A Randomized Controlled Trial of Core Strengthening Exercises in Helicopter Crewmembers with Low Back Pain

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BACKGROUND: The purpose of this study was to determine if five core strengthening exercises would decrease pain severity and related disability in U.S. Air Force helicopter aircrew members with low back pain.

METHODS: The study was a randomized control group repeated measures design. The experimental manipulation consisted of a set of five core strengthening exercises performed 4 d/wk for 12 wk. Self-reported pain severity and disability were ascertained at baseline and 12 wk using the Numerical Pain Rating Scale (NPRS) and Modified Oswestry Low Back Pain Disability Index (MODI), respectively. The NPRS was used to ascertain both daily pain ($NPRS_{daily}$) and in-flight pain ($NPRS_{flight}$). Self-reported improvement or deterioration in low back pain was measured using the Global Rating of Change Scale (GRCS).

RESULTS: There were 12 subjects enrolled and 5 were randomized to the intervention group. The mean $NPRS_{flight}$ score decreased 1.8 points vs. increasing 0.1 points during the trial for the intervention and control groups, respectively. The mean MODI score decreased 4.8 points vs. increasing 1.7 points during the trial for the intervention and control groups, respectively. The mean GRCS score at the end of the trial was 4.0 vs. 0 for the intervention and control groups, respectively. There was no difference between groups in terms of mean $NPRS_{daily}$ scores.

CONCLUSIONS: Core strengthening exercises were effective in reducing in-flight pain and led to a reduction in pain symptoms and disability over the 12-wk study period as compared to those subjects who maintained their regular exercise regimen.

KEYWORDS: disability, whole body vibration, ergonomics.

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The reported prevalence of low back pain in helicopter aircrew members ranges from 51–92% as compared to 12–33% in the general population.[21,22] The greater prevalence of low back pain in helicopter aircrew members is hypothesized to result from the combination of ergonomic strain (i.e., poor posture) and exposure to vibration.[22] The ergonomic layout of helicopter controls leads pilots to adopt a posture in which the torso is forward flexed and tilted to the left. This body position creates the most risk for back problems when coupled with exposure to seated vibration.[22] Notwithstanding occupation, helicopter aircrew members are susceptible to the many other physical and psychological factors that are related to the experience of back pain in the general population.[9,11]

As a result of occupation, helicopter aircrew members are exposed to vertical whole-body vibration at the principal resonance frequency of the upper body (i.e., 4.5–5.5 Hz).[11,23] Extended exposure to this vibration frequency may result in muscle fatigue and vibro-creep, the latter involving load-induced distortion of tissues that remains once the load has been removed.[23] These vibration-induced changes to the spine are associated with an increased likelihood for degenerative changes. Although there may be instances when degenerative change in the spine does not lead to low back pain, degenerative changes in the spine tend to be the primary source of pain symptoms in the general population.[23]

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While helicopter aircrew members are at increased risk for back pain, direct mitigation of the purported injurious ergonomic and vibratory exposures through redesign of helicopter seating arrangements is not a quickly executable solution.[22] Consequently, alternative mitigations are required in the near term, if not longer. It is known that individuals suffering from back pain generally lose stiffness between spinal motion segments, the latter resulting in a decreased tolerance to externally generated spinal loads. However, pain may be reduced if the individual is able to train muscular motor patterns to increase spinal stability and restrain aberrant micromotion.[13] Additionally, specific exercises that build core body strength have been shown to reduce pain in chronic low back pain patients.[18,20] The purpose of this study was to determine if five core strength exercises would mitigate pain severity and related disability in U.S. Air Force helicopter aircrew members with low back pain. The following research hypotheses were adopted for the present study:

- H1: Mean self-reported pain severity levels will be less for helicopter aircrew members with low back pain performing core strengthening exercises as compared to controls.
- H2: Mean self-reported disability levels will be less for helicopter aircrew members with low back pain performing core strengthening exercises as compared to controls.
- H3: Mean improvement in pain symptoms will be greater for helicopter aircrew members with low pain back performing core strengthening exercise as compared to controls.
- H4: The proportion not achieving a minimal clinically important difference in pain severity level and disability level over 3 mo will be lower for helicopter aircrew members with low back pain performing core strengthening exercise vs. controls.

METHODS

Subjects

The study was conducted under a human-use protocol approved by the 711th Human Performance Wing Institutional Review Board and in accordance with Federal and USAF regulations on the protection of human subjects in biomedical and behavioral research. The subjects were active Air Force helicopter aircrew members assigned to Air Force Global Strike Command, Air Combat Command, Air Force District of Washington, Pacific Air Forces, and U.S. Air Forces in Europe during the period from July 2012 to September 2013 who responded to an electronic solicitation for volunteers for a study investigating the effect of exercises in helicopter aircrew members experiencing low back pain.

The study inclusion criteria was an active duty helicopter aircrew member with $\geq$ 4 wk of self-reported low back pain (i.e., nonacute low back pain as defined by the Joint Clinical Practice Guideline from the American College of Physicians and the American Pain Society[6]) who was currently flying $\geq$ 1 h/wk. Study exclusion criteria included: 1) history of low back pain attributable to a traumatic event; 2) history of preexisting low back pain prior to exposure to the helicopter work environment; 3) chronic lower extremity radicular symptoms below the knee; 4) chiropractic manipulation therapy, physical therapy, or acupuncture within the prior 4 wk; 5) current medical restriction from performing flying duties; and 6) currently pregnant.

Materials

The initial study questionnaire was comprised of 27 items. Five items addressed basic demographic information: age, gender, rank, height, and weight. Four items inquired about the type (i.e., cigarettes, cigars, chewing tobacco, other tobacco products) and quantity of tobacco use. Six items characterized subjects' aviation experience and exposure to the helicopter work environment: total flight hours, total helicopter flight hours, average monthly helicopter flight hours, percentage of missions greater than 4 h ($\leq$ 10%, 10–25%, 25–50%, 50–75%, 75–100%), crew position (pilot, flight engineer, gunner, other), and primary helicopter model (UH-1, HH-60, other). One dichotomous item was an indicator for recurring exposure to the helicopter work environment: "do you currently fly helicopters at least one hour per week?" Four items characterized whether subjects ever experienced pain or discomfort in the lower back, upper back/shoulders, neck, and/or thighs that was self-attributed to exposure to the helicopter work environment; for positive responses, subjects were queried about the frequency and intensity using a Likert-type scale. Seven dichotomous items identified subjects with: residual pain or discomfort after performing flight duties and whether this pain or discomfort impacted subjects' ability to perform flight duties; currently experienced low back pain of 4 or more weeks in duration; continuous lower extremity sensory symptoms; lower extremity symptoms attributed to exposure to the helicopter work environment; a history of involvement in a helicopter mishap requiring medical treatment; and use of nonpharmacological interventions (acupuncture, chiropractor, physical therapy, and/or spinal injections) to control pain symptoms.

Self-reported pain severity was ascertained using the Numerical Pain Rating Scale (NPRS). The NPRS asks subjects to rate their current pain intensity from 0 ("no pain") to 10 ("worst possible pain"). The NPRS is ubiquitous as a screener in many health care environments and has been validated as a measure of pain intensity in populations with known pain.[7,15] One NPRS score was computed for daily activity ($\mathrm{NPRS}_{\mathrm{daily}}$) and one NPRS score was specifically related to flight ($\mathrm{NPRS}_{\mathrm{flight}}$). Self-reported improvement or deterioration in low back pain was measured using the Global Rating of Change Scale (GRCS).[10] The GRCS asks subjects to rate the change in their symptoms and has 15 possible choices ranging from 7 ("a very great deal better") to -7 ("a very great deal worse"), with 0 representing no change. The GRCS has been used to effectively monitor symptom progression in patients with painful disorders.[7]

The impact of low back pain on everyday activities was assessed using the Modified Oswestry Low Back Pain Disability

Index (MODI). The MODI consists of 10 items addressing the following considerations: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and changing degree of pain. For each item, the subject selects only one response from six choices. Each of the 10 items is scored separately (0 to 5 points each) and then added up (max total = 50 points).[8]

Procedure

The study used a randomized control group repeated measures design. The experimental manipulation consisted of a set of 5 core strengthening exercises chosen by the physical therapist member of the study team and described by Childs and colleagues[4,5] and Liebenson:[18]

- Supine with bilateral upper extremity and lower extremity lifts (modified deadbug): subjects start in the supine position with their arms extended perpendicular to their torso and they raise their legs to a 45° angle with the ground.
- Supine curl-up: subjects start in the supine position with their knees bent at a 90° angle and they lift their head, neck, and shoulders off the ground while extending their arms perpendicular to their torso.
- Quadruped with alternate upper extremity and lower extremity lift: subjects start on their hands and knees/lower legs (i.e., "on all fours") and one arm is extended parallel to the ground in front of their body while the opposite leg is extended straight out parallel to the ground behind their body.
- Horizontal side support: subjects start lying on their side with their weight supported by their elbow, forearm, hand, and dependent foot and their nonsupporting hand is placed on their upper hip; they hold their body in a straight line by not allowing their torso, hips, or legs to sag toward the ground.
- Prone with bilateral upper extremity and lower extremity lift (modified superman): subjects start in the prone position with their arms extended parallel to the ground in front of their body and they lift their head, arms, and legs at least 6″ off the ground; ideally their upper chest and lower thighs do not touch the ground as well.

These exercises were chosen because they activate the transverse abdominus and multifidus muscles, which are key spinal stabilizers. With these exercises, individuals must maintain a neutral spine posture and then activate movement of the trunk or lower extremities. One set of 12 repetitions of each of the 5 exercises was performed on any 4 d in a week for 12 wk. The experimental manipulation was thus comprised of 48 exercise sessions performed during a 3-mo period. The control condition was continuation of the subject's prestudy exercise regimen. Outcome measures were assessed at baseline and 12 wk.

An informational e-mail message was sent to helicopter aircrew members in the aforementioned organizations explaining the general nature of the study, the voluntary nature of participation, and instructions for participating. Helicopter aircrew members who volunteered to enroll in the study were asked to attend a 20-min briefing with the principal investigator. At a subject's location, a local representative, who was not part of the research team, assisted the principal investigator by facilitating the study recruitment briefing via teleconference. The principal investigator described the study and answered the subject's questions. The local representative then provided the subject with the informed consent document (ICD), allowing them to review it while the principal investigator was on the phone. The local representative witnessed the subject sign the ICD and e-mailed it to the principal investigator. Upon receipt of the signed ICD, each subject was e-mailed the URL for the electronic study questionnaire. Subjects who met study inclusion criteria were then medically cleared by their local flight surgeon for involvement in the study based on a medical record review and were then subsequently randomized to either the experimental or control group.

Subjects in the experimental group were mailed an exercise DVD with the five core strengthening exercises. They were instructed to follow the DVD to ensure correct and safe execution of the core strengthening exercises. They also maintained an exercise log that was sent weekly to the principal investigator. Subjects in both the experimental and control groups accomplished the NPRS and MODI at baseline and the NPRS, GRCS, and MODI at 12 wk. Subjects were asked to provide pain ratings using the NPRS for both "daily pain" and "pain experienced in flight."

Statistical Analysis

The dependent variables used to measure pain included scores of the NPRS and the GRCS. The dependent variable used to measure disability was the MODI. A dichotomous variable denoting group membership (intervention or control) was the primary independent variable.

Descriptive statistics were computed for all study variables and intervention and control groups compared at baseline. Categorical variables were summarized using frequencies and percentages. Continuous variables that were normally distributed were summarized using the mean and SD, and continuous variables that were not normally distributed were summarized using the median and range. Categorical baseline characteristics, where appropriate, were compared between the treatment groups using Fisher's exact test, whereas differences between treatment groups for the continuous variables were tested using a *t*-test for the normally distributed variables and a median test for variables nonnormally distributed.

To determine whether or not the experimental manipulation had a significant impact on pain and disability, comparisons were made between the intervention and control groups with respect to scores on the $\mathrm{NPRS}_{\mathrm{daily}}$, $\mathrm{NPRS}_{\mathrm{flight}}$, and MODI at baseline and 12 wk and the GRCS score at 12 wk. A repeated measures ANOVA was used to test for an interaction effect of group with time for NPRS and MODI scores. Simple *t*-tests were used to examine the change in response score from baseline to 12 wk. The GRCS score between the intervention and control group was compared at 12 wk using a nonparametric test on the median since this response was not normally distributed. Response variables were also compared using the Minimal Clinically Important Difference (MCID). The MCID was conservatively defined to be a change of −2 for the NPRS,[14] −6 for the MODI,[13] and +3 for the GRCS.[7] All analyses were conducted using SAS (SAS Institute, Cary, NC) version 9.3 software and the level of significance was set to 0.05.

RESULTS

There were 13 subjects, all male, who were enrolled in the study. Of these, six were randomly assigned to the intervention group and seven were assigned to the control group. One subject in the intervention group was lost to follow-up (i.e., baseline data only); this subject did not differ in demographic characteristics from those subjects who completed the study. Subjects' responses on the prestudy questionnaire and survey instruments are summarized in **Table I**; overall, there were no observed significant differences between the intervention and control groups at baseline.

Only three subjects (one in the intervention group and two in the control group) were taking medications; reported medications included acetaminophen, celecoxib, esomeprazole, ibuprofen, levothyroxine, losartan, and simvastatin. Only one subject in the control group reported the use of tobacco products (1 dip per day). Half the subjects were pilots, and gunners and flight engineers each comprised one-quarter of the subjects; this distribution of crew positions was similar across both groups. All subjects reported satisfaction with their job. No subjects reported any Duties Not Including Flying (DNIF) days or other days of restricted duty attributable to low back pain; four subjects reported restricted duty attributable to other reasons (one in the intervention group and three in the control group). Based on the exercise logbooks, it was determined that all subjects in the intervention group completed the 48 exercise sessions (i.e., four sessions per week for 12 wk).

Fig. 1A and **Fig. 1B** display the ANOVA model estimated least-square means and standard errors for $NPRS_{daily}$ and $NPRS_{flight}$, respectively, by group and time. The results of the ANOVA models for both $NPRS_{daily}$ and $NPRS_{flight}$ partially support Hypothesis 1. For the $NPRS_{daily}$ model, there was no significant interaction effect between group and time [$F(3,10) = 2.26$, $P = 0.144$]. For the $NPRS_{flight}$ model, however, there was a significant interaction effect [$F(3,10) = 2.76$, $P = 0.020$]; the mean $NPRS_{flight}$ score decreased by about 1.8 points on average over the 12-wk period for the intervention group ($t_{10} = 2.46$, $P = 0.034$, $\eta^2 = 2.46$) vs. an increase of 0.7 points for the control group (n.s., $t_{10} = -1.26$, $P = 0.235$).

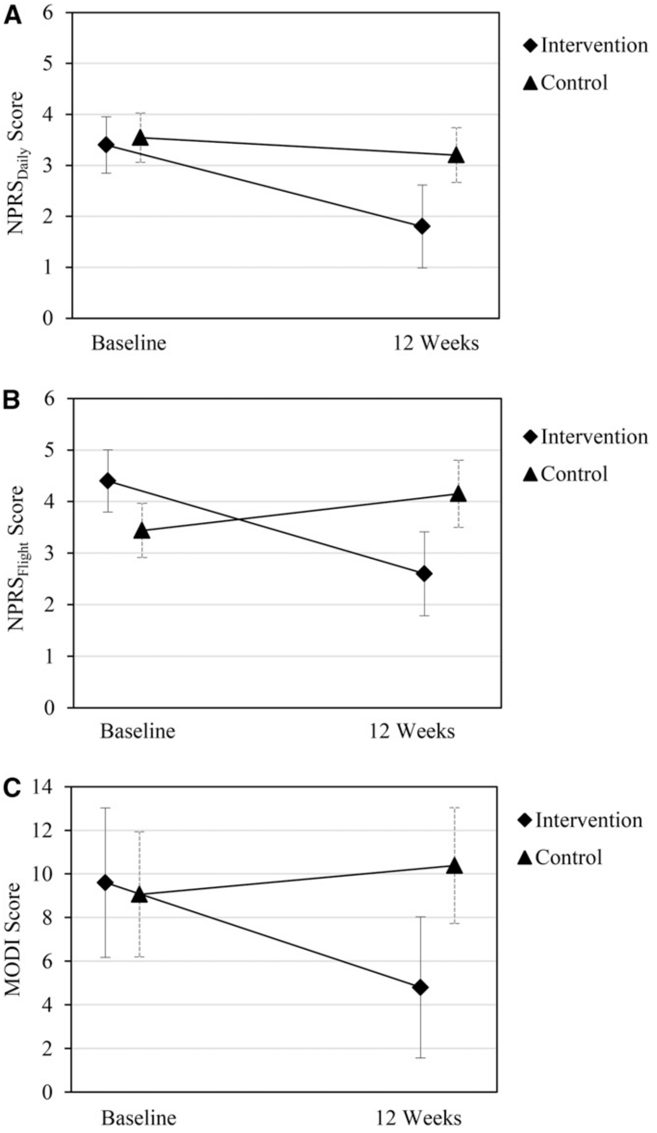

Fig. 1. ANOVA model estimated least-square means and standard errors for A) the Numerical Pain Rating Scale (NPRS) score with respect to daily activity ($NPRS_{daily}$), B) the NPRS score with respect to the flight environment ($NPRS_{flight}$), and C) the Modified Oswestry Low Back Pain Disability Index score (MODI). Error bars are ± 2 SE from the mean.

Table I. Subject Baseline Characteristics.

CHARACTERISTIC	(*N* = 12)
Age (yr), median (range)	30.0 (25-45)
Height (inches), mean (SD)	71.7 (2.2)
Weight (lb), mean (SD)	181.6 (18.0)
BMI (kg/m^2), mean (SD)	24.9 (2.3)
Time in service (yr), mean (SD)	8.0 (5.2)
Total flight hours, mean (SD)	1065.4 (600.9)
Total helicopter flight hours, mean (SD)	957.8 (601.5)
30-d helicopter flight hours, mean (SD)	22.7 (15.2)
60-d helicopter flight hours, mean (SD)	44.7 (25.0)
90-d helicopter flight hours, mean (SD)	73.9 (35.6)
Low back pain onset age (yr), mean (SD)	26.2 (3.5)
$NPRS_{daily}$ score, mean (SD)	3.5 (1.2)
$NPRS_{flight}$ score, mean (SD)	3.8 (1.3)
MODI score, mean (SD)	9.2 (7.5)

Fig. 1C displays the ANOVA model estimated least-square means and standard errors for MODI score by group and time. The results of the ANOVA model support Hypothesis 2. Although the error bars overlapped for both the intervention and control groups, there nevertheless was a significant interaction effect between group and time effect [$F(3,10) = 3.75$, $P = 0.049$]. Comparing baseline to the end of the study period, the mean MODI score decreased by about 4.8 points for the intervention group ($t_{10} = 2.62$, $P = 0.026$, $\eta^2 = 2.62$); in contrast, the mean MODI score increased by 1.7 points in the control group (n.s., $t_{10} = -1.11$, $P = 0.295$).

There was a significant difference between the median GRCS scores of the intervention and control groups at 12 wk ($P = 0.006$). Median reported GRCS for the intervention group was 4.0, with a range from 0 to 5, indicating that, in general, these subjects reported improvements in symptoms. However, the median reported GRCS for the control group was 0 and ranged from −4 to 0, indicating at best that these subjects experienced no change, though some experienced a worsening of symptoms. The results of this nonparametric test support Hypothesis 3.

For all measures of pain severity and disability, there were more subjects failing to achieve the MCID in the control group as compared to the intervention group (**Table II**). There were significant differences in the proportion of those experiencing a MCID for $\text{NPRS}_{\text{flight}}$ score ($P = 0.046$) and GRCS score ($P = 0.010$). These results partially support Hypothesis 4.

DISCUSSION

Low back pain in helicopter aircrew members has been investigated since the 1960s. This literature has assessed the prevalence of low back pain in helicopter aircrew members and identified vibration and poor in-flight posture as contributing factors.[22] Additional aircrew equipment, such as body armor, survival vests, and night vision devices, augment the weight applied to musculature already stressed by vibration and poor in-flight posture. This additional equipment, coupled with increased mission durations, has exacerbated perceived low back pain in helicopter aircrew members.[16,19] The resultant outcome is that helicopter aircrew members are at elevated risk for acute low back pain that can decrease human performance because of reduced concentration and hurrying of key tasks,[1,24] and acute pain over time may yield chronic pain and disability.[2]

Table II. Number of Subjects Achieving Minimal Clinically Important Difference on Response Variables by 12 wk.

RESPONSE VARIABLE	MINIMAL CLINICALLY IMPORTANT DIFFERENCE YES	NO	*P*-VALUE
$\text{NPRS}_{\text{daily}}$			
Intervention	3	2	0.222
Control	1	6	
$\text{NPRS}_{\text{flight}}$			
Intervention	3	2	0.046
Control	0	7	
GRCS			
Intervention	4	1	0.010
Control	0	7	
MODI			
Intervention	3	2	0.061
Control	0	6	

$\text{NPRS}_{\text{daily}}$ = Numerical Pain Rating Scale with respect to daily activity, $\text{NPRS}_{\text{flight}}$ = Numerical Pain Rating Scale with respect to the flight environment, GRCS = Global Rating of Change Scale, MODI = Modified Oswestry Low Back Pain Disability Index.

Researchers have concluded that the best solution is new seats that alleviate ergonomic stresses resulting from poor in-flight posture and isolate crewmembers from vibration.[3,22] However, redesigning the seating arrangements of helicopter aircrew members may not be practical from a financial perspective and so other solutions are needed.[22] Proposed interim measures include a variety of low back pain mitigating interventions to the existing seating arrangements. Lumbar supports[3,16] and seat cushions that attenuate vibrations[16,22] have been demonstrated to be effective tools. Unfortunately, fielding this equipment to helicopter aircrew members and then replacing the equipment when it no longer provides support has proven challenging.[12,16] For example, the Kadix Business Case Analysis[16] of over 1700 helicopter aircrew members found that current lumbar support, if it exists, does not adequately address ergonomic needs and recommended that supplemental seat support aids be fast tracked for evaluation and deployment.

Another approach to interventions is to modify the helicopter aircrew member rather than the equipment.[22] This approach, which can be taken in conjunction with modifications to the seating arrangement such as lumbar supports and seat cushions, involves core strengthening exercises as investigated in the present study. Despite the small sample size, the present study demonstrated that core strengthening exercises were effective in reducing in-flight pain and led to a reduction in symptoms and disability over the 12-wk study period as compared to those subjects who maintained their regular exercise regimen. These results are consistent with the findings of a systematic literature review of randomized controlled trials (RCTs) investigating exercise interventions for treatment of chronic low back pain; a total of 16 RCTs involving 1730 patients were included in this review and exercises were shown to have a positive effect in all 16 trials (12 of the 16 trials specifically incorporated strengthening exercises).[17]

The primary study limitation was the small sample size. It was originally calculated, assuming a strong correlation between observations (the most conservative case), that a sample size of $N = 42$ per group for the NPRS, $N = 75$ per group for the MODI, and $N = 12$ per group for the GRCS would result in 80% power to detect the specified MCIDs at an alpha of 0.05. However, the observed variability in the study was only about half of that which was planned in the original analysis. Thus, although the desired group sizes were not achieved in the study, it was arguably not to the overall detriment of the study with respect to detectable differences. Nonetheless, the results of this study should be verified in a larger sample as it is possible that the small number of subjects may not be representative of the overall population of helicopter aircrew members with low back pain (i.e., the question of external validity). Additionally, the subjects in this study were very compliant in accomplishing the prescribed exercises; it remains to be seen if the efficacy of the exercise intervention holds when subjects are not being monitored for compliance.

Additional study limitations primarily involved failure to control for other potential contributing and confounding factors. For example, the nature of the control condition likely resulted in a heterogeneous comparison group as subjects were instructed to maintain their prestudy exercise regimen. Thus, the activity of subjects in the control group potentially ranged from sedentary to daily vigorous exercise. Also, subjects in the control group who included core strengthening exercises in their prestudy exercise regimen would bias the study toward the null hypothesis. Lastly, the study did not address other potential confounders such as aircraft type, differences in life support equipment and body armor, or differences in exposures and task demands between crew positions.

Another limitation of this study is that it relied on subjective measures to ascertain the efficacy of core strengthening exercises. Including objective measures of change in core strength would have lent further evidentiary support for the proposed mechanism of action by which the exercises reduced back pain symptoms and associated disability. However, given the widely dispersed locations of subjects, it was determined that inclusion of objective measures in this study would have been impractical.

Besides validating the findings of this study in a larger sample, future research should look at the relative efficacy of cointerventions in mitigating low back pain and follow subjects for a longer period of time to evaluate the durability of the observed improvements in pain and disability. Another avenue of investigation is to evaluate the value of core strengthening exercises on the prevention of low back pain versus the mitigation of existing low back pain in helicopter aircrew members.

In conclusion, the results of this present study, which involved a small number of subjects, nonetheless demonstrated that core strengthening exercises had a positive impact on perceived pain and disability in U.S. Air Force helicopter aircrew members with low back pain. A larger study is therefore warranted to validate the efficacy of core strengthening exercises as an approach for mitigating the adverse effects of vibration and poor in-flight posture on helicopter aircrew members pending a more permanent solution involving redesign of their seating arrangements.

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