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Defining Normal Cervical Spine Range of Motion in Rotary-Wing Pilots (Part 2): A Method of Estimating UH-60 Aviator Cervical Spine Range of Motion Using Head Position Data from an Optical-Based Inertial Tracker

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14. ABSTRACT
A human subject research protocol was performed by the U.S. Army Aeromedical Research Laboratory (USAARL) to evaluate UH-60 aviator cervical spine range of motion (CROM) in controlled real and simulated flight environments. Nine subjects performed one-hour flight missions in a UH-60 aircraft, and the same mission was performed in the USAARL NUH-60 flight simulator at least two days after the initial flight. Subjects were equipped with a head tracker clipped on the night vision goggle mount of their flight helmet to capture head angles in each plane of motion. Flight parameters and instructed maneuvers were the same between both flights. The data showed that actual and simulated flight were biomechanically equivalent in regards to specific flight maneuvers, but neck twisting was statistically different when analyzing cumulative neck posture over the entire flight. The data also revealed that the general population norms for CROM statistically exceed the requirements of UH-60 aviators engaged in routine flight.

15. SUBJECT TERMS
CROM, cervical spine, range of motion, UH-60, Black Hawk, pilot, aviator, head tracking

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It was also found that UH-60 flights require statistically similar amounts of neck bending and flexing compared to AH-64 flights, but statistically different amounts of neck twisting.

Summary

Neck pain and injury are common issues among aviators. However, no U.S. Army regulation currently exists to define what cervical spine range of motion (CROM) is adequate for flight. This lack of regulation leaves flight surgeons responsible for determining the flight fitness of an aviator affected by neck pain or injury without an objective reference. Our initial research approach towards providing an objective reference for U.S. Army Aviator CROM involved quantifying the head motion requirements of AH-64 aviators by examining thousands of hours of head position data from the Integrated Helmet and Display Sighting System (IHADSS). The novel methodology proved to be an effective approach to estimate the CROM of pilots and co-pilots that are typically exhibited in flight. Analysis resulting from this novel application of head position data revealed a large amount of time spent in severe twisting postures, as well as a high amount of neck twist frequency. The limitations of this analysis were that the flight conditions and types of maneuvers performed during the flights were unknown and there was no information on aviator demographics. While the methodology provided the groundwork for future analyses by proving the concept of utilizing head position data to estimate CROM, more specific data regarding flight maneuvers, operational environment, and aviator demographics are needed to provide a more operationally relevant assessment of aviator CROM.

To address the limitations in the first approach, a human subject research protocol was conducted to evaluate UH-60 aviator CROM in real and simulated flight environments so that the flight mission and conditions could be controlled. Data were collected on nine subjects under a U.S. Army Medical Research and Development Command (USAMRDC) Internal Review Board (IRB)-approved protocol. Each subject performed two flights: a one-hour flight mission in a UH-60 aircraft, and the same mission performed in the U.S. Army Aeromedical Research Laboratory (USAARL) NUH-60 flight simulator at least two days after the initial flight. Subjects were equipped with a Thales IS-1200+ Hybrid Optical-based Inertial Tracker (HObIT) clipped on the night vision goggle mount of their Gentex Head Gear Unit 56 Personal (HGU-56/P) flight helmet. This device was used to capture head angles in each plane of motion, namely flexion (i.e., chin to chest) and extension (i.e., chin to sky), lateral bending (i.e., ear to shoulder), and twisting (i.e., chin to shoulder). Mild postures were defined as between 10 and 30 degrees for flexion, between 15 and 30 degrees in either direction for twist rotation, and between 10 and 40 degrees in either direction for lateral bending. Severe postures were defined as greater than 30 degrees for flexion, greater than 30 degrees in either direction for twist rotation, and greater than 40 degrees in either direction for lateral bending. Parameters such as pre-flight checks, visual flight rules, flight pattern, and instructed maneuvers were the same between both flights. Video of both flights was taken with two cameras mounted orthogonally to observe potential contributions of the torso or lumbar spine to head position.

Data were analyzed from eight participants (five male, three female). The average age of the participants was 41.5 years with the youngest being 34 years and the oldest being 56 years. The average reported total flight hours for the participants was 2400 hours with the lowest being 1200 hours and the highest being 3900 hours. The data showed that actual and simulated flight is biomechanically equivalent with regard to advanced flight maneuvers, but neck twisting was statistically different when analyzing cumulative neck posture over the entire flight. The data also revealed that the presently accepted population norms for CROM statistically exceed the requirements of UH-60 aviators engaged in routine flight. It was determined that UH-60 flights require statistically similar amounts of neck bending and flexing when compared to AH-64 flights, but statistically different amounts of neck twisting. Twist rotation was the predominant

neck movement in the UH-60 aircraft and simulator; the amount of time in a severe twisting posture was more than three times greater than lateral bending and more than 30 times greater than flexion.

The results of the statistical analysis suggest that a flight simulator could be a suitable environment for having aviators perform advanced flight maneuvers for flight fitness determinations. The results also suggest that the maximum CROM values from the general population are not a suitable reference for flight fitness determinations. Finally, there were statistically significant differences in neck twisting between the UH-60 and AH-64 platforms, which suggests that further investigations into CROM requirements between the Army rotary-wing platforms may be necessary to provide an accurate reference for flight fitness determinations.

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Introduction

Neck pain is a persistent issue within the military aviator community (Harrison et al., 2015). Cervical spine range of motion (CROM) is critical for safe and optimal operation of military aircraft. Aviators are required to wear a variety of flight helmet configurations depending on flight platform and mission. The repetitive loading on the neck caused by these flight helmet configurations over time is a significant contributor to neck pain, which can limit CROM (Rudolfsson et al., 2012). One study found that among 113 military aviators, 43% reported neck pain, and 20% reported regular or continuous neck pain (Van den Oord et al., 2010a). Harrison et al. (2010) reported higher peak and cumulative neck loading for flights requiring night vision goggles (NVGs). The issue of neck pain has become so prevalent that a branch of the U.S. military has proposed personalized health care for its pilots to treat and prevent neck pain and injury (Pawlyk, 2019; Novotny et al., 2021), and researchers within the U.S. Air Force have proposed a fitness regimen to treat and prevent neck pain and injury (Wade et al., 2021).

Military flight surgeons evaluating aviators for flight fitness based on CROM have no operationally relevant reference from which to make a reliable determination (Department of the Army, 2015). This lack of a regulation puts flight surgeons in the difficult position of determining the flight fitness of pilots with limited CROM due to neck pain or injury with no official guidance to follow (Van den Oord et al., 2010b). Physiological limits exist for the general population, but these values do not necessarily apply to military aviators. If flight surgeons were to use these references in flight fitness determinations, they could end up grounding aviators who may actually be fit for flight duties. It is necessary to determine the cervical spine performance metrics necessary for military aviators so that an accurate and authoritative set of guidelines, for reference by aeromedical waiver specialists, can be established for flight fitness determinations.

This report presents the second of two studies, conducted by the U.S. Army Aeromedical Research Laboratory (USAARL), which aim to define required CROM in U.S. Army rotary-wing aviators for the AH-64 and UH-60 platforms (Williams et al., 2022). The companion AH-64 study characterized pilot and co-pilot CROM from head position data from the Maintenance Data Recorder (MDR). Using a novel methodology, the data were filtered down to three-dimensional pilot and co-pilot head position data reported as unit vectors. Missions were classified as a day flight, night flight, or unknown. Each data point was analyzed to determine neck posture. Neck postures were then categorized as neutral, mild, or severe for flexion/extension, lateral bending, and axial twist, based on neck postural categories established in previous literature. Severe neck twisting movement rate was also estimated based on these measurements. The resulting estimated posture analysis was used to gain insight regarding the direction and rate of neck movement required by military aviators during rotary-wing flight.

The analysis of almost 105,000 flight files showed a large amount of time spent in flexion and twist rotation. This finding suggests that cumulative loading on the neck, resulting from helmets and helmet system wear in combination with vibration exposure in rotary-wing aviation operational environments, could be a factor for Army aviators. The data also revealed that pilots showed a higher rate of head twisting than co-pilots. Additionally, pilots and co-pilots showed a higher rate of head twisting during day flights in comparison to night flights. The frequent neck twisting exhibited in the daytime flights could affect muscular endurance, as the repeated activation of various neck muscles could result in fatigue or injury. A higher amount of time was spent in severe neck twisting postures at night. This finding was supported by other published data that suggested higher peak and cumulative neck loading for flights requiring night vision goggles (Harrison et al. 2010). Lastly, statistical analysis of the data revealed a significant difference between estimated neck posture for pilots and co-pilots as well as between day and night flight operations.

The novel methodology developed by Williams et al. (2022) proved to be an effective approach to estimate the CROM of pilots and co-pilots typically exhibited in flight. This approach was convenient because it provided the ability to leverage thousands of hours of preexisting data that were easy to process since it was provided in a simple and consistent format. However, there were a few limitations. Study outcomes did not take into account the ability of aviators to enhance their CROM capabilities with minor torso or lumbar spine movement. Furthermore, there was no knowledge of the types of maneuvers performed during flight, no knowledge of flight conditions, nor was there any demographic or anthropometric information regarding the aviators.

To address these limitations, USAARL performed a human subject research protocol to evaluate UH-60 aviator CROM in controlled real and simulated flight environments. The objective of this human research effort was to characterize typical head/neck motion of UH-60 helicopter pilot CROM during normal flight operations by quantifying head and neck motion. Rated UH-60 pilots were recruited to fly a predetermined flight profile while wearing an optical-based inertial tracker to calculate head position. Hence, the mission and flight conditions would be controlled such that neck postures can be associated with specific flight maneuvers. During flight, video recordings of the pilots were taken to observe possible contributions of the lumbar spine and torso to head motion. Demographic and anthropometric information was collected from each participant.

The human subject study was designed to address four aims. The first aim was to characterize the head and neck motion by: (a) measuring the head and neck motion and calculating CROM in terms of multiple postures (flexion/extension, rotation, and lateral bending), and (b) documenting frequency, duration, and severity of pilot head movements. The second aim was to compare findings on head and neck motion requirements for UH-60 pilots in actual and simulated flight to determine if the two are biomechanically equivalent. The third aim was to compare findings on head and neck motion requirements for UH-60 pilots against previous studies assessing maximum CROM found in the general population. For the fourth aim, study findings would be compared with the AH-64 companion study to determine if typical CROM use is the same across rotary-wing platforms.

This foundational research is the first to establish a functional estimate of CROM required for UH-60 aviators during flight. Results from this study will provide a more ideal and specific reference on what CROM is required for aviators. Aeromedical policy and waiver authorities as well as flight surgeons, who must judge the operational significance of various medical problems and interventions that may limit CROM (such as degenerative disc disease and cervical spine fusion), will then be able to more accurately judge if a pilot has sufficient CROM to fly safely. This report outlines the research methodology of the UH-60 CROM investigation, details the process of collecting and analyzing the data, and summarizes the results of the data analysis.

Methods and Materials

Data were collected on nine subjects under a U.S. Army Medical Research and Development Command (USAMRDC) Internal Review Board (IRB)-approved protocol. Subjects were recruited from the local Fort Rucker area. Eligibility was determined by a screening evaluation to confirm that prospective subjects met the inclusion and exclusion criteria (Appendix A). The study required all prospective subjects to have:

1. passed an Annual Proficiency and Readiness Test for the UH-60 within the past 12 months and had flown within the past 60 days,
2. a current, unrestricted Department of the Army medical clearance to fly,
3. English fluency, and
4. required flight gear.

Subjects were excluded from the research for:

1. taking nonsteroidal anti-inflammatory drugs (NSAIDs) or other pain medication used for any reason other than as part of a physician-advised or prescribed regimen within 24 hours of testing,
2. current existence of neck pain,
3. any history of neck pain or neck pathology that, in the judgment of the Study Physician, could interfere with normal CROM, or
4. inability to follow verbal or written directions.

Each subject performed two flights: a one-hour flight mission in a UH-60 aircraft, and the same mission performed in the USAARL JUH-60 flight simulator at least two days afterward. Parameters such as pre-flight checks, visual flight rules (VFR), flight pattern, and instructed maneuvers were the same between both flights. Video of both flights were recorded with two cameras mounted orthogonally to observe potential contributions of the torso or lumbar spine to head position.

Anthropometric Measurements

Anthropometric measurements were taken of each subject and included height, weight, neck circumference, and neck length. All measurement standards were those described by Gordon et al. in the 2012 Anthropometric Survey of U.S. Army Pilot Personnel (ANSUR II).

Demographic and Flight History Questionnaire

Participants were given a demographic and flight history questionnaire upon positive determination of eligibility for the study. The questionnaire included fields for age, sex, years of flight, career flight hours, platforms flown, and flight frequency. A copy of the questionnaire is provided in Appendix B.

Neck Angle Measurement Device

In order to measure typical head and neck motion of the pilots while engaged in routine operations, the subjects were equipped with an IS-1200+ Hybrid Optical-based Inertial Tracker (HObIT) (Thales Visionix, Billerica, MA) clipped on the night vision goggle mount of their HGU-56/P flight helmet (Gentex, Zeeland, MI) (Figure 1). This device was used to capture head angles in each plane of motion, namely flexion (chin to chest) and extension (chin to sky), lateral bending (ear to shoulder), and twisting (chin to shoulder). The HObIT is a six degree-of-freedom (DoF) inertial tracker containing an inertial measurement unit (IMU) and an optical tracker to eliminate inertial drift using pose recovery via a Kalman filter (Atac et al., 2018). IMU drift is eliminated by the optical samples through a pose recovery algorithm.

Figure 1. Gentex HGU-56/P flight helmet with the HObIT attached to the night vision goggle mount.

The HObIT uses a fiducial constellation to achieve optical lock. Fiducial markers were placed on the canopy of the UH-60 aircraft and simulator so that optical lock could be achieved while the participant's head was at a neutral position (Figure 2). While the fiducials are not visible, the HObIT enters "free run" mode, in which measurements are based purely on the IMUs. The IMU orientation drifts at a rate of 10 milliradians root mean square (RMS) per minute, but the accuracy is refreshed once optical lock is once again achieved.

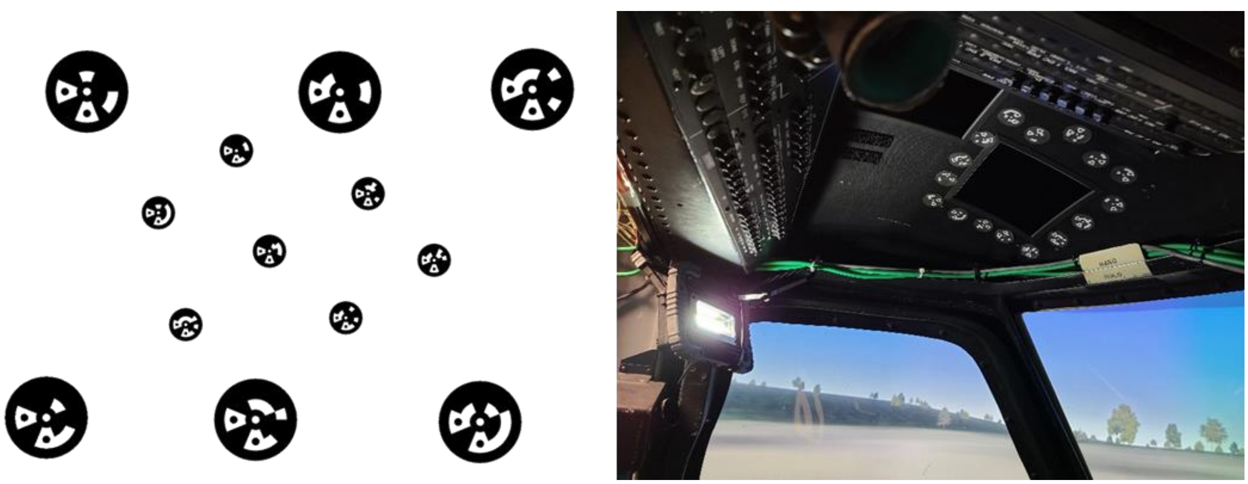

Figure 2. (Left) An example of the fiducial markers used by the HObIT. (Right) A fiducial constellation installed in the flight simulator.

Baseline, Pre-Flight,-and Post-Flight CROM

Aviator CROM was measured with the recording of the anthropometric data during the consent day, immediately before pre-flight procedures, and immediately after post-flight procedures. The consent day measurements were recorded by visual observation with a CROM goniometer device (Performance Attainment Associates, Lindstrom, MN) (Figure 3). The pre- and post-flight measurements were collected by the HObIT and saved into separate files. The participants were instructed to set their posture at a neutral position. The neutral position was defined as the position where the participant’s head is comfortably placed over the shoulders with the eyes looking straight ahead and the chin level with the ground. The participants were then requested to perform the following procedures (repeated three times in succession):

1. Flex their neck toward their chest as far as possible, hold and return to neutral.
2. Extend their neck toward the headrest as far as possible, hold and return to neutral.
3. Twist their neck toward their right shoulder as far as possible, hold, and return to neutral.
4. Twist their neck toward their left shoulder as far as possible, hold, and return to neutral.
5. Laterally bend their neck toward their right shoulder as far as possible, hold, and return to neutral.
6. Laterally bend their neck toward their left shoulder as far as possible, hold, and return to neutral.

Figure 3. CROM system used for measuring cervical spine range of motion in left twisting (left) and left lateral bending (right).

Participants were advised to keep their necks in one plane of motion during this test while keeping their torso and lumbar spine stationary. The measurements taken by the HObIT while the participant was sitting at a neutral position were also used as boresight values to zero the HObIT fiducial coordinate system.

Flight Mission

Data collection occurred over a predetermined controlled flight profile representative of normal visual flight rules military operations. The flight profile incorporated standard aircrew training base and mission tasks as described in the UH-60 Aircrew Training Manual (Department of the Army [DA], 2013). The flight mission was designed to incorporate numerous basic flight maneuvers to get an accurate representation of pilot head movement over routine flight. The flight mission also featured two different advanced flight maneuvers that would require subjects to move their neck at considerable angles. This allowed comparisons of these advanced flight maneuvers between the aircraft and flight simulator as well as comparisons to general population norms. Pre-flight tasks were performed in the aircraft and the simulator, and the simulator flight profile was the same as the aircraft flight, including all take-off and landing locations. Flight gear was worn in the simulator, just like for the actual flight, for measurement consistency. Both aircraft and simulator flights began at Lowe Army Heliport (AHP) in Fort Rucker, AL.

In both the aircraft and simulator flights, participants performed start-up procedures and then taxied the aircraft to North Hover to complete the required pre-flight checks. Once all pre-mission checks were completed, the flight mission began with a departure from North Hover. Participants were instructed to maintain an 800-foot mean sea level (MSL) altitude and 100 knots-indicated airspeed (KIAS) for approximately 10 minutes before reaching a predefined corridor at which the participants increased the airspeed to 120 KIAS. At the end of the corridor, the participants turned south to head directly to Geneva Municipal Airport (33J).

Upon reaching 33J, participants entered the traffic pattern on a right downwind to land on Runway 29. After turning for the final approach to Runway 29, participants conducted a Visual Meteorological Conditions (VMC) approach to the ground. The flight instructor then took the flight controls, conducted a VMC take-off, and completed a traffic pattern with a roll-on landing. After the roll-on landing, participants resumed duties of the flying pilot and conducted a rolling take-off. Once the rolling take-off was complete, the flight instructor initiated a simulated emergency procedure resulting in loss of the Automatic Flight Control System (AFCS). Participants executed the traffic pattern and landed on Runway 29 with a VMC approach.

After completing the approach, the flight instructor restored the AFCS and instructed the participants to depart the runway and navigate the aircraft along a river directly off the departure end of the runway. After reaching another waypoint, participants executed another VMC approach landing on rural farmland. The flight instructor then executed a VMC take-off with level acceleration completing two hard right turns (henceforth referred to as a hard right advanced maneuver) and landing back at the rural farmland. The participant then duplicated those maneuvers. The flight instructor then took the controls and performed a vertical take-off near the tree line. Upon clearing the tree line, the flight instructor performed a maneuver requiring the aircraft to be pitched up roughly 45 degrees, and then executed a right roll of the aircraft, allowing the nose of the aircraft to fall through the horizon (henceforth referred to as an up and right advanced maneuver). This maneuver was performed a second time before landing at the rural farmland. The participants then duplicated those maneuvers and landed at the rural farmland. The flight instructor then took the flight controls for the return flight to Lowe AHP. During the return flight, participants were responsible for cockpit management tasks such as tuning radios, setting the flight plan, and navigating. The flight concluded with the termination of the approach into North Hover prior to taxiing the aircraft to parking.

Neck Angle Import and Posture Definition

Each neck angle data point during flight was imported from the HObIT output files using an in-house developed MATLAB function. This study evaluated head and neck motion using the same postures assessed in the AH-64 companion study (Williams et al., 2022): flexion, twisting, and lateral bending. Figure 4 illustrates the neck posture definitions and Table 1 shows the classification ranges for the mild and severe postures (Forde et al., 2011).

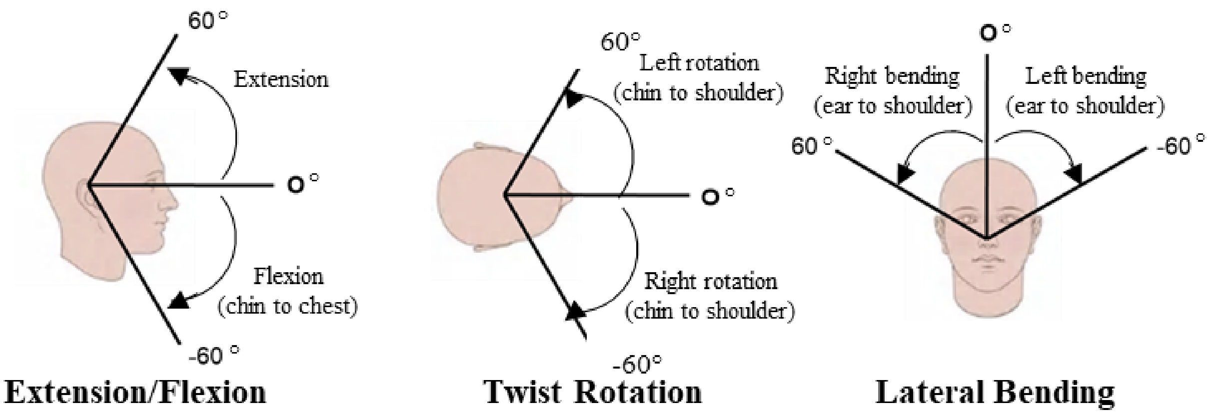

Figure 4. Visual diagram of neck postures. The postures are separated into three planes of motion. Extension and flexion correspond to moving the head up and down (chin to chest). Twist rotation corresponds to turning the head right and left (chin to shoulder). Lateral bending corresponds to bending the head right and left (ear to shoulder).

Table 1. Mild and Severe Neck Posture Classification Ranges

Posture	Mild	Severe
Flexion	-(10-30°)	<-30°
Twist Rotation	±(15-30°)	>30° or <-30°
Lateral Bending	±(10-40°)	>40° or <-40°

Posture Aggregation

The pilot posture data were referenced to perform an aggregate analysis of each respective flight to determine the amount of time aviators are typically spending in the three posture bins. The total time in each posture bin was compared to the total flight time to calculate the percentage of flight time within those posture bins. This process resulted in the determination and documentation regarding the rate, duration, and severity of pilot head movement during flight.

Statistical Analysis

Statistical analyses were performed to compare data findings outlined in the study aims. The study aims and corresponding analyses are listed below:

1. To compare findings on head and neck motion requirements for UH-60 pilots in actual and simulated flight to determine if the two are biomechanical equivalent:
    - Matched pair t-test: UH-60 aircraft and simulator CROM posture percentages over the entire flight mission.

- Matched-pair t-test: UH-60 aircraft and simulator CROM for advanced flight maneuvers.
- Two-way analysis of variance (ANOVA): UH-60 aircraft and simulator pre- and post-flight CROM.

2. To compare findings on head and neck motion requirements for UH-60 pilots against previous studies assessing maximum CROM found in aviators and the general population:
    - Two-sample t-test: Maximum required UH-60 CROM during flight and values from the general population. This was done by creating a sample of data based on the means and standard deviations of the general population from Thoomes-de Graaf et al. (2020).

3. To compare findings with the AH-64 companion study to determine if typical CROM use is the same across rotary-wing platforms
    - Two-sample t-test: UH-60 and AH-64 CROM (AH-64 values are from Williams et al., 2022).

Results

Demographics, Anthropometric, and Flight History Questionnaire

The subject population consisted of six males and three females. Nine subjects completed testing; data analysis from head position data was conducted on eight data sets. The demographic data and questionnaire information of the subject population are presented in Table 2.

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Table 2. Summary of Subject Population Demographic, Anthropometric, and Flight History Data

Volunteer Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Mean ± S Dev**
Age	40	40	39	44	41	34	40	39	56	**41.4** ± **6.04**
Sex	F	M	F	M	M	M	M	M	F	
Height (cm)	166.5	189	171	172.5	174.5	180	182	178.5	164	**175** ± **7.88**
Weight (kg)	68.9	104.6	74.6	105.4	96.9	82.9	91.3	85.8	94.3	**89.4** ± **12.6**
Neck Length (cm)	13.5	16.5	11.3	17	15.5	16.5	16.5	12	12	**14.5** ± **2.32**
Neck Circumference (cm)	35.5	44.5	34.5	46	43	40.5	37	34	34	**38.8** ± **4.79**
Years of Flying Experience	8	14	16	19	15	9	13	12	26	**14.7** ± **5.43**
Total Flight Hours	1400	1740	1200	3781	3900	1500	2200	2365	3000	**2340** ± **1010**
Platforms Currently Flying	UH-60M/L	UH-60M	UH-60M/L	UH-60M/L	UH-60M/L	UH-60M	UH-60M/L	UH-60M/L	UH-60M	
Flight Frequency Over Past Year (Daily/Weekly/Monthly)	Weekly	Weekly	Monthly	Weekly	Weekly	Daily	Weekly	Daily	Daily	
Average Flight Length Over Past Year (in hours)	3	2.5	2	3	2.4	2.8	3	2.5	2.5	**2.63** ± **0.343**
Most Flight Hours in a Month	40	25	20	4	15	50	30	27	20	**25.7** ± **13.5**
Times Over 80 Flight Hours In One Month In Past Year	0	0	0	0	0	0	0	0	0	**0** ± **0**
Platform and Total Hours	--	--	--	--	--	--	--	--	--	
UH-60	--	--	--	--	--	--	--	--	--	
A	0	0	750	200	0	0	50	0	1000	**222** ± **381**
L	80	1000	300	3200	50	500	900	20	1200	**806** ± **1000**
M	1000	740	40	300	200	1000	1200	2300	800	**842** ± **677**
V	0	0	0	0	0	0	0	0	0	**0** ± **0**
CH-47	0	0	0	0	0	0	0	0	0	**0** ± **0**
AH-64	0	0	0	0	0	0	0	0	0	**0** ± **0**
LUH-72	0	0	12	0	0	20	40	0	0	**8** ± **14**
OH-58	30	0	0	20	3000	50	0	0	0	**344** ± **996**
Fixed Wing	80	0	0	20	0	0	0	0	0	**11.1** ± **26.7**
Other	0	0	0	0	350	0	0	0	0	**38.9** ± **117**

UH-60 Aircraft versus Simulator CROM: Entire Flight

Matched pair t-tests were performed for the aircraft and simulator aggregated posture data. The percent of flight time in severe flexion and lateral bending was not statistically different ($p > 0.05$) between real and simulated flight, but was statistically different for severe twist rotation ($p < 0.05$). Figure 5 shows the box plots of the posture percentages over each flight.

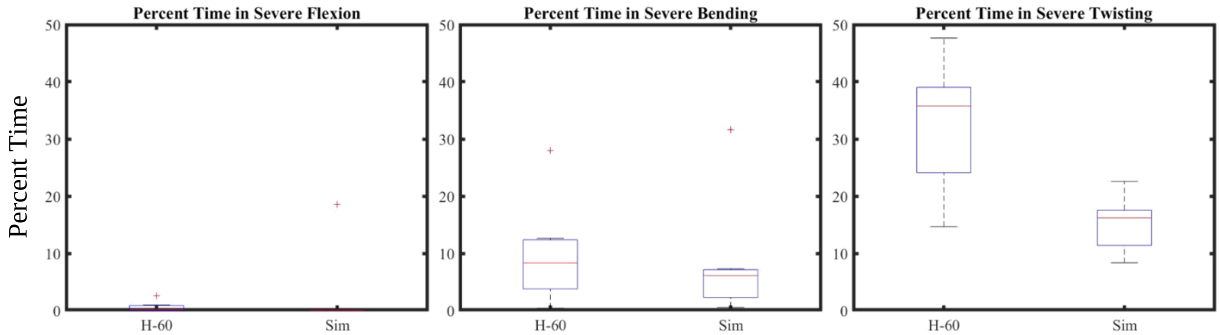

Figure 5. Comparison of percent time spent in severe flexion, bending, and twisting for the aircraft and simulator flights. Severe flexion median values for UH-60 aircraft (0.16%) and simulator (0) are small and consequently not visible. The top of the blue boxes denote the 75th percentile and the bottom represents the 25th percentile. The red line represents the median value. The black hash marks are the upper and lower adjacents. Red marks are outliers.

UH-60 Aircraft versus Simulator CROM: Advanced Maneuvers

Matched pair t-tests were performed for the aircraft and simulator maximum CROM during the hard right and up and right advanced maneuvers. Severe twist rotation and lateral bending were not statistically different for the 50-degree hard right maneuver ($p > 0.05$) or up and right roll maneuver ($p > 0.05$). Severe flexion was not statistically different for the 50-degree hard right maneuver ($p > 0.05$), but was statistically different for the up and right roll maneuver ($p < 0.05$). Figures 6 and 7 show the box plots of the maximum CROM for the advanced maneuvers.

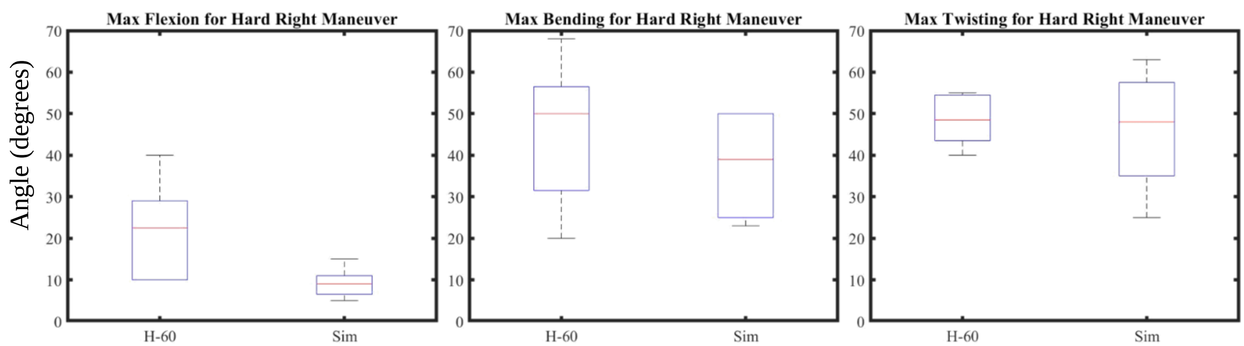

Figure 6. Maximum flexion, bending, and twisting values for the hard right advanced manuever (50-degree right roll maneuver) in the aircraft and simulator flights. The top of the blue boxes denote the 75th percentile and the bottom represents the 25th percentile. The red line represents the median value. The black hash marks are the upper and lower adjacents. Red marks are outliers.

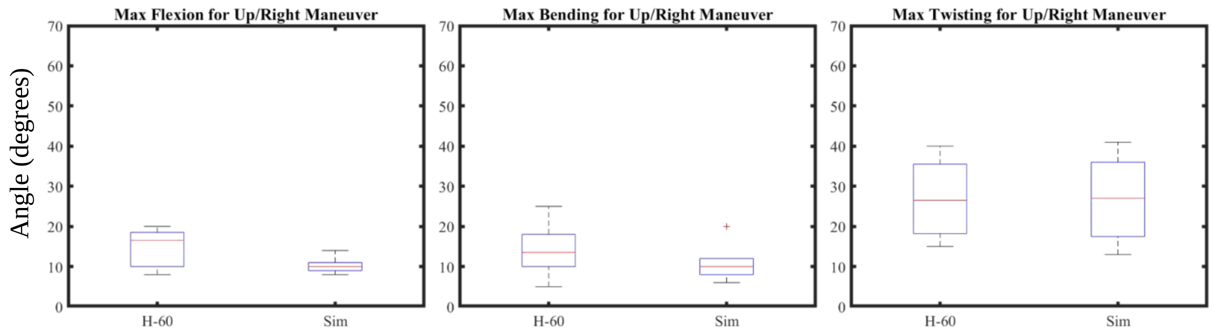

Figure 7. Maximum flexion, bending, and twisting values for the up and right advanced manuever in the aircraft and simulator flights. The top of the blue boxes denote the 75th percentile and the bottom represents the 25th percentile. The red line represents the median value. The black hash marks are the upper and lower adjacents. Red marks are outliers.

Pre- and Post-Flight CROM: Aircraft and Simulator

A two-way ANOVA was performed on the aircraft and simulator pre- and post-flight CROM measurements to determine significance. The results are shown in Tables 3, 4, and 5. There was no statistically significant difference between the bending and twisting measurements for aircraft and simulator and pre- or post-flight CROM, nor was there a significant difference in the interaction between those variables. There was a significant difference found in the pre- and post-CROM flexing values, but not between the aircraft and simulator measurements or the interaction. Figure 8 shows a box plot of the combined aircraft and simulator pre- and post-flight CROM values for flexing, bending, and twisting, respectively.

Table 3. Results of the Two-Way ANOVA on the Pre- and Post-Flight CROM Flexion Measurements in the Aircraft And Simulator

Flexion					
Source	**Sum of Squares**	**Error DoF**	**Mean Squares**	**F-statistic**	**P-values**
Aircraft vs Sim	89.2857	1	89.286	2.029	> 0.05
Pre vs Post	763.214	6	127.202	2.891	< 0.05
Interaction	82.2143	6	13.702	0.311	> 0.05
Error	616.000	14	44.000		
Total	1550.71	27			

Table 4. Results of the Two-Way ANOVA on the Pre- and Post-Flight CROM Bending Measurements in the Aircraft And Simulator

Bending					
Source	**Sum of Squares**	**Error DoF**	**Mean Squares**	**F-statistic**	**P-values**
Aircraft vs Sim	160.321	1	160.321	1.922	> 0.05
Pre vs Post	1082.86	6	180.476	2.164	> 0.05
Interaction	249.429	6	41.571	0.499	> 0.05
Error	1167.50	14	83.393		
Total	2660.11	27			

Table 5. Results of the Two-Way ANOVA on the Pre- and Post-Flight CROM Twisting Measurements in the Aircraft and Simulator

Twisting					
Source	**Sum of Squares**	**Error DoF**	**Mean Squares**	**F-statistic**	**P-values**
Aircraft vs Sim	38.8929	1	38.893	0.181	> 0.05
Pre vs Post	1374.93	6	229.155	1.064	> 0.05
Interaction	407.357	6	67.893	0.315	> 0.05
Error	3015.50	14	215.393		
Total	4836.68	27			

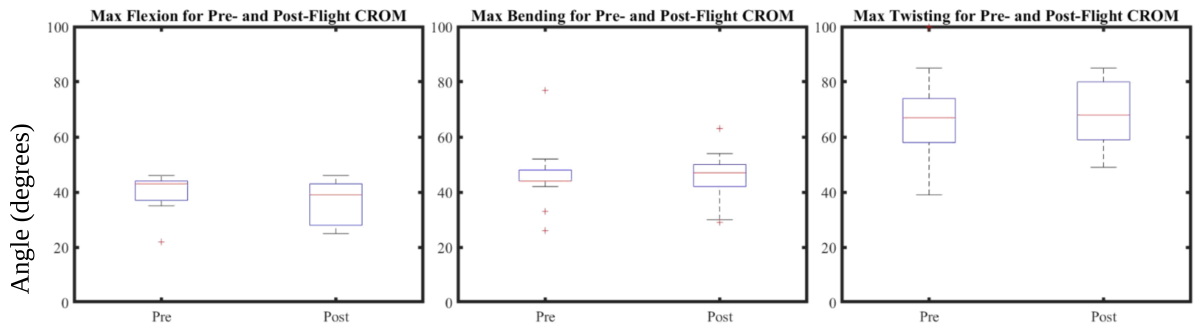

Figure 8. Combined pre- and post-flight CROM values for flexing, bending, and twisting. The top of the blue boxes denote the 75th percentile and the bottom represents the 25th percentile. The red line represents the median value. The black hash marks are the upper and lower adjacents. Red marks are outliers.

Maximum CROM: UH-60 Aircraft and Simulator Advanced Maneuvers versus General Population

Two-sample t-tests were performed to compare the maximum CROM in the hard right and up and right maneuvers in the UH-60 aircraft and simulator flights to the mean maximum values from the general population. Maximum values were significantly different for twisting, bending, and flexing for the simulator and significantly different for twisting and flexing for the aircraft ($p < 0.05$). Table 6 shows the mean maximum CROM measured in the UH-60 advanced maneuvers compared to the mean maximums from the general population.

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Table 6. Mean Maximum CROM Measured in the UH-60 Advanced Maneuvers Compared to the Mean Maximum Values From the General Population

UH-60 Advanced Hard Right Maneuver Maximum CROM vs General Population Maximums					
	UH-60 Aircraft	UH-60 Simulator	General Population	P-Values (Aircraft)	P-Values (Simulator)
Mean Max Flexing	21.5°	9.1°	60.88°	< 0.05	< 0.05
Mean Max Bending	45.5°	37.6°	45.21°	> 0.05	< 0.05
Mean Max Twisting	48.5°	46.1°	67.47°	< 0.05	< 0.05

UH-60 versus AH-64 CROM: Entire Flight

Two-sample t-tests were performed to compare the UH-60 aircraft data to the AH-64 IHADSS data analyzed in a separate USAARL effort (Williams et al., 2022). This was done by calculating the mean cumulative values for the aggregated severe posture data for each flight. The posture data were significantly different for twisting ($p < 0.001$), but not for bending or flexing ($p > 0.05$). The mean severe posture values for the UH-60 and AH-64 are shown in Table 7.

Table 7. UH-60 and AH-64 Mean Percent Time in Severe Postures Over the Entire Flight

UH-60 vs AH-64 CROM: Entire Flight			
	UH-60 Mean	AH-64 Mean	P-Values
% Time - Severe Flexing	0.58%	1.31%	> 0.05
% Time - Severe Bending	9.66%	7.15%	> 0.05
% Time - Severe Twisting	32.52%	20.75%	< 0.001

Discussion

Each research flight began at Lowe AHP in Fort Rucker, AL with the exception of the first, which began at Cairns AHP due to aircraft availability. This deviation did not affect the performance or outcomes of the flight mission. Aircraft flight data for one of the male subjects was lost due a computer malfunction, resulting in eight aircraft and simulator flight matched pairs for analysis.

Demographics, Anthropometric, and Flight History Questionnaire

The subject population demographic, anthropometric, and flight history data reveal that this study was conducted using a group of highly experienced H-60 aviators (Table 2). Additionally, the population included male and female aviators. The mean age of the subject population was 41.4 ± 6.0 years. The mean number of years of flight experience of the subject population was 14.7 ± 5.4 years. The mean total flight hours was 2340 ± 1000 hours. The subject population mean height and weight was 175 ± 7.88 centimeters (cm) and 89.4 ± 12.6 kilograms (kg), respectively. The mean neck length and circumference of the subject population was 14.5 ± 2.32 cm and 38.8 ± 4.79 cm, respectively.

Additionally, the subject population almost unanimously reported daily or weekly flight occurrences with an estimated mean flight mission length of 2.6 ± 0.34 hours per flight and an estimated monthly flight hour log of 25.67 ± 13.5 hours. All but one of the subjects reported at least 1000 hours of flight time on the UH-60 platform and all subjects reported experience with multiple UH-60 platform models. Several subjects also reported experienced with other aircraft platforms. Based on the demographic, anthropometric, and flight history data presented, the authors believe that the implemented study inclusion and exclusion criteria (Appendix A) allowed the recruitment, screening, and subsequent enrollment of a sample population representative of the current broad UH-60 aviator population on Fort Rucker. As a result, we are confident that the head and neck motion data obtained in this study can be used to establish a functional estimate of CROM required for UH-60 aviators during flight.

UH-60 Aircraft versus Simulator CROM: Entire Flight

Similar to the outcomes observed in the previous reported AH-64 data, the UH-60 aircraft and simulator data show that twist rotation was the predominant neck movement in routine flight. The median time in a severe twisting posture in the aircraft was more than three times greater than lateral bending and more than 30 times greater than flexion (Figure 5).

Most results did not show statistically significant differences in CROM between the real and simulated UH-60 flights; however, there were observed differences in the means and standard deviations between the aircraft and simulator cumulative flight data. There were several differences observed as a consequence of the simulated flight environment. For instance, the lack of a canopy meant that the pilot had no reason to considerably extend their neck. However, this potential scenario had no influence on the data presented in this work because no extension postures were analyzed. This omission was intentionally done to match the methodology and rationale for not including extension postures in the AH-64 companion study (Williams et al., 2022). Furthermore, while the simulator was "full-motion," it provides a less natural kind of feedback to the pilot than the aircraft when performing certain maneuvers. There was no threat to safety for the pilot in the simulator and no air traffic. As a result, the pilot did not have to perform twisting motions as often as they did in the aircraft.

UH-60 Aircraft versus Simulator CROM: Advanced Maneuvers

The data showed that actual and simulated flight is biomechanically equivalent with regard to advanced flight maneuvers (Figures 6 and 7). This implies that if some of the limitations mentioned in the previous section can be addressed or incorporated into future simulated missions, the flight simulator could be a legitimate platform in which to evaluate pilots for CROM-related flight fitness determinations, particularly as it pertains to the more extreme head movements required for the advanced flight maneuvers.

Pre- and Post-Flight CROM: Aircraft and Simulator

The two-way ANOVA for the CROM pre- and post-flight measurements showed no significant difference except for aircraft and simulator flexion measurements (Tables 3-5 and Figure 8). This indicates that the one-hour flight mission did not induce the muscular fatigue necessary to reduce CROM. It is noteworthy that the subject population consisted entirely of subjects with no reported history of neck pain or neck pathology that could interfere with CROM. This was likely a key factor in these results. Nevertheless, more direct methods to measure fatigue, such as the utilization of surface electromyography (EMG) sensors, would have provided a more accurate assessment. Using these sensors was not possible in this environment due to their electromagnetic sensitivity.

Maximum CROM: UH-60 Aircraft and Simulator Advanced Maneuvers versus General Population

The most noteworthy finding is that the maximum CROM measured during the advanced flight maneuvers was lower than the referenced maximum CROM values of the general population for all but the bending posture for the aircraft flight (Table 6). This suggests that, while certain aviators may not meet the referenced maximum CROM values of the general population, it does not necessarily indicate they are unfit to pilot an aircraft. Furthermore, there is substantial evidence that CROM alone is insufficient in evaluating flight fitness. For instance, neck strength and muscular endurance are pivotal not only for flight performance but also for injury mitigation and prevention (Berg et al., 1994; Thuresson et al., 2003; Nagai et al., 2014; Novotny et al., 2021). Fighter aircrew conditioning programs (FACP) have been used in the U.S. Air Force for physical training of high performance aircraft pilots with documented cases of success in injury prevention (Wade et al. 2021). Additionally, increasing neck strength and the resulting increase in neck musculature could effectively decrease CROM, which would be counterproductive if flight surgeons were to base their flight fitness evaluations exclusively on CROM.

UH-60 versus AH-64 CROM: Entire Flight

Comparisons of the UH-60 data with the AH-64 data from the comparison study revealed a significant difference between the amount of time in a severe twisting posture (Table 7). This indicates that differences in aircraft design, such as aviator seating arrangements, instrumentation layout, and field-of-view could change the amount of CROM necessary for aircraft operation. Therefore, CROM values should be measured and quantified in all rotary-wing aircraft platforms and models during actual or simulated flight in order to clearly define and classify CROM requirements for aviators during normal flight operations.

Lastly, investigations into neck performance in relation to flight fitness should involve measurements of strength, endurance, and muscular activation while executing neck movements required during flight as well as additional examinations of possible differences due to cockpit and platform configurations. We were unable to incorporate the required instrumentation devices needed to conduct these assessments during the actual flight due to airworthiness and flight safety concerns. Future work will leverage simulated aircraft environments so that the aforementioned neck muscle performance assessments can be incorporated.

Recommendations

1. CROM values should be measured and quantified in all rotary-wing aircraft platforms and models during actual or simulated flight in order to clearly define and classify CROM requirements for aviators during normal flight operations.
2. Flight surgeons tasked with making neck-related flight fitness determinations should not use referenced maximum CROM values representative of the general population. Instead, neck-related flight fitness determinations should be based on referenced CROM values representative of the specific aircraft platform(s) the aviator is cleared to fly.
3. CROM should not be used by flight surgeons as the singular or sole decisive factor in neck-related flight fitness evaluations.
4. Beyond kinematic assessments such as CROM, other cervical spine-related metrics to investigate include biomechanical/physiologic assessments (e.g., neck strength and

endurance) and aviation-based operational performance evaluations (e.g., flight length and frequency and neck movement frequency).

5. There is a need for further research on additional operationally relevant cervical spine metrics so that all mechanisms of neck fatigue, pain, and injury can be investigated for consideration or inclusion into neck-related flight fitness evaluations and determinations. The next recommended step is to conduct a study involving human subject research volunteers executing neck movements associated with operational flight in simulated environments representative of multiple rotary-wing aircraft platforms and cockpit configurations while applying techniques to quantify muscle activation and fatigue.
6. USAARL should continue to provide subject matter expert consultation and assessment support to aeromedical authorities regarding guidelines and policy recommendations for neck-related flight fitness evaluations and determinations by conducting research in order to improve aviator operational readiness and efficiency, improve flight safety and performance, and increase aviator retention.

Conclusions

This work presented the second component of novel foundational research which aimed to establish a functional estimate of CROM required for rotary-wing aviators during normal flight operations. Head and neck motion during actual and simulated UH-60 flights were successfully characterized and quantified using a sample population of aviators representative of the current experienced aviator population at Fort Rucker, AL.

Similar to the outcomes observed in the previous reported AH-64 companion study (Williams et al., 2022), the UH-60 aircraft and simulator data show that twist rotation was the predominant neck movement in routine flight. Despite observed differences in the means and standard deviations between the aircraft and simulator data, the data presented did not show statistically significant differences in CROM between the real and simulated UH-60 flights. Therefore, the flight simulator could be a legitimate platform on which to evaluate pilots for CROM-related flight fitness determinations. The UH-60 data also revealed that the typical maximum CROM values from the general population are not an appropriate reference for flight fitness determinations. UH-60 aviators required significantly less neck movement in all planes of motion (with the exception of bending in the aircraft) when performing advanced flight maneuvers that demanded the highest range of motion. Comparisons of the UH-60 data with the AH-64 data from the companion study (Williams et al., 2022) also revealed a significant difference between the amount of time in a severe twisting posture, suggesting that typical CROM use during normal flight operations may vary across rotary-wing aircraft platforms.

While the primary aims of the work presented successfully addressed shortcomings identified in the companion AH-64 study, there are limitations that must be acknowledged. First, all actual and simulated UH-60 flights were conducted under daylight conditions. Therefore, the effects of mission time of day and helmet system components such as NVGs on CROM, neck posture severity, and neck movement rates could not be assessed. Additionally, the enrolled study aviators only conducted flights in the pilot position; therefore, no co-pilot data was available for comparisons. Furthermore, neck muscle strength, endurance, and muscle activation are other factors that should be considered in flight fitness determinations; however, we were unable to include these assessments in this study. Nevertheless, the data presented provide a useful reference for future research needed to develop updated operationally relevant guidelines and policy recommendations for neck-related aviator flight fitness.

References

Atac, R., Spink, S., Calloway, T., & Foxlin, E. (2014). Scorpion Hybrid Optical-based Inertial Tracker (HObIT) test results. *Proceedings of the SPIE 9086, Display Technologies and Applications for Defense, Security, and Avionics VIII; and Head- and Helmet-Mounted Displays XIX*, 90860U. doi: 10.1117/12.2050363

Berg, H. E., Berggren, G., & Tesch, P. A. (1994). Dynamic neck strength training effect on pain and function. *Archives of Physical Medicine and Rehabilitation, 75*(6), 661-65.

Department of the Army. (2013). *Aircraft Training Manual, Utility Helicopter, H-60 Series, TC 3-04.33*. Department of the Army.

Department of the Army. (2015). *U.S. Army Aeromedical Policy Letters and Technical Bulletins*. Department of the Army

Forde, K. A, Albert, W. J., Harrison, M. F., Neary, J. P., Croll, J., & Callaghan, J. P. (2011). Neck loads and posture exposure of helicopter pilots during simulated day and night flights. *International Journal of Industrial Ergonomics*. doi: 10.1016/j.ergon.2011.01.001

Gordon, C. C., Blackwell, C. L., Bradtmiller, B., Parham, J. L., Barrientos, P., Paquette, S. P., Corner, B. D., Carson, J. M., Venezia, J. C., Rockwell, B. M., Mucher, M., & Kristensen, S. (2012). *2012 Anrthropometric survey of U.S. Army personnel: Methods and summary statistics* (Report No. TR-15/007). U.S. Army Natick Soldier RD&E Center.

Harrison, M. F., Neary, J. P., Albert, W. J., Veillette, D. W., McKenzie, N. P., & Croll, J. C. (2010). Cytochrome oxidase changes in trapezius muscle with night vision goggle usage. *International Journal of Industrial Engineering; 40*, 140-45.

Harrison, M. F., Coffey, B., Albert, W. J., & Fischer, S. L. (2015). Night vision goggle-induced neck pain in military helicopter aircrew: a literature review. *Aerospace Medicine and Human Performance, 86*(1), 46-55.

Nagai, T., Abt, J. P., Sell, T. C., Clark, N. C., Smalley, B. W., Wirt, M. D., & Lephart, S. M. (2014). Neck proprioception, strength, flexibility, and posture in pilots with and without neck pain. *Aviation, Space, and Environmental Medicine*, *85*(5), 529-535.

Novotny, B. L., Madison, A. M., Holderfield, M. H., McGovern, S. M., Shivers, B. L, & Chancey, V. C. (2021). *Resistance band exercise regimen effects on cervical spine range of motion, strength, and muscular control* (Report No 2021-49). U.S. Army Aeromedical Research Laboratory.

Pawlyk, O. (2019). Air Force fighter pilot units will get personal therapists to fight chronic pain. *Military.com*. 17 April. https://www.military.com/daily-news/2019/07/17/air-force-fighter-pilot-units-will-get-personal-therapists-fight-chronic-pain.html

Rudolfsson, T., Björklund, M., & Djupsjöbacka, M. (2012). Range of motion in the upper and lower cervical spine in people with chronic neck pain. *Manual Therapy; 17*(1) 53-59.

Thoomes-de Graaf, M., Thoomes, E., Fernandez-de-las-Peñas, C., Plaza-Manzano, G., & Cleland, J. (2020). Normative values of cervical range of motion for both children and adults: A systematic review. *Musculoskeletal Science and Practice, 49*(102182). doi: 10.1016/j.msksp.2020.102182.

Thuresson, M., Ang, B., Linder, J., & Harms-Ringdahl, K. (2003). Neck muscle activity in helicopter pilots: Effect of position and helmet-mounted equipment. *Aviation, Space, and Environmental Medicine, 74*, 527-32.

Van den Oord, M. H. A. H., De Loose, V., Meeuwsen, T., Sluiter, J. K., & Frings-Dresen, M. H. W. (2010a). Neck pain in military helicopter pilots: Prevalence and associated factors. *Military Medicine, 175*(1), 55-60.

Van den Oord, M. H. A. H., De Loose, V., Sluiter, J. K., & Frings-Dresen, M. H. (2010b). Neck strength, position sense, and motion in military helicopter crew with and without neck pain. *Aviation, Space, and Environmental Medicine*, *81*(1), 46-51.

Wade, M., Reed, J., Shewbridge, K., & Haas, D. (2021). *Fighter aircrew conditioning program analysis* (Report No. Technical Report 2021-0061). Air Force Research Laboratory.

Williams, S. T., Madison, A. M., & Chancey, V. C. (2022). *Defining normal cervical spine range of motion in rotary-wing pilots (Part 1): A method of estimating AH-64 aviator cervical spine range of motion using head position data from the maintenance data recorder* (USAARL-TECH-FR--2022-33). U.S. Army Aeromedical Research Laboratory.

Appendix A. Inclusion/Exclusion Criteria

Day 1:

Inclusion Criteria	Check One
1. *19 ≥ Age ≤ 60 years*	○ Yes ○ No
2. Currently rated on the H-60M platform (Passed Annual Proficiency and Readiness Test (APART) in a UH-60 within the past 12 months and have flown within the last 60 days)	○ Yes ○ No
3. Current, unrestricted Department of the Army medical clearance to fly (DD 2992)	○ Yes ○ No
4. English Fluency	○ Yes ○ No
5. Flight Gear (helmet, flight suit, gloves, etc.)?	○ Yes ○ No
Exclusion Criteria	**Check One**
1. Nonsteroidal anti-inflammatory drugs (NSAIDs) or other pain medication used for any reason other than as part of a physician advised or prescribed regimen within 24 hours of testing	○ Yes ○ No
2. Currently experiencing neck pain?	○ Yes ○ No
3. Any history of neck pain or neck pathology that, in the judgment of the Study Physician, could interfere with normal cervical ROM	○ Yes ○ No
4. Cannot follow verbal and written directions in English	○ Yes ○ No

Please check one:

☐ Participant ***meets*** all criteria required for enrollment and does not have, in my opinion, any findings or factors that may negatively impact compliance or the participant's safety by participation in this study.

☐ Participant ***does not meet*** all criteria required for study enrollment. This subject is considered a screen failure.

Comments:

____

____

____

______________ ______________

Study Physician Initials **Date**

______________ ______________

PI Initials **Date**

Day 2:

Nonsteroidal anti-inflammatory drugs (NSAIDs), muscle relaxers, or other pain medication used for any reason other than as part of a physician advised or prescribed regimen, within 24 hours of testing. If any of this medication must be taken within 24 hours of the aircraft flight, it should be taken at a similar interval prior to the simulator flight.

○ Yes ○ No

Initials **Date** **PI Initials**

Day 3:

Nonsteroidal anti-inflammatory drugs (NSAIDs), muscle relaxers, or other pain medication used for any reason other than as part of a physician advised or prescribed regimen, within 24 hours of testing. If any of this medication must be taken within 24 hours of the aircraft flight, it should be taken at a similar interval prior to the simulator flight.

○ Yes ○ No

Initials **Date** **PI Initials**

Appendix B. Demographic and Flight History Questionnaire

Subject #: ___________ Date: ___________ Administered by:___________________

1. Age: ___________ Sex: ___________

2. How many years have you been flying (military and/or civilian)? ___________

3. Using your best guess, what is your total number of military and civilian flight hours? _____

4. What platform(s) do you fly currently? ____

5. Over the past year, on average, how frequently did you fly the platform listed above (Circle one)?

   Daily **Weekly** **Monthly**

6. Over the past year, on average, how many hours did you fly per week?

Fixed Wing	Military	
	Civilian	
Rotary-Wing	Military	
	Civilian	
Simulator		

7. Over the past year, on average, how many hours was your typical flight? ___________

8. Over the past year, what is the most hours flown in any given month? ___________

9. Over the past year, how many times did you exceed a threshold of 80 hours of flight time per month? ___________

10. Use your best guess to fill out the table below. Circle the best option for frequency and write the total hours you have flown each of the platforms listed.

Platform		**Frequency** (Circle One)	**Total Hours**
UH-60	A	daily weekly monthly occasionally never	
	L	daily weekly monthly occasionally never	
	M	daily weekly monthly occasionally never	
	V	daily weekly monthly occasionally never	
CH-47		daily weekly monthly occasionally never	
AH-64		daily weekly monthly occasionally never	
LUH-72		daily weekly monthly occasionally never	
OH-58		daily weekly monthly occasionally never	
Fixed wing		daily weekly monthly occasionally never	
Other		daily weekly monthly occasionally never	

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