Initial Evaluation of the Operational Neck Pain Index

Phillip E. Whitley; Barry S. Shender; Bethany L. Shivers

INTRODUCTION: Neck pain during military flight is well documented. Characterizing operationally relevant, specific pain location(s), severity, character, and exacerbating or relieving conditions is needed to develop musculoskeletal neck pain prediction models.

METHODS: An anonymous, web-based questionnaire and weighted numerical response index was developed with the help of an expert clinical panel. The questionnaire was reviewed, approved, and disseminated to military pilots. Respondents reported their current neck and upper back musculogenic and neurogenic pain with a 5-level severity at 14 locations, pain onset time, duration, and relief measures, and three-axis neck mobility.

RESULTS: Of 222 fixed and rotary wing pilot respondents, 117 completed questionnaires were used for index calculation. Bilateral moderate musculogenic and neurogenic pain in the 10 posterior muscle areas was most common. Flexor muscles were infrequently indicated. Typically, neck pain started within 30 min of flight or pilots were already in pain, pain duration was less than 7 d, and pain was relieved by rest with over-the-counter medications or by a chiropractor or physical therapist. Neck motion limitations were equally rated as very limited, slight, or no restriction. The normalized index was divided into five ranges where 78% were very mild to mild severity.

DISCUSSION: This new approach differentiates between musculogenic and neurogenic pain by discrete location and severity, addressing pain pattern, structural involvement, and neck mobility changes beyond pain absence or presence. This information can help define necessary model complexity to simulate neck pain biomechanics. The index has potential medical use in tracking pain progression and treatment progress.

KEYWORDS: biomechanics, cervical spine, injury, musculoskeletal, aviation, neck pain.

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Neck pain in military aviation is a significant problem. The significance was highlighted in the NATO Aircrew Neck Pain Research Task Group (HFM-252) report encompassing an extensive problem review with recommendations.[1] U.S. military helicopter pilots experienced ICD-9 cervical disorders at 5.4 per 1000 person-years compared to 3.2 and 3.4 per 1000 person-years for tactical and nontactical fixed wing aircraft, respectively. The helicopter flight exposure, piloting environment, and mission equipment are thought to play a role in this increased cervical disorder incidence.[2] A survey of flight-related neck pain among Austrian helicopter pilots within the armed forces, airborne police, and airborne rescue personnel reported the 3- and 12-mo prevalence of neck pain was 64.4% and 67.3%, respectively.[3] Similar neck pain incidences were documented in multiple countries where regular to continuous neck pain was indicated.[1,3] Countries posited differing causations for the neck pain incidence rates, including helmet weight, head-neck task-related posture, accumulated flight hours, extensive night vision goggle use, and anthropometry.[1,3] While the information in the HFM-252 report is too great to summarize here, the report demonstrates that neck pain is a real operational problem that has multiple factors contributing to pain evocation that can be computationally modeled. Of note is that the report stressed the need to identify significant flight-related pain, i.e., pain that interferes with performing flight tasks, not trivial mild aches. The report also

From CFD Research Corporation, Huntsville, AL, United States; and the Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States.

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Address correspondence to: Phillip Whitley, Ph.D., Senior Principal Engineer, CFD Research Corporation, 6820 Moquin Dr. NW, Huntsville, AL 35806, United States; phlwhit@gmail.com.

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described the need for a model that could be used to evaluate the efficacy of proposed equipment design or procedural changes that would lead to reduced instances and magnitude of acute and chronic pain.

However, to biomechanically model the neck pain problem one must understand its nature. A pain description can indicate the pain type and the biological mechanism.[4,5] The subjective pain level can indicate the personal pain experience severity.[6,7] The pain physical location and extent can indicate the anatomical structure origin such as muscle, joint (e.g., the facet), or a disc.[8,9] Events that evoke pain are found in flight tasks and mission equipment where these physical contributions are an important contributor to the pain mechanism and model requirements. The onset time for neck pain to be noticed during the mission can indicate whether the pain is ongoing and unresolved or whether the severity is such that the insult may resolve but be evoked again.[8] The pain duration can indicate an acute or chronic condition.[10] The type of methods needed to give pain relief can indicate pain intractability.[11] As neck pain evolves from acute to chronic, the magnitude of efforts to relieve pain increases. The degree of neck mobility can indicate muscle and structural involvement through motion limitation and provide insight into potential flight task interference.[12]

Understanding these neck pain factors that contribute to model development can come through a pilot population survey. Current civilian neck pain[13,14] or disability surveys[15,16] are not suitable for military use because the represented scenarios, while relevant to everyday life, do not include the required specificity for model development as it pertains to military pilot flying duties. Since these duties likely play a role in pain development and evocation, representative piloting task responses should be included. The documenting, tracking, and modeling of operationally relevant neck pain requires a customized version of a neck pain survey and rating scale that takes into account the military pilot's special needs . Military pilots must be more physically capable and resilient than civilians and must also, if their aircraft is downed, be able to assist in their own escape and recovery and, if not recovered, endure the rigors of capture. Military pilots wear additional equipment for protection such as torso body armor, night vision goggles, and head-mounted displays for mission augmentation that impose added physical burdens. A recent military survey approach provides a population-specific perspective on the occupational, psychological, and social factors surrounding neck pain, but does not go far enough in specifying location and severity to inform biomechanical model development.[17] This paper will report on the initial use of a questionnaire specifically developed to inform biomechanical modeling and create a new operational neck pain index.

METHODS

Subjects

The subject base was derived from the active-duty Naval Aviation fixed- and rotary-wing communities. The questionnaire was reviewed and approved (CFDRC-IRB-2022-01) by the CFD Research Corporation Institutional Review Board (NIH OHRP IRB00007686) and the Naval Air Warfare Center Aircraft Division (NAWCAD) Human Research Protection Office and then hosted on a commercial survey site (SurveyMonkey, www.surveymonkey.com). The initial survey page included the informed consent information where subjects had to agree to participate in the questionnaire before moving forward. Respondents could refuse to answer any question and still proceed through the survey. The questionnaire was totally anonymous and neither email nor Internet Protocol addresses were collected.

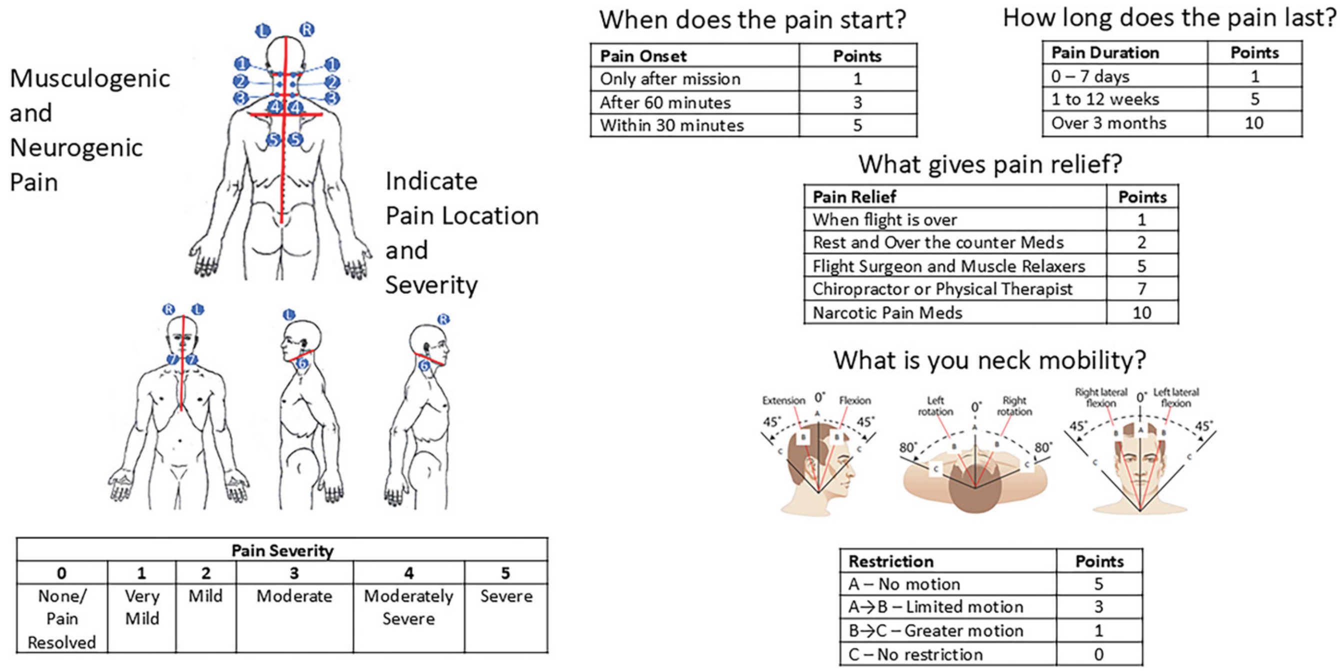
Materials

A questionnaire was developed using the information contained in the HFM-252 report to set boundaries and a publication on fundamental principles of index development as a guide.[18] A key developmental element involved a four-person expert panel's input and review. The expert panel was comprised of a senior U.S. Navy pilot/neurologist and three U.S. Navy flight surgeons.

The operational neck pain index (ONPI) development involved documenting the operationally relevant neck pain components. The ONPI calculation from the questionnaire was intended to capture the respondent's current pain experience. The pain character can suggest mechanism. Musculoskeletal pain, described as aching, sore, dull, or cramping pain, involves different structures than neuropathy, described as stinging, burning, stabbing, or shooting pain. Neck mobility limitation can suggest the magnitude of the muscle and/or structural involvement. The location of pain by anatomical region can suggest mechanism and establishes the pain points to track for severity on an increasing intensity scale. Modeling the correct pain characteristics are essential. If the combined information from pain mechanism, pain location, and neck mobility suggest primarily muscle involvement, then lumped parameter musculoskeletal models are useful, but if predominantly neurogenic pain and structural limitation are indicated, then finite element or hybrid methods are necessary. The mission or flight task events that evoke pain are important to characterize as they help define the initiating biomechanical stress and the time during the mission for pain onset, suggesting severity, pain duration, and pain relief methods.

One of the clinical gaps that the HFM-252 identified was the need for a subjective pain scale that was specifically tailored for the military aviation community. Existing tools, such as the visual analog scale, were deemed inadequate for this highly dynamic environment. The ONPI rationale was to create a relevant index that could document acute pain onset and the progression to pain resolution or worsening to chronic pain. The approach to computing the ONPI was based on the summation of weighted scores for the pain severity at specified neck and upper back locations, as seen in **Fig. 1**, pain onset, pain duration, the magnitude of efforts to relieve pain, and the degree of neck mobility limitation.

The number of musculogenic and neurogenic pain locations, scored by the pain severity at each location, captures the



Pain Onset	Points
Only after mission	1
After 60 minutes	3
Within 30 minutes	5

Pain Duration	Points
0 – 7 days	1
1 to 12 weeks	5
Over 3 months	10

Pain Relief	Points
When flight is over	1
Rest and Over the counter Meds	2
Flight Surgeon and Muscle Relaxers	5
Chiropractor or Physical Therapist	7
Narcotic Pain Meds	10

Pain Severity					
0	1	2	3	4	5
None/ Pain Resolved	Very Mild	Mild	Moderate	Moderately Severe	Severe

Restriction	Points
A – No motion	5
A→B – Limited motion	3
B→C – Greater motion	1
C – No restriction	0

Fig. 1. Operational Neck Pain Questionnaire overview.

extent of the pain experience. Pain location and patterns of pain presentation can indicate anatomical structure involvement, essential for model development, such as in a muscle, a joint such as the facet, or a disc.[19–21] The anatomical locations were based on the clinical experience and consensus of the expert panel of where pilots typically presented pain symptoms. The pain scale was represented by a five-point, Likert-type scale which was recommended for relative degrees of a single item.[18]

The pain onset descriptions were recommended by the expert panel to reflect three cases. The first case, "within 30 minutes," was to reflect the scenario of an on-going neck pain problem easily evoked by the mission and equipment stresses. The second case, "after 60 minutes," was to reflect a neck pain problem in the early stage of becoming an on-going problem. The last case, "only after mission," was to reflect the set-up for the beginning of a recurring neck pain problem. The weightings were determined using a maximum of 5 points for the described first case as the worst case and following with the second and third cases with an arbitrary 2-point separation.

The pain duration descriptions were chosen from the recommendations from the HFM-252 report based on published definitions for acute, subacute, and chronic pain.[10,22,23] The expert panel recommended the weightings where, given the ONPI goal of alerting chronic pain progression, the pain duration weightings were advanced in a more aggressive approach as seen in Fig. 1.

The neck pain management levels were also based on the expert panel clinical expertise with pilot patients and a standard clinical management progression. The pain management descriptions were specifically worded to be easily recognizable by the pilot population. The expert panel recommended that the OPNI be heavily weighted toward chronic pain progression.

The neck motion limitation for flexion, extension, right and left axial rotation, and right and left lateral rotation, as depicted in Fig. 1, were determined by the expert panel to identify the level of pain-induced neck motion restriction by dividing the motion arcs into regions typically encountered while performing cockpit tasks. The weighting of these motion restrictions were established to weigh the highest restriction, i.e., "No motion," as the highest followed by a 2-point separation for "Limited motion," and then "Greater motion." The case of "No restriction" was weighted with a zero value.

The normalized ONPI value was calculated using an arbitrary summation of scores using:

ONPI = G*(sum of the musculogenic pain location-severity scores + sum of the neurogenic pain location-severity scores + sum of the neck mobility directional scores + pain onset score + pain duration score + pain relief score).

Note that a 100-point scale was considered more convenient to apply and understand. A normalizing factor, G, of 0.51 was determined by proportionally scaling the maximum index value of 195 to a 100-point scale.

The minimum, midrange, and maximum scores were determined by setting the questionnaire response values to the lowest, middle, and highest values to establish these points in the index range. A five-level severity indication was developed by arbitrarily dividing the maximum score by five (levels). The resulting value formed the threshold for Level I with multiples of that value creating the thresholds for the remaining levels. The initial normalized severity table is shown in **Table I**. More details of the questionnaire and index development are found in the freely available NAWCAD technical report.[24]

Table I. Normalized Operational Neck Pain Index Score Thresholds.

THRESHOLD	SEVERITY	DESCRIPTION
≤20	Level I	Very Mild: lowest scores indicating little to no neck pain
20–40	Level II	Mild: marginal muscle pain and functional factors
40–60	Level III	Moderate
60–80	Level IV	Moderately Severe
80–100	Level V	Severe: maximum significant neck pain values

Procedure

The internet address for the questionnaire was disseminated within U.S. Navy aviation squadrons through the squadron Aviation Safety Officers. Questionnaire participants were presented with an informed consent document to review. Participants could agree to participate and proceed or decline and they would exit the program.

The questionnaire items were always presented in the same order described as follows. Respondents were asked in freeform fashion to comment on the flying tasks that contributed most to their pain and then the number of days between flying missions. They were next asked for a yes/no response whether they were still in pain the next time they flew. They were asked in freeform fashion to comment on the flight maneuvers and then the flight equipment that contributed most to their pain.

Respondents were next asked a question series used to compute the ONPI value. They were asked to grade their posterior neck and upper back musculogenic pain severity. Musculogenic pain was described as aching, sore, dull, or cramping pain at specific locations using the body diagram and pain severity scale seen in Fig. 1. They were then asked to perform the same musculogenic pain severity grading for anterior and lateral locations as seen in the body diagram in Fig. 1. The same severity grading by specific locations for the posterior and then anterior/lateral locations was performed for neck and upper back neurogenic pain, which was described as stinging, burning, stabbing, or shooting pain. After providing the pain type location and severity self-assessment, the respondents were asked to indicate when their pain started, how long their pain lasted, and what measures gave them pain relief using the choices seen in Fig. 1, respectively. Respondents were asked to self-assess how far they could move their neck in flexion-extension, left and right rotation, and left and right lateral flexion using the motion grading diagram seen in Fig. 1. At each response step participants were given the opportunity to state in their own words anything they wanted to share about that response item.

Lastly, respondents were asked to rate on a five-point "unlikely-neutral-likely" scale the likelihood that their pain would affect their mission performance, physical activities, relationships, and future life. These results are not included in this paper but mentioned for completeness. Only results necessary for ONPI calculation and whether the respondents were still in pain at their next flight are covered in this paper. The other responses can be reviewed in the technical report.[24]

The questionnaire was active for 7 mo. The data was downloaded from the survey website for analysis and reporting.

Statistical Analysis

An open-source graphical user interface for R language, JASP [Version 0.17.2.1, University of Amsterdam (jasp-stats.org)], was used for statistical analysis. Musculogenic and neurogenic results for the number of responses and weighted score were analyzed for anterior and posterior location, anatomical side, and pain severity simple effects and interactions using a two-way Analysis of Variance (ANOVA). The onset, duration, and relief responses were analyzed with a Chi-squared goodness of fit analysis. The neck mobility results were analyzed for motion axis and limitation simple effects and interaction with a two-way ANOVA. The significance level for all tests was $P < 0.05$. For a significant ANOVA result, a post hoc Tukey HSD analysis was performed to determine the source of significant differences. These analyses results were complex and are presented and discussed in the NAWCAD technical report.[24]

RESULTS

While 222 informed consents were recorded, 117 respondents completed the full questionnaire, which was needed to calculate the ONPI. The anterior and posterior muscle location and severity response results are reported separately for musculogenic and neurogenic pain by the number of responses as a percentage of total responses and the weighted score.

Fig. 2 shows the percentage responding within right and left anterior and posterior muscle pain sites. The Moderate pain level was the highest reported at right and left Levels 2 (mid-neck), 3 (lower neck), and 4 (upper back) posterior locations. The highest response for anterior regions, 6 (side of neck) and 7 (front of neck), was the "None/Pain Resolved" response. **Fig. 3** shows the weighted score results for right and left posterior and anterior muscle pain sites. The "Moderate" pain weighted score predominated along the pain locations. The high percentage of "None/Pain Resolved" responses have no weighted score due to zero weighting.

Anterior and posterior pain locations were separated for statistical analysis. ANOVA results indicated that while the number of posterior musculogenic pain location and severity responses were not significantly influenced by the pain location [$F(4,30) = 0.456$, $P = 0.767$], they were significantly influenced by the pain severity level [$F(5,30) = 478$, $P < 0.001$]. The interaction between pain location and severity on the number of responses distribution was significant [$F(20, 30) = 31.7$, $P < 0.001$].

ANOVA results indicated that for the number of responses for right vs. left side posterior musculogenic pain severity, differences based on anatomical side were not significant [$F(1,48) = 0.285$, $P = 0.596$], but the pain severity level did significantly influence the response distribution [$F(5,48) = 35.4$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the number of responses distribution was not significant [$F(5, 48) = 0.215$, $P = 0.954$.]

For the posterior musculogenic pain location and severity level influence on the weighted pain score distribution, both

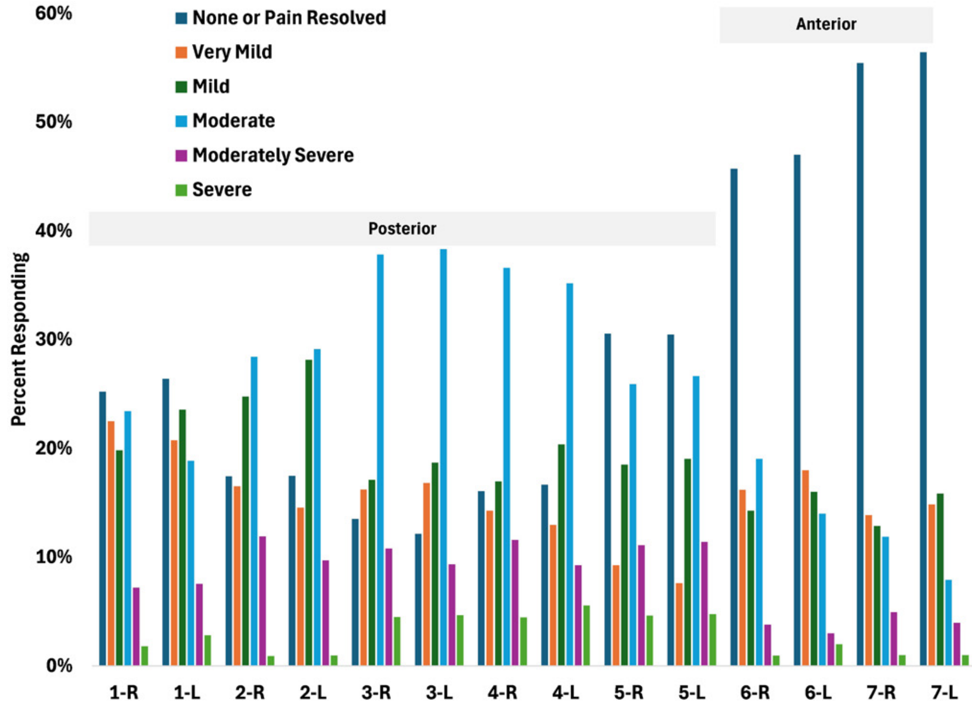


Fig. 2. Percentage responding by muscle location and severity for musculogenic pain: 1) upper neck; 2) midneck; 3) lower neck; 4) upper back; 5) midback; 6) side of neck; and 7) front of neck.

pain location and severity level had a significant effect [$F(4,30) = 17.1$, $P < 0.001$, $F(5,30) = 747.4$, $P < 0.001$, respectively]. The interaction between posterior muscle musculogenic pain location and severity level on the weighted pain scores distribution was also significant [$F(20, 30) = 16.0$, $P < 0.001$].

ANOVA results indicated that for the weighted pain score responses for right vs. left side posterior musculogenic pain severity, differences based on anatomical side were not significant [$F(1,48) = 0.279$, $P = 0.6$], but the pain severity level did have a significant effect [$F(5,48) = 89.1$, $P < 0.001$].

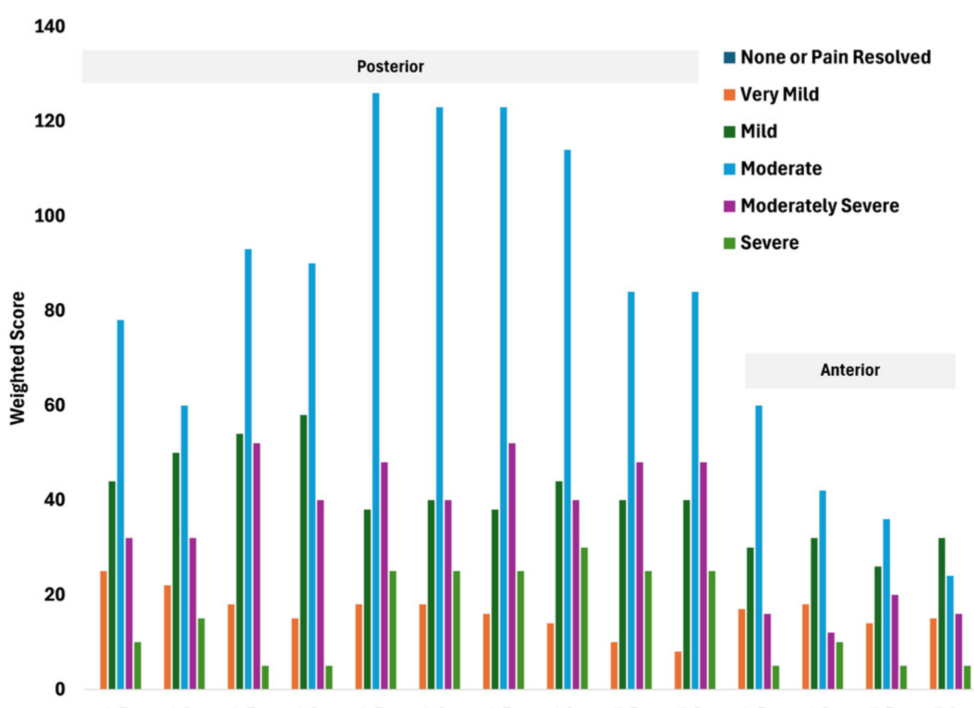


Fig. 3. Weighted score distribution by location and severity for musculogenic pain: 1) upper neck; 2) midneck; 3) lower neck; 4) upper back; 5) midback; 6) side of neck; and 7) front of neck.

The interaction between anatomical side and posterior musculogenic pain severity level on the weighted scores distribution was not significant [$F(5, 48) = 0.344$, $P = 0.883$].

ANOVA results indicated that while the number of anterior musculogenic pain location and severity responses were not significantly influenced by the pain location [$F(1,12) = 0.13$, $P = 0.724$], they were significantly influenced by the pain severity level [$F(5,12) = 762$, $P < 0.001$]. The interaction between location and severity on the number of responses distribution was significant [$F(5, 12) = 9.8$, $P < 0.001$].

ANOVA results indicated that for the number of responses for right vs. left side anterior musculogenic pain severity, differences based on anatomical side were not significant [$F(1,12) = 0.087$, $P = 0.774$], but the pain severity level did significantly influence the response distribution [$F(5,12) = 110$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the number of responses distribution was not significant [$F(5, 12) = 0.502$, $P = 0.770$].

For the anterior musculogenic pain location and severity level influence on the weighted pain score distribution, location did not have a significant effect on the weighted scores distribution [$F(1, 12) = 4.23$, $P = 0.062$], but severity did have a significant effect [$F(5,12) = 37.9$, $P < 0.001$]. The interaction between pain location and severity level on the weighted pain scores distribution was significant [$F(5, 12) = 3.19$, $P = 0.046$].

ANOVA results indicated that for the weighted pain score responses for right vs. left side anterior musculogenic pain severity, differences based on anatomical side were not significant [$F(1, 12) = 0.534$, $P = 0.48$], but the pain severity level did have a significant effect [$F(5,12) = 21.7$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the weighted score distribution was not significant [$F(5, 12) = 1.17$, $P = 0.377$].

The percentage of the responses indicating neurogenic pain within the posterior and anterior neck muscle locations is shown in **Fig. 4**. Most respondents indicated "None/ Resolved Pain." **Fig. 5** shows the weighted scores distribution among the posterior and anterior muscle locations for neurogenic pain. While "None/Resolved Pain" had the highest percentage response, when multiplied by zero, this value drops out and the Moderate Pain level became the highest weighted score found among those who reported neurogenic pain.

ANOVA results indicated that while the number of posterior neurogenic pain location and severity responses were not significantly influenced by the pain location [$F(4,30) = 2.3$, $P = 0.079$], they were significantly influenced by the pain severity level [$F(5,30) = 8.7$, $P < 0.001$]. The interaction between location and severity on the number of responses distribution was significant [$F(20, 30) = 8.7$, $P < 0.001$].

ANOVA results indicated that for the number of responses for right vs. left side posterior neurogenic pain severity, differences based on anatomical side were not significant [$F(1,48) = 0.181$, $P = 0.683$], but the pain severity level did significantly influence the response distribution [$F(5,48) = 1369$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the number of responses distribution was not significant [$F(5, 48) = 0.675$, $P = 0.644$].

ANOVA results indicated that the weighted number of posterior neurogenic pain location and severity responses were not significantly influenced by the pain location [$F(4,30) = 6.9$,

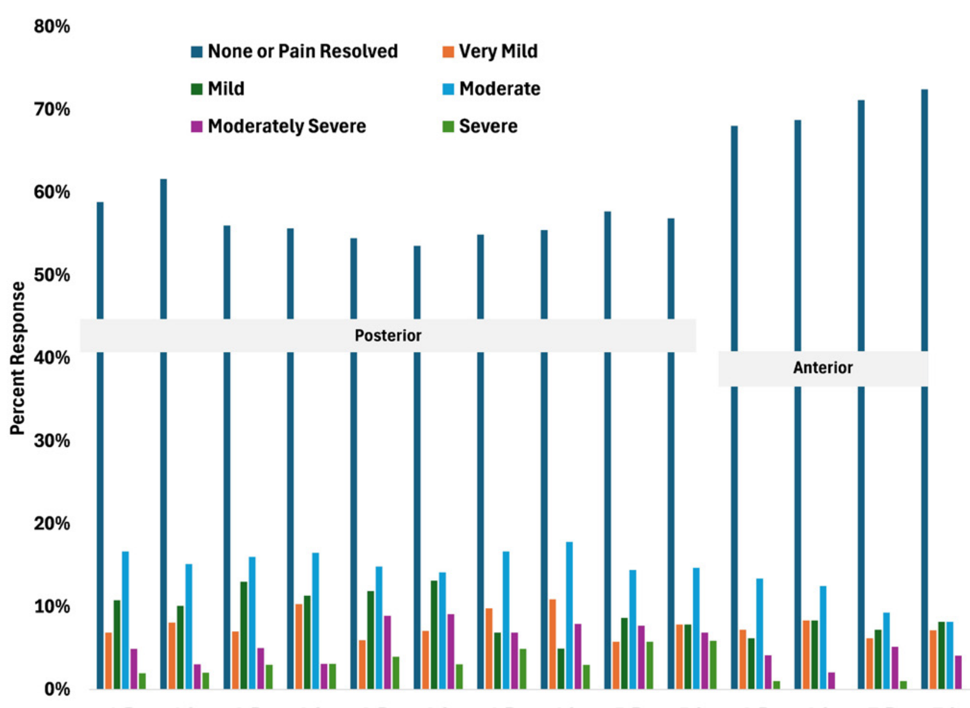


Fig. 4. Percentage responding by muscle location and severity for neurogenic pain: 1) upper neck; 2) midneck; 3) lower neck; 4) upper back; 5) midback; 6) side of neck; and 7) front of neck.

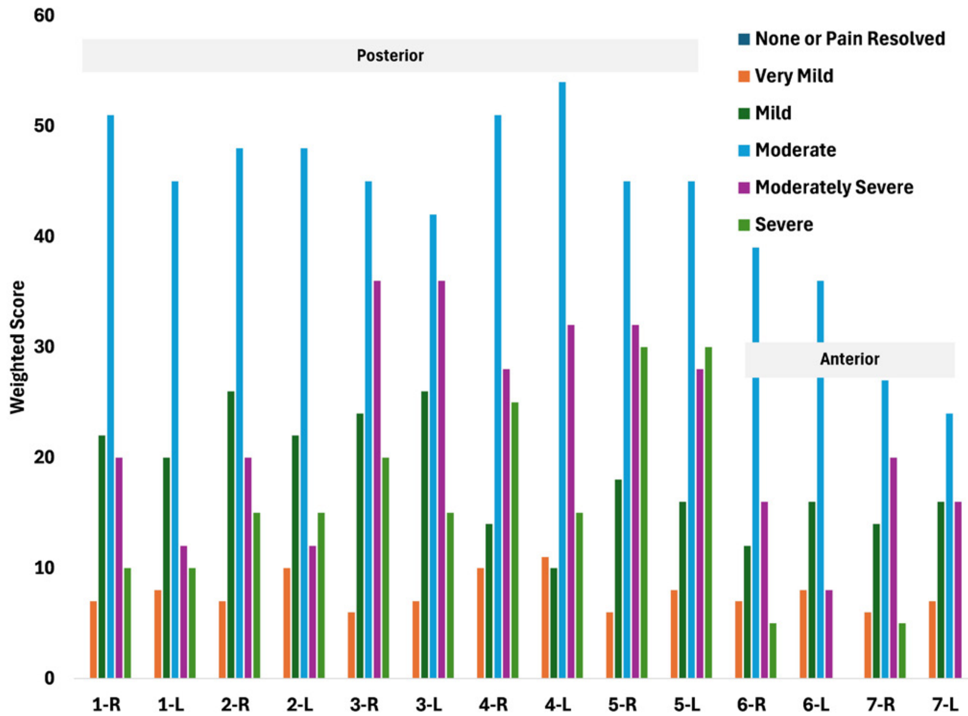


Fig. 5. Weighted score distribution by location and severity for neurogenic pain: 1) upper neck; 2) midneck; 3) lower neck; 4) upper back; 5) midback; 6) side of neck; and 7) front of neck.

$P < 0.001$] nor pain severity level [$F(5,30) = 399$, $P < 0.001$]. However, the interaction between posterior neurogenic pain location and severity level on the weighted pain score distribution was significant [$F(20, 30) = 9.49$, $P < 0.001$].

ANOVA results indicated that for the weighted responses for right vs. left side posterior neurogenic pain severity, differences based on anatomical side were not significant [$F(1,48) = 0.77$, $P = 0.384$], but the pain severity level did significantly influence the response distribution [$F(5,48) = 80.0$, $P < 0.001$]. The interaction between anatomical side and posterior neurogenic pain severity level on the weighted score distribution was not significant [$F(5, 48) = 0.260$, $P = 0.933$].

ANOVA results indicated that while the number of anterior neurogenic pain location and severity responses were not significantly influenced by the pain location [$F(1, 12) = 2.25$, $P = 0.159$], they were significantly influenced by the pain severity level [$F(5,12) = 3007$, $P < 0.001$]. The interaction between location and severity on the number of anterior neurogenic pain responses distribution was significant [$F(5, 12) = 5.4$, $P < 0.001$].

ANOVA results indicated that for the number of responses for right vs. left side anterior neurogenic pain severity, differences based on anatomical side were not significant [$F(1,12) = 0.167$, $P = 0.757$], but the pain severity level did significantly influence the response distribution [$F(5,12) = 1202$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the number of anterior neurogenic pain responses distribution was not significant [$F(5, 12) = 0.88$, $P = 0.523$].

ANOVA results indicated that the weighted number of anterior neurogenic pain location and severity responses were not significantly influenced by the pain location [$F(1, 12) = 4.23$, $P = 0.376$], but pain severity did have a significant effect [$F(5,12) = 73.9$, $P < 0.001$]. The interaction between pain location and severity level on the weighted pain scores distribution was significant [$F(5, 12) = 4.97$, $P = 0.011$].

ANOVA results indicated that for the weighted responses for right vs. left side anterior neurogenic pain severity, differences based on anatomical side were not significant [$F(1,12) = 1.0$, $P = 0.321$], but the pain severity level did significantly influence the response distribution [$F(5,12) = 33.6$, $P < 0.001$]. The interaction between anatomical side and pain severity level on the weighted score distribution was not significant [$F(5, 12) = 0.81$, $P = 0.563$].

Pilots were asked to indicate the pain onset time at intervals of "within 30 minutes of flight," "after 60 minutes of flight," or "after the mission was over." Pain onset within 30 min of flight was the highest response percentage (50%), followed by after 60 min of flight (31%), and lastly after the mission was over (19%). Of pilot respondents, 72% were still in pain when the mission started. A Chi-squared goodness of fit test was performed to determine whether the pain onset responses were equal among the three groups. The pain onset responses were significantly different [$\chi^2(2,115) = 17.3$, $P = 0.05$]. The pain onset weighted score was calculated from the number of responses for each onset category. For the weighted score, within 30 min of flight was the highest total weighted score (290), followed by after 60 min of flight (105), and then only after the mission was over (22). A Chi-squared goodness of fit test was performed to determine whether the pain onset scores were equal among three pain onset groups. The pain onset score proportions were significantly different by pain onset group [$\chi^2(2, 115) = 271$, $P = 0.05$].

Pilots indicated their pain duration responses for periods of "0–7 days," "1–12 weeks," and "over 3 months" durations. The highest percentage was 0–7 d (59%), followed by a duration of over 3 mo (25%), and then 1–12 wk (16%). A Chi-squared goodness of fit test was performed to determine whether the pain duration responses were equal. Pain duration response proportions were significantly different by pain duration [$\chi^2(2,121) = 60.1$, $P = 0.05$]. Pain duration weighted scores were calculated from the number of responses in each duration category. The highest weighted score total was for over 3 mo (310), followed by 1–12 wk (95), and then 0–7 d (71). A Chi-squared goodness of fit test was performed to determine whether the pain duration weighted scores were equal. The weighted pain score proportions were significantly different by pain duration category [$\chi^2(2,121) = 218$, $P = 0.05$].

Pilots were asked how their pain was relieved using the choices of: 1) pain resolved by itself when the flight was over; 2) rest and over-the-counter medications; 3) a Flight Surgeon visit and muscle relaxers; 4) a chiropractor or physical therapist visit; or 5) narcotic pain medications. Rest with over-the-counter medications was the highest response (49%), followed by chiropractor or physical therapy (37%), then when the flight was over (10%), Flight Surgeon and muscle relaxers (3%), and narcotic medications (1%). A Chi-squared goodness of fit test was performed to determine whether the pain relief responses were equal among the five pain relief groups. The pain relief group proportions were significantly different [$\chi^2(4,120) = 112.4$, $P = 0.05$]. Pain relief weighted scores were calculated by multiplying the number of responses in each pain relief category by the category weight. The highest weighted score total was a chiropractor or physical therapist visit (308), followed by rest and over-the-counter medicines (118), visiting the Flight Surgeon and getting muscle relaxers (20), when the flight was over (12), and narcotic pain medications (10). A Chi-square goodness of fit test was performed to determine whether the pain relief weighted scores were equal among five pain relief groups. For pain relief weighted scores, the proportions were significantly different by pain relief category [$\chi^2(4, 120) = 705$, $P = 0.05$].

Pilots were asked to judge their range of motion based on the motion diagram as shown in Fig. 1, where ranges of motion were shown as: A) no motion, A-B) limited motion, B-C) greater motion, and C) no restriction. **Fig. 6** shows the percentage responding to varying motion restrictions for left and right lateral flexion, left and right rotation, extension, and forward flexion. Few respondents (2% average) reported "no motion" across motion axes while "Restricted," "Some Restriction," and "No Restriction" had average respondent percentages of 33%, 29%, and 36%, respectively, across the motion axes. **Fig. 7** shows the weighted scores for neck mobility. Since the weighting for "No Restriction" is zero, those values drop out. The Restricted level showed the highest weighted scores followed by Some Restriction. ANOVA results indicated that a statistically significant number of respondents reported motion limitation [$F(3,15) = 52$, $P < 0.001$]. This was also the case for the weighted score [$F(3,15) = 146$, $P < 0.001$]. However, ANOVA of the motion direction indicated neither the unweighted or weighted number of responses was statistically significant [$F(5,15) = 0.001$, $P = 1.0$, and $F(5,15) = 1.17$, $P = 0.37$, respectively].

The ONPI was calculated for each respondent using the described formula. **Fig. 8** shows the ONPI score distribution, which indicates a symmetric main curve with a peak around an ONPI of 27, and a small second peak at an ONPI of 58. Examining the score composition around these two peaks

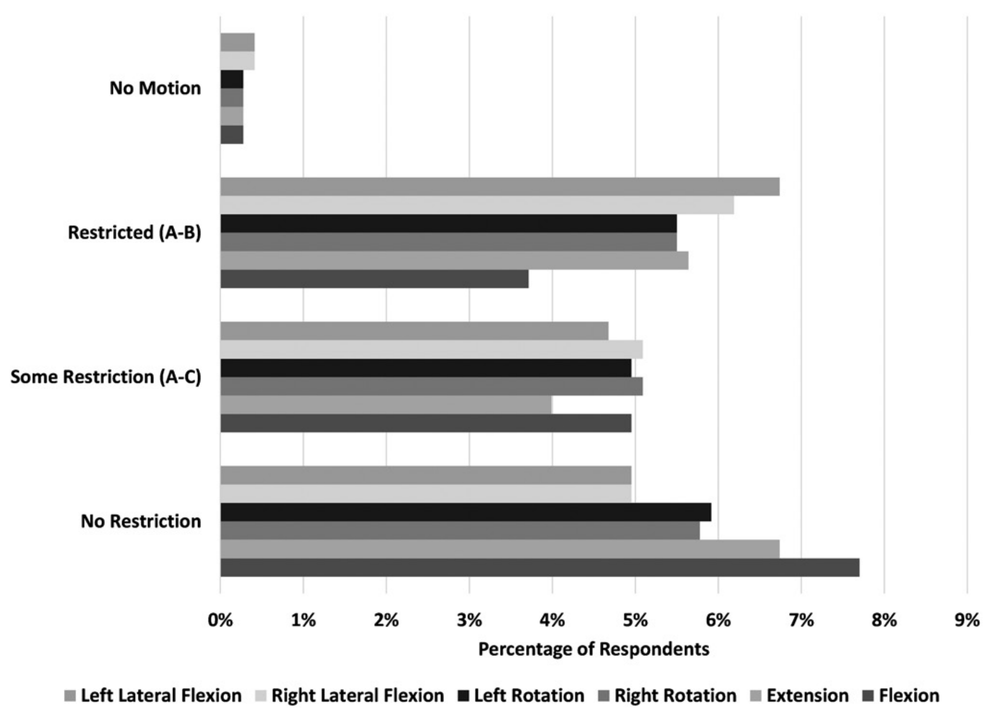


Fig. 6. Percentage responding for mobility restriction.

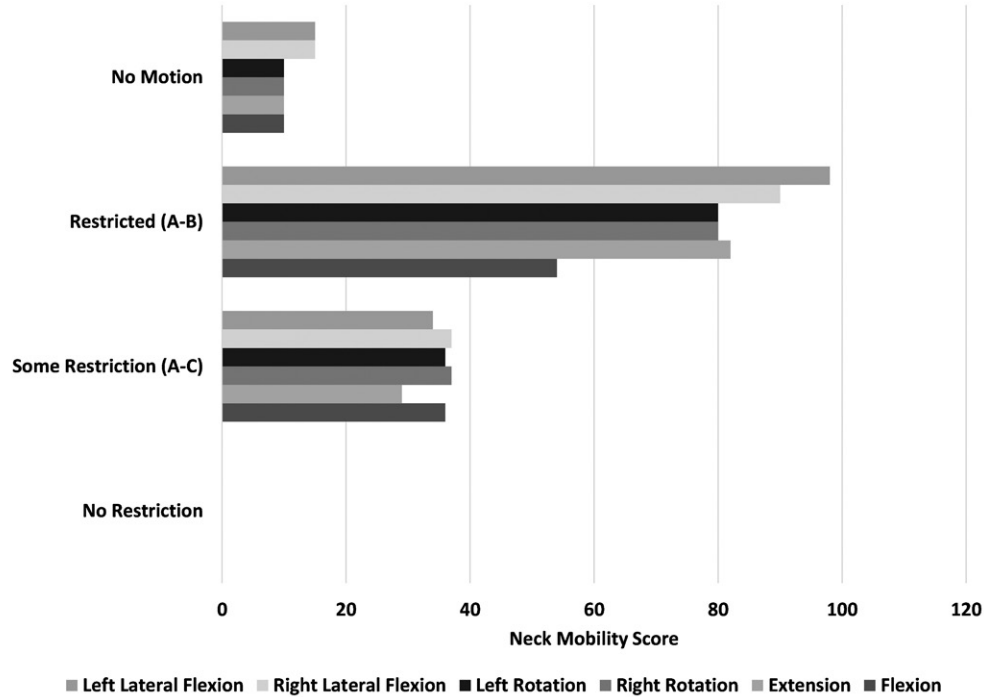


Fig. 7. Weighted scores for mobility restriction.

revealed that the second peak tended to consist of a higher percentage of neurogenic pain scores with other score component contributions roughly unchanged. Removing the neurogenic scores from the ONPI calculation removed the second peak in the distribution curve. Within the context of the ONPI threshold scheme, 37% of respondents were Level I (very mild), 41% of respondents were Level II (mild), 18.8% were Level III (moderate), 1.71% were Level IV (moderately severe), and 0.86% were Level V (severe).

DISCUSSION

Respondents subjectively indicated their pain type and location. While all respondents reported musculogenic pain, 61% reported neurogenic pain as well. No responses with only neurogenic pain were found. Pain severity differences were a significant factor across the board for both pain types in anterior and posterior regions. For the posterior regions the difference may be attributed to the extensor muscles keeping the head at design eye position while the differences in the anterior regions may be attributed to the large number of "None/Pain Resolved" responses. Pain location alone was only significant for the weighted score musculogenic and neurogenic anterior and posterior muscle pain cases. The weighting approach, especially zero weighting, may have played a significant role in creating separation in this case. The location and severity interaction was significant in a number of musculogenic and neurogenic anterior and posterior cases. In these interactions the significance is likely due to severity level influences. No differences in right vs. left side pain were found, which is interesting given that many pilot and copilot tasks involve moving their heads to different sides, as indicated by the pilots' narratives.

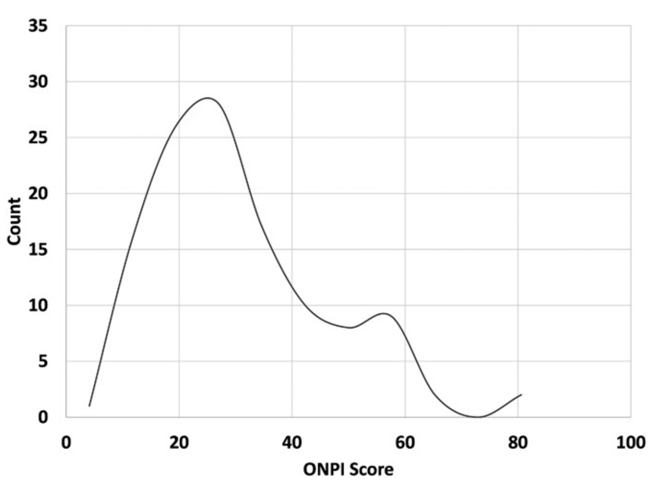


Fig. 8. Distribution of ONPI scores.

Pain onset differences for response number and weighted score were significantly different where pain within 30 min of starting the flight predominated, but 72% indicated they were already in pain before entering the cockpit. This suggests amending the ONPI scoring to consider pain at the start of the mission, which would help identify progression to pain persistence and might suggest flight scheduling modifications. The pain duration differences for response number and weighted score were significant where the number of responses for between 0–7 d were highest but the weighted score, skewed toward severity, emphasized the over 3 mo indication. The high number of responses for shorter duration reflects resolvable muscle pain and perhaps early in the progression to chronic pain. Since a goal was to identify pain progression, the heavier weighting for the longer pain duration seems justified. Pain relief differences for the number of responses and weighted score were significantly different where most responses indicated pain relief was achieved by rest and over-the-counter anti-inflammatory medications or alternatively by either chiropractic medicine or physical therapy. The weighted score approach emphasizes the increasing treatment intensity which placed the chiropractic medicine and physical therapy interventions with the highest score. The two different intensity interventions might suggest treatment for musculogenic and neurogenic pain groups or alternatively suggest the progression from initial musculogenic to chronic musculogenic to neurogenic pain.[11]

Few respondents (2%) reported no neck mobility and the number of respondents were similarly distributed across the restriction levels. The number of responses across motion direction were equally distributed and not statistically different. Giving higher weight to greater motion restriction likely contributed to the significant difference by restriction level. Motion direction was not significantly different considering the weighted score.

The preliminary Operational Neck Pain Index application has the potential for tracking neck pain progression and resolution. The current arbitrarily established severity level thresholds serve as a starting point for classification. The 79% of pilots reporting the "Very Mild" to "Mild, Muscle Only" pain classifications was supported by the higher numbers indicating low pain duration and less aggressive pain management. The remaining 21% of respondents would fall into higher severity classifications.

The weighted score approach was used to place an emphasis on increased pain experience and conditions that were considered by the panel to be indicative of chronic pain existence and development. For musculogenic and neurogenic pain, anterior, posterior, and right vs. left side severity was significant by both the number of responses and by weighed score. The pain location sites were not weighed and the numbers of responses for location alone for anterior, posterior, and right vs. left side musculogenic and neurogenic pain was not significantly different except for posterior neurogenic, where a high number of "None/Pain Resolved" responses were found (Fig. 2). The interaction of location with severity was significant for number of responses and weighted score in all conditions except for right vs. left side. Using a weighted score approach facilitated the separation of severity states to highlight "Moderate" as a predominate pain state in the posterior lower neck (Fig. 3). For pain onset, duration, and relief the number of responses and the weighted scores were both significantly different in all cases. Symptom severity weighting facilitated separation of conditions tending toward chronicity and is necessary as part of an additive weighted score approach. While motion direction as a factor was not significant for number of responses or weighted score, the degree of limitation was significantly different for number of responses or weighted score. Again, symptom severity weighting provides separation for respondents who have a greater problem.

There are several limitations to this approach. The questionnaire and subsequent index values are based on self-report and self-assessment, which can be error prone. The goal is to obtain the pilot's current personal pain experience and use of this approach in a clinical setting would provide training and help minimize error with continued use. In this initial use of ONPI, the desire to protect anonymity created potential challenges and some useful data was missing. As examples, neither aircraft type nor pilot sex was asked to limit potential identification. Subsequent questionnaire versions contain an aircraft class to select and an option to indicate sex. No limitation on repeated respondent inputs existed, which generates the chance for multiple uncontrolled entries. In a controlled clinical context approach, unique identifiers can be assigned for multiple entries to facilitate historical tracking and secure identifying protected information. As with any initial use, lessons learned highlight potential process weaknesses. Embedding the opportunity for narrative response with the ONPI questions may have induced questionnaire fatigue given the large number of responses that only gave narrative input. Subsequent questionnaire versions have moved the narrative response opportunities to the end of the process to help ensure the data for ONPI calculation is obtained. The initial questionnaire language is a first attempt and will improve with usage and feedback. The proposed initial ONPI severity classifications have not been validated against medical records and very few Level V (Severe) cases were observed. Additional research correlating ONPI values with medical records with longitudinal follow-up would help validate the severity classifications and improve the process overall.

The ONPI questionnaire as disseminated represents a first attempt at characterizing the spectrum of military pilot neck pain. The categories, category element descriptions, and weightings are evolutionary and should be improved through further research and validation with medical data. Future considerations should add a still-in-pain choice for pain onset with higher weighting for this unresolved neck pain case. Unresolved neck pain with repeated exacerbations through flight could be a scenario for chronic pain development.

A questionnaire has been developed in conjunction with Navy Medicine subject matter experts to describe, document, and follow current individual neck pain experience and progression based on the military pilot neck pain location, characteristics, and treatment. The pain characteristics derived from this approach inform biomechanical computational model development for neck pain by identifying the potential etiology, location, and severity of pain. Continued applications allow the user to track pain location along with pain factors and can and should be used multiple times to collect data on progression.

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Authors and Affiliations: Phillip E. Whitley, MS, Ph.D., CFD Research Corporation, Huntsville, AL, United States; and Barry S. Shender, MS, Ph.D., and Bethany L. Shivers, MS, Ph.D., Human Systems Engineering Department, Naval Air Warfare Center Aircraft Division, Patuxent River, MD, United States.

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