 (°)
Neck Strength (%BW)	**ICC (2.1)**	**SEM**
Flexion	0.97	0.4 (%BW)
Extension	0.79	1.8 (%BW)
R Lateral Flexion	0.96	0.6 (%BW)
L Lateral Flexion	0.94	0.7 (%BW)
R Cervical Rotation	0.93	0.6 (%BW)
L Cervical Rotation	0.92	0.6 (%BW)
Scapular Strength (%BW)	**ICC (2.1)**	**SEM**
R Upper Trapezius	0.92	12.3 (%BW)
L Upper Trapezius	0.88	16.3 (%BW)
R Middle Trapezius	0.89	0.4 (%BW)
L Middle Trapezius	0.78	0.6 (%BW)
R Lower Trapezius	0.56	0.9 (%BW)
L Lower Trapezius	0.62	0.8 (%BW)
Active ROM (°)	**ICC (2.1)**	**SEM**
Flexion	0.92	1.7 (°)
Extension	0.98	0.6 (°)
R Lateral flexion	0.60	3.1 (°)
L Lateral flexion	0.53	3.8 (°)
R Rotation	0.92	1.5 (°)
L Rotation	0.92	1.4 (°)
Posture (cm)	**ICC (2.1)**	**SEM**
Forward Head	0.90	0.4 (cm)
R Forward Shoulder	0.41	1.8 (cm)
L Forward Shoulder	0.39	1.4 (cm)
R Pec Min Length	0.90	0.4 (cm)
L Pec Min Length	0.95	0.3 (cm)

JPS = joint position sense; ICC(2.1) = intraclass correlation coefficient model (2.1); SEM = standard error of measurement; R = right; L = left; %BW = percent of body weight; ROM = range-of-motion; Pec Min = pectoralis minor.

custom head-on-trunk model in the Vicon software. First, full left and right active rotation trials were performed three times to ensure pilots had more than 60°. Then, the examiner verbally cued pilots to rotate to the target angles using the Vicon real-time feedback function and standardized instructions. The target angles were 30° and 60° on both right and left directions. The testing order was randomized using a Latin-square method. Pilots performed a target angle trial followed by a replication trial. Pilots held the target angle for 5 s and were asked to concentrate on feeling where the head is in space. Pilots were then instructed to face forward. After a 5-s rest, pilots were instructed to replicate the target angle and press a stop-button when they felt they had done so. This procedure was repeated five times for both angles in both directions. The difference between the target trial angle and the subsequent replication trial angle was expressed in degrees as absolute error (AE) for each measured trial (4), the mean of five trials used for analysis.

For the isometric neck strength testing (flexion, lateral flexion, and rotation), pilots lay supine with their feet hip-width apart, their hands resting on the abdomen, and pillows placed under the knees. For flexion, the HHD stirrup was positioned horizontally in the longitudinal midline of the face, its lower edge just above the eye brows, and the HHD plunger was perpendicular to the contour of the forehead. Pilots were instructed to first lift the head to where the plane of the face was at 45°. For lateral flexion, the HHD stirrup was positioned vertically just above the ear with the HHD plunger perpendicular to the contour of the head. An assistant stabilized the opposite shoulder. For rotation, the HHD stirrup was positioned horizontally over the temporal line of the frontal bone, the HHD plunger immediately over the temporal line and perpendicular to the contour of the head. For extension, pilots lay prone, arms hanging over the side of the treatment table, pillows under the shins, and face resting on a prone pillow. The HHD stirrup was positioned horizontally over the occiput in the longitudinal midline of the head. For all neck muscle testing, the same procedures were used: the first warm-up set of two at 50% perceived maximum effort and the second warm-up set of two at 100% maximum effort. After a 60-s rest, three maximal effort trials were collected for data analysis with 60 s rest between trials. In order to prevent excessive body movement and HHD ballistic artifacts, pilots were asked to slowly ramp up to a maximum effort over 5 s versus performing a single ballistic effort.

For the isokinetic upper trapezius muscular strength testing, pilots were seated comfortably on the Biodex. The chest strap ipsilateral to the test arm was left undone to permit free movement of the shoulder girdle. The closed kinetic chain attachment was orientated vertically downwards with the axis of rotation of the dynamometer just below the head of the humerus. The long axis of the arm was parallel with the long axis of the trunk to place the shoulder in neutral flexion-extension. Range-of-motion limits were set just inside the maximum shrug excursion and with the arm fully relaxed holding the attachment handle. Pilots were instructed to shrug up as hard and fast as they could and then relax down while keeping the elbow straight at all times. After two sets of warm-up with 50% and 100% maximal effort, respectively, five consecutive shrugs with 100% maximal effort trials were collected for data analysis. Data were normalized by dividing mean peak force (Newtons) from the computer print-out by pilots' body weight and then multiplying the result by 100 to yield a %BW.

For the isometric middle and lower trapezius strength testing, pilots lay prone and were tested in the position described by Kendall et al. (13). The HHD stirrup was positioned transversely just above the radial styloid process. An assistant stabilized pilots by pressing down on the contralateral posterior superior iliac spine. For both tests, the same HHD procedures were used: the first warm-up set of two at 50% perceived maximum effort and the second warm-up set of two at 100% maximum effort. After a 60-s rest, three maximal effort trials were collected for data analysis with 60 s rest between trials. For neck and scapular HHD strength testing, data were normalized by dividing the mean of the three measured trials (kg) by body weight and then multiplying the result by 100 to yield a percentage body weight (%BW).

For neck active ROM, pilots were seated on a wooden chair with hips and knees at approximately 90° flexion and feet hip-width apart wearing the CROM. The elbows and forearms were supported by cushions on top of the chair armrests. For all tests, subjects began with their head in the Frankfort plane (16). Three practice trials were followed by three measured trials. For all trials, pilots were instructed to move their head as far as they could until stopped by an uncomfortable stretch or pressure. To facilitate cardinal plane left and right rotation, the laser level was used to project a horizontal line on to a wall in front of the pilots at eye level. Pilots were instructed to turn their head while following the laser line with their eyes. An absolute angle (in degrees) from the neutral position was recorded for three trials, and a mean of three trials was used for analysis.

For forward head posture, the test began in the same starting position as neck flexibility wearing the CROM with the forward head arm attachment. The base of the vertebral locator arm (with the bubble level attached) was on the C7, and the arm was oriented vertically to intersect with the forward head arm. The examiner read the values on the forward head arm.

For standing forward shoulder posture, pilots were standing with their feet together with their buttock just touching the wall (20). The combination square was placed above the shoulder to measure the horizontal distance between the anterior tip of the acromion process and the wall.

For pectoralis minor length testing, pilots lay supine with their arms resting on the abdomen. The combination square was place on the table to measure the vertical distance between the posterior tip of the acromion and the table surface (15). For all postural assessments, an average of three measures was used for analyses. For the upper quadrant posture tests, a mean of three trials (centimeters) was used for data analysis.

Statistical Analyses

Dependent variables were categorized into several groups: 1) demographics: age, height, mass, BMI; 2) flight characteristics: total flight-years, total flight-hours, total NVG fight-hours, and 12-mo flight-hours; 3) physical fitness information: APFT push-ups, sit-ups, 2-mile run time, and a combined APFT score, hours per week spent in resistance and cardiorespiratory training; 4) neck proprioception (absolute joint position sense errors at 30° and 60° target angles on both right and left directions); 5) neck strength (flexion, extension, lateral flexion, and rotation); 6) scapular strength (upper trapezius, middle trapezius, and lower trapezius); 7) neck active ROM (flexion, extension, lateral flexion, and rotation); and 8) upper quadrant posture (forward head posture, forward shoulder posture, and pectoralis minor length).

All statistical analyses were performed using IBM SPSS Statistics (version 20.0; IBM Corporation, Armonk, NY). Descriptive statistics (means and standard deviations) were calculated for each variable. Each dependent variable within each group was assessed for the assumption of normality (Shapiro-Wilk test). Based on the normality results, either paired *t*-tests or Wilcoxon Signed Rank tests were performed to compare groups. Significance was set at $P \leq 0.05$ a priori.

RESULTS

For the pain group, NPRS at the time of the worse NP was 4.0 ± 1.7. Pain duration and NDI were 1.5 ± 1.7 d and 6.9 ± 5.6, respectively. Means and standard deviations for all dependent variables are presented (**Table III**). The pain group had significantly less cervical extension (63.7 ± 8.5°) and rotation ROM (R rotation: 67.7 ± 8.8°; L rotation: 67.4 ± 9.0°) when compared to the nonpain group (extension: 68.3 ± 7.4°; R rotation: 73.4 ± 7.4°; L rotation: 72.9 ± 6.8°). The remaining dependent variables were not statistically different between groups.

DISCUSSION

Despite a high prevalence of NP in military helicopter pilots, few studies have evaluated musculoskeletal and neuromuscular characteristics in pilots with a history of NP. The purpose of this study was to compare demographics, flight characteristics, physical fitness information, neck proprioception, neck/scapular muscular strength, neck ROM, and forward head/shoulder posture between the pain group and the nonpain group.

TABLE III. MEAN (SD) FOR PROPRIOCEPTION, STRENGTH, FLEXIBILITY, AND POSTURE.

Dependent Variables	Pain Group	No-Pain Group	*P*-Value
JPS Absolute Error (°)			
R30° Target	3.2 (1.6)	3.2 (1.8)	0.857
R60° Target	2.0 (1.2)	2.2 (1.3)	0.334
L30° Target	3.2 (1.7)	3.0 (1.4)	0.600
L60° Target	1.9 (0.7)	2.2 (1.3)	0.946
Neck Strength (%BW)			
Flexion	17.6 (3.5)	17.5 (3.9)	0.904
Extension	31.3 (5.2)	32.3 (4.9)	0.518
R Lateral Flexion	25.2 (3.5)	26.9 (5.0)	0.154
L Lateral Flexion	26.1 (3.8)	28.2 (6.0)	0.152
R Cervical Rotation	20.3 (3.7)	21.2 (4.0)	0.366
L Cervical Rotation	20.7 (3.6)	22.3 (4.9)	0.241
Scapular Strength (%BW)			
R Upper Trapezius	503.1 (111.7)	533.4 (105.9)	0.363
L Upper Trapezius	538.9 (131.4)	576.9 (109.8)	0.279
R Middle Trapezius	13.2 (4.1)	14.4 (3.6)	0.195
L Middle Trapezius	12.7 (3.5)	13.5 (3.3)	0.385
R Lower Trapezius	13.8 (3.9)	15.2 (4.0)	0.160
L Lower Trapezius	13.5 (3.9)	14.7 (3.8)	0.297
Neck Active ROM (°)			
Flexion	56.1 (9.9)	59.1 (8.3)	0.271
Extension	63.7 (8.5)	68.3 (7.4)	0.048*
R Lateral flexion	48.4 (6.7)	52.4 (9.7)	0.054
L Lateral flexion	49.8 (8.3)	54.3 (8.6)	0.051
R Rotation	67.7 (8.8)	73.4 (7.4)	0.034*
L Rotation	67.4 (9.0)	72.9 (6.8)	0.030*
Posture (cm)			
Forward Head	22.1 (1.5)	21.7 (1.6)	0.201
R Forward Shoulder	16.8 (2.0)	16.4 (1.9)	0.437
L Forward Shoulder	16.7 (2.4)	15.7 (2.0)	0.079
R Pec Min Length	7.1 (1.7)	7.3 (1.5)	0.819
L Pec Min Length	6.5 (1.4)	6.6 (1.4)	0.726

* Represents significant differences ($P < 0.05$) between the groups. JPS = joint position sense; R = right; L = left; %BW = percent of body weight; ROM = range-of-motion; Pec Min = pectoralis minor.

First, it was hypothesized that there would be no significant group difference for demographics and flight characteristics, largely due to age-matching. The first hypothesis was supported as no group differences were observed in demographics and flight characteristics. Second, it was hypothesized that the pain group would be less fit (based on lower APFT score) and spent less time in physical training when compared to the nonpain group. The second hypothesis was rejected as there were no significant group differences for any of the physical fitness tests. Third, it was hypothesized that the pain group would exhibit significantly impaired neck proprioception, neck/scapular strength, neck active ROM, and posture when compared to the nonpain group. The third hypothesis was partially supported as only neck active ROM was significantly lower in the pain group while there were no significant differences for other variables.

In the current investigation, pain intensity in the pain group was comparable to a previous study on military helicopter pilots (2). Further, the NDI results revealed that the disability level at the time of the worst episode of NP was categorized as 'mild' and was lower in severity than NP reported in civilian subjects (25). An important aspect in the current study was that all pilots had to be fully operational and medically cleared for flight at the time of testing. Pilots with severe NP were likely being treated by medical professionals and/or had been removed from flight duty. For these reasons, detailed investigation of pain behavior is needed to clearly understand NP and any resultant disability in military pilots.

There are several characteristics that may be associated with NP. Harrison et al. (10) indicated that pilots' height is a predictor of NP. In the current investigation, pilots' mean height was between that of the symptomatic and asymptomatic groups reported by Harrison et al. (10). Van den Oord et al. (23) reported no significant differences in height between the pain and nonpain groups although the authors did identify greater age as a contributing factor for NP. In the current investigation, demographics were not significantly different between groups.

It was also observed that pilots in the current study had more total NVG flight-hours when compared to the previous study with similar total flight-hours (2). This is likely the result of frequent night missions during multiple deployments in recent overseas conflicts. Military pilots face new challenges to operate aircraft with added weight of body armor, NVG, counterweight, pistol, and ammunition. To support this, increases in pain frequency of spine and upper/lower extremity and flight-hour during deployment have been reported by other authors (18).

Contrary to our hypothesis, both physical fitness level and duration of cardiorespiratory and resistance training were not significantly different between groups. Ang et al. (1) reported that pilots who engaged in resistance training more than one hour per week had a lower risk of NP. In the current study, all pilots except one in the pain group and all in the nonpain group engaged in both resistance and cardiorespiratory training more than one hour per week. For future studies, it would be interesting to determine how many pilots are engaged in specific exercises for the neck, shoulder, and back.

For neck proprioception testing, contrary to our hypotheses, there were no significant differences between groups for active joint position sense AE. The current values for neck active joint position sense AE were similar to previously reported values (24), suggesting that the results were within expected data range. In civilian studies, individuals with NP had a decreased ability to reproduce target and neutral positions when compared to individuals without NP (17). However, in military studies, similar to our current results, Van den Oord et al. (24) did not find any significant differences in JPS absolute errors at R30 and L30 between helicopter pilots with and without a history of NP, and suggested that fully-operational military helicopter pilots/aircrew with NP were simply not comparable with civilian individuals with NP. The current results support that contention.

Similar to the neck proprioception findings, there were no significant differences for neck and scapular strength in the current investigation. Our results were in accordance with similar work (24). Interestingly, Ang et al. (2) reported significantly lower neck extensor strength in fighter-jet pilots with NP compared to the fighter-jet pilots without NP, but no differences between helicopter pilots with and without NP. We included the scapular strength testing to further elucidate the potential role of the trapezius in NP. However, there were no significant differences between groups for trapezius muscle performance. According to Harrison et al. (11), the smaller muscles of the neck (splenius capitis and sternocleidomastoid) can fatigue earlier than the upper trapezius muscle during muscle endurance tests. The authors defined fatigue as a reduction in the normalized mean electromyography (EMG) frequency during muscle endurance testing (11). The current investigation did not collect muscle endurance data; however, it would be interesting to compare a reduction in the normalized mean EMG frequency during muscle endurance testing between pilots with and without a history of NP since muscle endurance and EMG tests may be more sensitive for detecting changes in neuromuscular function as a result of NP.

The current investigation found significantly less neck extension and rotation active ROM in the pain group versus the no-pain group. The current results agree with previous work (3). Except for the neck flexion flexibility, a trend of less active ROM was observed in all directions. Similar trends toward less flexibility on pilots with NP were reported previously (24). Based on the current investigation, pilots can exhibit less neck active ROM even when neck proprioception and strength are within normal range. When combined with the previous finding (3), neck active ROM appears to be one of the most sensitive musculoskeletal tests for evaluating helicopter pilots with and without a history of NP. Ang et al. (3) have indicated that neck active ROM was significantly less in pilots with acute NP when compared to pilots with subacute NP. It is recommended that medical providers monitor neck active ROM regularly in pilots with a history of NP.

The current investigation also included postural assessment of the upper quadrant. Contrary to our hypotheses, increased forward head and shoulder posture were not detected in pilots with a history of NP. Previously, sitting in helicopter cockpit with poor posture has been suggested as a potential mechanism of NP (8). This is due to a confined cockpit space forcing pilots to bend forward, flexing at the upper thoracic spine and excessively extending the cervical spine (8). In this position, the upper trapezius muscle can demonstrate increased activation compared to other postures, and the smaller cervical flexor muscles (splenius capitis and sternocleidomastoid) fatigue early, especially during night missions wearing NVG (11). An overactive and/or shortened upper trapezius muscle in conjunction with a weak middle and lower trapezius muscle could compromise the alignment of the glenohumeral and scapulothoracic joints (21) and might also be associated with the onset of NP (19). In the current investigation, it could be argued that simply sitting on a chair to measure forward head posture might not represent actual sitting position during helicopter operation. It would be of interest to measure upper quadrant posture while in real flight or a simulator with pilots wearing full flight gear. Another explanation was that individuals with NP might be better examined by total head excursion rather than forward head posture as reported by a civilian study (9).

Limitations of self-report and recall bias on NP behavior should be recognized. The NPRS and NDI are commonly used in clinical practice and both have also been widely employed in research with subjects with current episodes of NP. Use of the NPRS and NDI in recall studies of NP, however, requires validation. In addition, it is possible to have some pilots in the nonpain group who had NP in the past. A medical chart review can be included in future studies in addition to self-reported injuries.

In conclusion, the current investigation has demonstrated impaired neck active ROM in pilots with a history of NP. Operating a helicopter with NP and/or impaired active neck ROM may negatively impact flight safety and force readiness. Therefore, routine assessment of neck active ROM is recommended. It may also be clinically important to incorporate early intervention strategies such as stretching exercises for pilots with a history of NP. Scientifically developed and validated intervention programs may have a great potential to address NP issues in helicopter pilots and optimize force readiness.

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REFERENCES

1. Ang B, Harms-Ringdahl K. Neck pain and related disability in helicopter pilots: a survey of prevalence and risk factors. Aviat Space Environ Med 2006; 77:713–9.
2. Ang B, Linder J, Harms-Ringdahl K. Neck strength and myoelectric fatigue in fighter and helicopter pilots with a history of neck pain. Aviat Space Environ Med 2005; 76:375–80.
3. Ang BO. Impaired neck motor function and pronounced pain-related fear in helicopter pilots with neck pain - a clinical approach. J Electromyogr Kinesiol 2008; 18:538–49.
4. Armstrong B, McNair P, Taylor D. Head and neck position sense. Sports Med 2008; 38(2):101–17.
5. Aydoğ ST, Turbedar E, Demirel AH, Tetik O, Akin A, Doral MN. Cervical and lumbar spinal changes diagnosed in four-view radiographs of 732 military pilots. Aviat Space Environ Med 2004; 75:154–7.
6. Cleland JA, Childs JD, Whitman JM. Psychometric properties of the Neck Disability Index and Numeric Pain Rating Scale in patients with mechanical neck pain. Arch Phys Med Rehabil 2008; 89:69–74.
7. De Loose V, Van den Oord M, Burnotte F, Van Tiggelen D, Stevens V, et al. Functional assessment of the cervical spine in F-16 pilots with and without neck pain. Aviat Space Environ Med 2009; 80:477–81.
8. Forde KA, Albert WJ, Harrison MF, Neary JP, Croll J, Callaghan JP. Neck loads and posture exposure of helicopter pilots during simulated day and night flights. Int J Ind Ergon 2011; 41:128–35.
9. Hanten WP, Olson SL, Russell JL, Lucio RM, Campbell AH. Total head excursion and resting head posture: normal and patient comparisons. Arch Phys Med Rehabil 2000; 81:62–6.
10. Harrison MF, Neary JP, Albert WJ, Croll JC. A predictive logistic regression equation for neck pain in helicopter aircrew. Aviat Space Environ Med 2012; 83:604–8.
11. Harrison MF, Neary JP, Albert WJ, Kuruganti U, Croll JC, et al. Measuring neuromuscular fatigue in cervical spinal musculature of military helicopter aircrew. Mil Med 2009; 174:1183–9.
12. Heikkilä HV, Wenngren BI. Cervicocephalic kinesthetic sensibility, active range of cervical motion, and oculomotor function in patients with whiplash injury. Arch Phys Med Rehabil 1998; 79:1089–94.
13. Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. Muscles: Testing and Function with Posture and Pain. 5th ed. Baltimore, MD: Lippincott Williams and Wilkins; 2005.
14. Lecompte J, Maisetti O, Guillaume A, Skalli W, Portero P. Neck strength and EMG activity in fighter pilots with episodic neck pain. Aviat Space Environ Med 2008; 79:947–52.
15. Lewis JS, Valentine RE. The pectoralis minor length test: a study of the intra-rater reliability and diagnostic accuracy in subjects with and without shoulder symptoms. [Abstract] BMC Musculoskelet Disord 2007; 8:64.
16. Lohman T, Roche A, Martorell R. Anthropometric standardization reference manual. Champaign, IL: Human Kinetics; 1988.
17. Loudon JK, Ruhl M, Field E. Ability to reproduce head position after whiplash injury. Spine 1997; 22:865–8.
18. Nevin RL, Means GE. Pain and discomfort in deployed helicopter aviators wearing body armor. Aviat Space Environ Med 2009; 80:807–10.
19. Petersen SM, Wyatt SN. Lower trapezius muscle strength in individuals with unilateral neck pain. J Orthop Sports Phys Ther 2011; 41:260–5.
20. Peterson DE, Blankenship KR, Robb JB, Walker MJ, Bryan JM, et al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. J Orthop Sports Phys Ther 1997; 25:34–42.
21. Reinold MM, Escamilla RF, Wilk KE. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. J Orthop Sports Phys Ther 2009; 39:105–17.
22. Salmon DM, Harrison MF, Neary JP. Neck pain in military helicopter aircrew and the role of exercise therapy. Aviat Space Environ Med 2011; 82:978–87.
23. van den Oord MH, De Loose V, Meeuwsen T, Sluiter JK, Frings-Dresen MH. Neck pain in military helicopter pilots: prevalence and associated factors. Mil Med 2010; 175:55–60.
24. Van den Oord MH, De Loose V, Sluiter JK, Frings-Dresen MH. Neck strength, position sense, and motion in military helicopter crew with and without neck pain. Aviat Space Environ Med 2010; 81:46–51.
25. Vernon H. The Neck Disability Index: state-of-the-art, 1991-2008. J Manipulative Physiol Ther 2008; 31:491–502.
26. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther 1991; 14:409–15.