Self-Kinematic Training for Flight-Associated Neck Pain: a Randomized Controlled Trial

Hilla Sarig Bahat; Dmitry German; Galia Palomo; Hila Gold; Yael Frankel Nir

BACKGROUND: Flight-associated neck pain (FANP) is a serious problem in fighter pilots. Despite the high impact of FANP there is little evidence for effective management. However, self-kinematic training showed a positive effect in the general population. The purpose of this study was to investigate the effectiveness of a self-kinematic training program using virtual reality in improving neck pain in fighter pilots.

METHODS: There were 45 pilots with FANP who were randomized to a control group ($N = 23$) or a training group ($N = 22$). Training participants were instructed to exercise using a personalized self-training program, for 20 min/wk, for 4 wk. Primary outcome measures were neck disability (NDI%) and mean velocity ($^\circ \cdot s^{-1}$), and secondary were pain, health status, accuracy, and isometric strength. Assessments were conducted by a blinded assessor and intention-to-treat analysis by a blinded statistician.

RESULTS: There were 40 pilots who completed the postintervention assessments, and 35 completed the 6-mo follow-up. Baseline measurements showed mild pain and disability (mean VAS = 43 ± 22.73, NDI = 17.76 ± 9.59%) and high kinematic performance. Compliance with self-training was poor. No differences were observed in self-reported measures and strength. Exercise duration was correlated with NDI% improvement.

DISCUSSION: This self-kinematic training promoted kinematic performance, but was ineffective in engaging the pilots to exercise, and consequently did not improve pain and disability. Poor compliance was previously reported in self-training for FANP, suggesting further studies should prioritize supervised training. Considering the high baseline kinematic performance, kinematics does not seem to be a key factor in FANP, and future exercise research should aim for intense strengthening to increase endurance to the high G_z pilots experience.

KEYWORDS: neck pain, pilots, VR, randomized controlled trial, cervical kinematics.

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Military helicopter and fighter pilots are a special population at risk of neck pain, with epidemiological reports indicating a significantly higher annual prevalence of neck pain in combat pilots compared to the general population (46–83% vs. 30–50%, respectively) and at a younger age.[9,37]

Several factors expose pilots to an increased risk of flight-associated neck pain (FANP): high G forces, heavy helmets, inadequate back support, and requirements for quick neck motion. During air combat flying maneuvers, acceleration can reach +9 G_z, multiplied by the weight of the head and helmet. This applies high axial compression on the cervical spine.[14] In addition, the cockpit's reclined sitting position provides no spinal support for when pilots are upright checking their surroundings (known as "checking six").[37] Helicopter pilots often wear night-vision aids that place an additional compressive and forward flexion load on the neck,[33] along with longer sorties,[7] vibrations in the cockpit,[31] and lack of neck support,[37] all of which contribute to the development of FANP.

FANP may have a high functional impact on pilots. FANP may lead to decreased endurance and strength, and could limit

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From the Department of Physical Therapy, Faculty of Social Welfare & Health Sciences, University of Haifa, Mount Carmel, Haifa, Israel; and the Aerospace Medicine Unit, Israel Defence Force, Tel Hashomer, Israel.

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Address correspondence to: Hilla Sarig Bahat, Department of Physical Therapy, Faculty of Social Welfare & Health Sciences, University of Haifa, Mount Carmel, Haifa, 31905 Israel; hbahat@research.haifa.ac.il.

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flight duration.[1,15] In 11–42% of cases, FANP can lead to a temporary change in flying fitness status[14,19] or even permanent flying disqualification.[16] The high impact of neck pain on pilots and their functional requirements emphasizes the need for an effective treatment approach.

Several impairments which are commonly associated with neck pain in the general population have been studied. These include cervical range of motion (ROM),[20] muscle strength,[6] and sensorimotor control.[36] Sensorimotor control was investigated using measures of motion/position sense,[12] oculomotor control,[35] and kinematic measures such as velocity, smoothness, and accuracy of cervical motion.[5,17] These kinematic measures of neck motion are functionally relevant to military pilots with neck pain, but have yet to be studied in this group.

Strong evidence, based on multiple randomized control trials (RCTs) in the general population, supports the effectiveness of active exercise regimes for the treatment of neck pain. However, these include a variety of protocols and exercise types, with no specific regime proven most effective.[10,11]

Unfortunately, only three RCTs of methodological quality (PEDro 7–8) were identified that had investigated active interventions for FANP in combat pilots.[2,13,18] Among these, one RCT found no effect of a self-exercise program on neck pain,[18] and the other two RCTs showed a significant improvement in the frequency of neck pain occurrence in the supervised training group compared to the control group.[2,13] Other studies were either noncontrolled, of poor quality, or investigated passive interventions.

We recently investigated the effect of kinematic training in civilian patients with neck pain in two trials, first providing supervised training, and second promoting self/home-training.[25,27] Good compliance and significant improvements were demonstrated in the Neck Disability Index (NDI) and velocity with notable effect sizes in kinematic training groups compared to control.[25,27] Of the subjects, 74–84% perceived improvement or were satisfied with the exercise intervention. Significant advantages to the virtual reality (VR) training group were found in velocity, pain intensity, health status, and accuracy at two time points.[25,27] The results demonstrated the advantages for the VR training group, which supported the use of home VR kinematic training for improving disability, neck pain, and kinematics in the short and intermediate term, and therefore directed this study's objectives and methodology. The objective of this RCT was to evaluate the effectiveness of self- kinematic exercises using VR on neck pain, disability, and cervical kinematics in combat pilots.

METHODS

This study was designed as an RCT with concealed allocation and blinded assessments. The study was set up at Israeli Air Force bases. Recruitment was initiated via the Israeli Air Force Aeromedical Unit (IAMU) and via the squadron commanders. In addition, the units' physiotherapists provided relevant information regarding the study to their pilot patients. Data collection was conducted between August 2016 and August 2017. All subjects provided informed consent before enrollment to the study. The ethics approvals were obtained from the Helsinki Committee of the Israel Defense Force (no. 1519) and from the institutional review board at the University of Haifa (no. 062/16). This trial was registered at the NIH clinical trial registry ClinicalTrials.gov (ID: NCT02979041).

Study Population

We included in the study fighter and helicopter pilots from the Israeli Air Force with acute, subacute, or chronic neck pain; with or without referral to the upper limbs; and with an average neck pain intensity (during the past week) of at least 20% [on a Visual Analog Scale (VAS)/100 mm]. Participants were excluded if they reported suffering from neurological disorders, systemic disease, history of spinal surgery, or any disorders that may have limited the ability to complete the study's procedure.

Volunteering for this study were 58 aircrew members, of which 45 were found eligible. These 45 were comprised of 25 fighter jet pilots, 16 fighter jet navigators, and 4 fighter helicopter pilots. There were 41 young men and 4 female pilots in the study, reflecting the gender distribution in this unique population (**Table I**).

A randomization scheme was generated using Randomization.com software (http://www.randomization.com). The randomization procedure was operated by the Air Force investigator, who was blinded to baseline assessments.

Experimental Equipment

An interactive VR system was used to evaluate and train cervical motion control. This system used hardware and software to provide simple, yet engaging games monitored via motion tracking. The system included a head-mounted display (HMD) (Oculus Rift, DK1, http://www.oculusvr.com) with a built-in 3D tracker. The Oculus Rift DK2 integrates numerous sensors, including gyroscopes, accelerometers, and magnetometers, calculating momentum and rotation tracking. To assess neck motion kinematics, we used angular displacement data: in yaw for cervical left and right rotation, and in pitch for flexion and extension.[8]

The individualized VR training software programs were installed on personal laptops for independent use by the subjects. Every activation of the training setup generated an automated data output that included motion tracking data by time. The time record was used for monitoring exercising time, which reflected compliance.

During the interactive VR sessions, the subject's head was visualized as an animated image of a pilot flying a small airplane, as shown in **Fig. 1**. The subject's head movements controlled interactions within the virtual environment and the various tasks stimulated different therapeutic aims. The VR software included three modules aimed at stimulating: 1) increased ROM, 2) faster motion with a quick response, and 3) increased neck motion accuracy.

Table I. Methods for Prescription of Kinematic Training Program by Impaired Parameter.

STAGE A. CUTOFFS TO DEFINE KINEMATIC IMPAIRMENTS BASED ON NORMATIVE DATA FOR ROM[23] AND FOR VELOCITY AND ACCURACY[24]

MEASURE DIRECTION	ROM	PEAK VELOCITY	MEAN VELOCITY	ACCURACY
Flexion	56	167	50	Y: 45
Extension	71	149	55	Y: 34
Right rotation	76	220	67	X: 36
Left rotation	78	262	74	X: 43
Condition for fail	Smaller than	Smaller than	Smaller than	Larger than
Additional conditions	1 or more to fail	2 or more to fail		1 or more to fail
		If there is a fail in 1 direction, exercise all directions		

STAGE B. THE ALGORITHM FOR PRESCRIPTION OF KINEMATIC TRAINING PROGRAM BY IMPAIRED PARAMETER

IMPAIRED ELEMENT	1	2	3	4	5	6
None/All	Accuracy	Velocity	ROM	Velocity	Accuracy	Velocity
ROM	ROM	Velocity	ROM	Accuracy	Velocity	Velocity
Velocity	Accuracy	Velocity	Velocity	Accuracy	Velocity	Velocity
Accuracy	Accuracy	Velocity	Accuracy	Velocity	Accuracy	Velocity
Velocity & ROM	ROM	Velocity	ROM	Accuracy	Velocity	Velocity
Velocity & Accuracy	Accuracy	Velocity	Accuracy	Velocity	Accuracy	Velocity
Accuracy & ROM	Accuracy	Velocity	ROM	Accuracy	ROM	Accuracy

ROM: range of motion.

Self-Reported Outcome Measures

1. Disability due to neck pain was measured by the NDI (%) and was the primary self-reported outcome measure.[38] NDI is a 10-item self-rated instrument assessing disability associated with neck pain. Each item is scored on a 0 to 5 rating scale and a higher score indicates greater disability. The NDI has proven to be a valid and reliable measure,[21] with a minimal clinically important change (MCIC) of 7% being suggested.[22]
2. The average pain intensity level during the past week was evaluated using the VAS (100 mm). VAS is a 100-mm line representing pain intensity, and has been established as a valid and sensitive pain intensity instrument which is commonly cited in neck pain studies. Researchers reported an MCIC of between 18 mm to 27 mm.[22,34]
3. Health status was assessed using the quality of life tool EQ5D-VAS (EQ-5D™, www.euroqol.org). Patients self-rated their health status out of 100, with a 100 representing the best possible health state and 0 the worst possible health state.[3] An MCIC of 10 points has been suggested for chronic low back pain.[32]

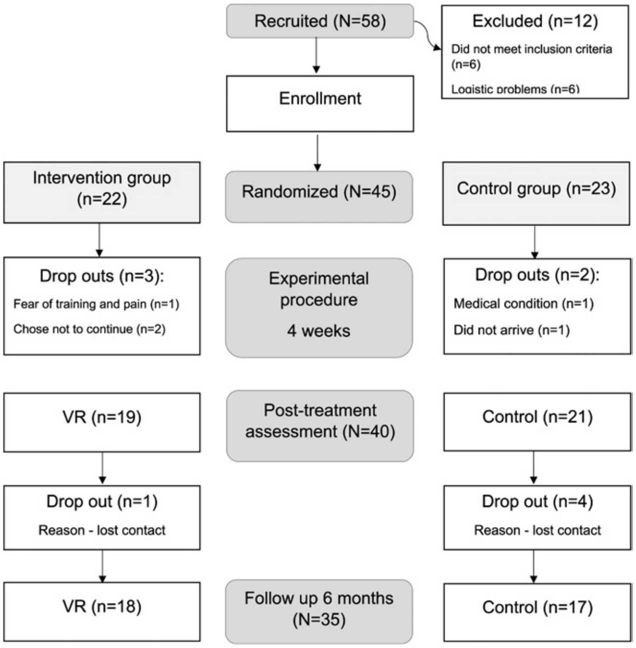

Fig. 1. Flow chart of recruitment process and drop-outs throughout the experimental period.

Performance Outcome Measures

Cervical kinematic measures were analyzed from data collected by the tracker for each of the four main directions: flexion, extension, and right and left rotation. Kinematic measures such as velocity and smoothness are reliable and valid diagnostic measures in patients with neck pain. The following kinematic variables were analyzed: peak and mean velocity, motion smoothness, and accuracy.

1. Mean Velocity was the primary performance measure, in addition to peak velocity (secondary measure) of cervical motion (V_{mean}, V_{peak}, respectively). V_{mean} was calculated as the mean of three maximal peak angular velocity results achieved from each direction. It has previously demonstrated repeatability and minimal detectable change (MDC) for a mean velocity of $14.31° \cdot s^{-1}$.[24]
2. Cervical ROM was measured in four directions: flexion, extension, and right and left rotation. Prior studies noted ROM performance was maximized in VR assessment vs. conservative methodology, and VR ROM assessment was reliable, both for inter- and intratester reliability.[23,28]
3. Time to Peak Velocity Percentage (TTP %) was the time from motion initiation to peak velocity moment as a percentage of total movement time, representing the ratio between the acceleration to deceleration phase in the velocity profile (MDC 7.31%).[24]

4. Accuracy Error (°) was measured during the smooth head pursuit task in the accuracy module and assessed the difference between the target's and the player's position in degrees. The accuracy error was measured in the plane of motion, with the X axis for rotation and the Y axis for flexion-extension. These measures of accuracy were shown to be significantly sensitive and specific.[24] MDC for these measures has not been previously investigated.
5. Cervical Isometric Strength was measured in the cervical flexion and extension directions using a dynamometer (HF-1000N Digital Force Gauge Meter, by Zhengzhou Nanbei Instrument Equipment Co. Ltd, Zhengzhou, China) fixed to a static object and connected to the head of the subject with a strap system designated for this purpose. Patients with chronic neck pain showed strength deficits compared to healthy controls.[29,30] Isometric strength testing reliability has been reported as substantial to almost perfect ($r = 0.76–0.89$) in patients with neck pain. The MDC was 8.7 for the flexors and 12.5 KgF for the neck extensors.[30]

Procedure

Following randomization, both groups (control and intervention) continued physical therapy, if receiving any, and this was the control intervention. In addition, the intervention group subjects received equipment and guidance for a self-management exercise program using a customized neck VR system.

The interactive VR exercise program was designed to train fast and accurate head control using three VR modules: ROM, Velocity, and Accuracy. We identified which of the three modules was impaired by the cutoffs presented in Table I, stage A. These cutoffs were based on previous normative data for ROM[23] and for velocity and accuracy.[24]

Once we mapped the impaired modules to be trained, we prescribed an individual program by the system presented in Table I (Stage B), aiming to train the impaired aspects more than others, but also to avoid side effects of prolonged VR use such as motion sickness. Each training program included six episodes of training in one session following the system presented in Table I, Stage B.

The VR training dosage was four times a week, 20 min/wk, 5 min per session. A 1-min break was set in between VR training modules to avoid simulator sickness. Subjects were instructed to perform one free exercise in each interval, for 1–2 min, out of four exercises taught and practiced in the initial session with the treating physiotherapist. This VR dosage was based on findings from previous clinical trials[25,27] in civilian populations with neck pain, and intended to minimize time consumed from the pilots' schedule to promote compliance.

Tailoring and instructing individual exercise programs was conducted by a qualified, experienced physiotherapist, who followed up with intervention group subjects weekly through text messaging and phone calls. VR training was based on the program for the general population, which has shown a positive effect on pain, disability, and kinematics.[25,27]

Training data records were retrieved from the subject's computer upon its return at the end of the intervention program. Recorded data was analyzed for performance and compliance measures. All subjects were assessed at baseline, at the completion of the intervention period after 4 wk, and self-reported measures were re-evaluated at 6 mo postintervention.

Statistical Analysis

The statistical analysis was performed by a blinded statistician and data were analyzed on an intention-to-treat basis. To account for the dropouts, the SAS's MI procedure for multiple imputations of missing data was used with the regression method to impute missing values.

In a preliminary analysis we searched for potential covariates that could affect the results of the association between group and intervention effect. We conducted univariate analysis on all baseline parameters (Table I) and found there was no significant association ($P > 0.05$) between baseline parameters and group, i.e., there were no covariates to adjust for. We conducted an additional univariate analysis to examine the association between groups (intervention vs. control group) for therapeutic effect measured by post-minus preintervention change and 6 mo post-minus preintervention change.

Group comparisons for continuous variables, which exhibited normal distribution, were performed by using a two-sample Student *t*-test and were reported by mean and standard deviation, and variables exhibiting abnormal distribution were compared by using the two-sample Wilcoxon test and reported by median and interquartile range. The Pearson Chi-squared test was used for group comparisons of categorical variables. The association between training duration and the change in main outcome measures (post/pre-intervention) in the intervention group was evaluated by Spearman correlation coefficient. A *P*-value of 0.05 was considered significant, and statistical analysis was performed by SAS for Windows, version 9.4.

RESULTS

Volunteering for this study were 58 aircrew members, of which 45 were found eligible. These included mostly fighter jet pilots and navigators, and four fighter helicopter pilots, all of whom reported suffering from neck pain. The majority of the subjects were young men with healthy BMI, and there were four female pilots in the study, reflecting the gender distribution in this unique population (**Table II**).

The overall reported neck pain intensity and associated disability were mild, but of extended duration. There were 40% who reported unilateral symptoms and 60% bilateral symptoms as accepted in prolonged neck pain. Only 18% reported neurogenic symptoms such as pins and needles, altered sensation, or referred pain below the elbow level.

Subjects reported approximately 2 weekly hours of physical activity (Table II) and only a third of the subjects reported receiving treatment such as physiotherapy for their neck pain at

Table II. Baseline Results in the Training and Control Groups, with *P*-Value for Group Difference, by Types: Demographic, Self-Reported, and Performance.

DEMOGRAPHIC CHARACTERISTICS	**TRAINING ($N = 22$)**	**CONTROL ($N = 23$)**	***P*-VALUE**
Age, Mean (SD)	30 (5.8)	28 (5.1)	0.25
Gender, M, *N* (%)	21 (95%)	20 (87%)	0.32
BMI, Mean (SD)	24 (1.8)	23.2 (2.4)	0.22
Symptoms' duration, median (Q1, Q3)	36 (5.0, 84.0)	12 (6.0, 48.0)	0.30
Pain distribution, *N* (%)			0.87
Unilateral	9 (43%)	9 (39%)	
Bilateral	12 (57%)	14 (61%)	
Neurogenic symptoms, *N* (%)	4 (18%)	4 (18%)	1.00
Physical activity (Hours per week), median (Q1, Q3)	2.3 (1.0, 4.0)	2 (1.0, 3.0)	0.80
Profession, *N* (%)			0.05
Combat fighter pilot	15 (68%)	9 (39%)	
Combat fighter navigator	7 (32%)	10 (43%)	
Combat helicopter pilot	0 (0%)	4 (17%)	
Service type, *N* (%)			0.67
Full time service	12 (55%)	14 (61%)	
Reserves service	10 (45%)	9 (39%)	
Monthly sorties No.	10 (9.0, 16.0)	10 (8.0, 18.0)	0.85
SELF-REPORTED MEASURES	**TRAINING ($N = 22$)**	**CONTROL ($N = 23$)**	***P*-VALUE**
VAS Pain (/100 mm), Mean (SD)	36.4 (22.8)	49.5 (21.1)	0.05
NDI %, Mean (SD)	17.6 (8.9)	17.9 (10.4)	0.91
EQ5D-VAS (/100), Mean (SD)	83.9 (10.2)	79.9 (15.9)	0.32
PERFORMANCE BASELINE MEASURES	**TRAINING ($N = 22$)**	**CONTROL ($N = 23$)**	***P*-VALUE**
ROM Flexion, median (Q1, Q3)	65.2 (65.1, 65.6)	65.2 (63.6, 65.9)	0.91
ROM Extension, median (Q1, Q3)	73.5 (70.9, 76.3)	73.3 (72.6, 75.2)	0.73
ROM Right Rotation, median (Q1, Q3)	81.5 (80.2, 83.1)	80.9 (80.1, 81.8)	0.33
ROM Left Rotation, median (Q1, Q3)	80.1 (78.1, 81.7)	80.7 (80.2, 81.3)	0.29
Isometric strength Flexors (N), Mean (SD)	137.0 (32.2)	128.5 (43.6)	0.46
Isometric strength Extensors (N), Mean (SD)	190.1 (51.3)	157.6 (50.9)	0.04*
Global Peak Velocity ($^\circ \cdot s^{-1}$), Mean (SD)	203.0 (67.4)	230.4 (69.2)	0.18
Global Mean Velocity ($^\circ \cdot s^{-1}$), Mean (SD)	125.4 (40.6)	145.0 (40.0)	0.11
Global TTP %, Mean (SD)	47.6 (14.7)	51.5 (13.1)	0.36
Global accuracy (°), median (Q1, Q3)	62.5 (60.1, 67.3)	66.2 (56.0, 75.6)	0.55

BMI: body mass index; EQ-VAS: European questionnaire health status VAS; ROM: range of motion; TTP: time to peak velocity (%); Q1: 1st quartile; Q3: third quartile; *$P < 0.05$.

the time of recruitment. An acceptable dropout rate of 11% was recorded during the intervention period and an additional 12% dropped out at the 6-mo follow-up.

Overall, the study subjects reported mild levels of pain intensity and associated disability (NDI). They reported a health status range of 80–84%, mainly due to neck pain as prestudy screening determined all subjects to be fit, healthy individuals.

There were no group differences in the performance baseline measures, excluding isometric neck extensors strength. Intervention group subjects presented with higher isometric extensor strength than the controls ($P < 0.05$). In addition, extensor strength in both groups was higher than flexors. Velocity, TTP, and accuracy results reflect overall good kinematic neck control at baseline by both groups compared to previous data in patients with neck pain.[25]

The VR training included three modules intended to train ROM, velocity, and accuracy. Subjects in the intervention group received computerized equipment and the program to use for their training, and the VR training was recorded on the computer. The instructed training regime was 20 min/wk, but on average, the majority of subjects did less than 10 min per week. Regarding the frequency of training over the 4-wk duration: four subjects trained only 2–12 min, six trained 26–37 min, five trained 47–74 min, and only four subjects followed the instructions and trained 92–147 min. Examination of the exercising data indicated that nearly half of subjects in the intervention group did not complete 1 d of exercise or only completed the exercises once weekly.

Table III presents the results in the intervention and control group at the three time points: baseline, postintervention, and 6-mo follow-up. Group difference was analyzed for the change scores post-minus preintervention and 6 mo post-minus preintervention (follow-up included only self-reported measures). Endpoints in Table III reported with an asterisk indicate significant differences. Significant group differences were found in three kinematic parameters: peak velocity, mean velocity, and TTP%, with the intervention group benefitting from the improvements. No differences were found between groups in the pre/post change in ROM, isometric strength, pain intensity, or disability. The trained individuals experienced increased neck motion velocity and reached peak velocity later in their velocity profile: VR subjects' TTP increased from 47.6 to 60.5% (12.9% increase) and controls' TTP increased from 51.5 to 56.3% (4.8% increase).

Spearman correlation assessed the relationship between total exercise time (min) and the outcome measures in the intervention group ($N = 22$). These results showed a single significant correlation between exercising duration and NDI

Table III. Results of Self-Reported Outcome Measures by Groups at the Three Time Points: Pre-, Postintervention (1 mo), and 6-mo Follow-Up, and of Performance Outcome Measures at Two Time Points: Pre- and Postintervention.

	PRE				**POST**				**6-mo FOLLOW-UP**			
	VR ($N = 22$)		**CONTROL ($N = 23$)**		**VR ($N = 19$)**		**CONTROL ($N = 21$)**		**VR ($N = 18$)**		**CONTROL ($N = 17$)**	
	MEDIAN	**(Q1, Q3)**	**MEDIAN**	**(Q1, Q3)**	**MEDIAN**	**(Q1, Q3)**	**MEDIAN**	**(Q1, Q3)**	**MEDIAN**	**(Q1, Q3)**	**MEDIAN**	**(Q1, Q3)**
NDI %	15	(12,22)	16	(10,20)	10	(6,26)	16	(8,20)	9	(6,18)	18	(6,26)
EQ5D-VAS	90	(75,90)	85	(75,90)	90	(75,90)	85	(80,90)	90	(70,92)	87.5	(50, 95)
	MEAN	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**
VAS Pain %	36.4	22.9	49.5	21.1	25.7	24.0	26.9	22.3	23	22.2	24.5	22.3

	PRE				**POST**			
PARAMETER	**TRAINING ($N = 22$)**		**CONTROL ($N = 23$)**		**TRAINING ($N = 19$)**		**CONTROL ($N = 21$)**	
	MEAN	**SD**	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SD**
Isometric strength Flx. (N)	137	32.2	128.5	43.7	152.5	41.9	140.9	38.8
Isometric strength Ext. (N)	190.1	51.3	157.6	50.9	209.6	68.5	177.6	59.1
Global Peak Velocity (° · s^{-1})	203.0	67.4	230.4	69.2	262.4*	94.9	242.4	60.5
Global Mean Velocity (°· s^{-1})	125.4	40.6	145.0	40	168.7*	55.1	153.2	34.6
global TTP%	47.6	14.7	51.5	13.1	60.5*	11.6	56.3	12.5
Global accuracy (°), Median (Q1, Q3)	62.5	(60.1, 67.4)	66.2	(56.0, 75.6)	51.2	(47.5, 56.7)	59.2	(54.8, 64.4)
global NVP	4.4	1.1	4.1	0.8	4.0	1.0	3.7	0.7

Q1: first quartile; Q3: third quartile; NDI: Neck Disability Index; VAS: Visual Analog Scale; EQ-VAS: European questionnaire health status VAS; Flx: flexors; Ext: extensors; TTP: time to peak velocity; NVP: number of velocity peaks, representing motion smoothness.

*$P \leq 0.05$, indicating a significant group difference in favor of the intervention group.

(r = 0.61), indicating that those who invested more time in exercising experienced significant improvement in their NDI (**Table IV**). Surprisingly, training duration was not correlated with the performance measures that were targeted in the training program, although it was found that kinematics improved significantly more in the intervention group compared to the control group.

DISCUSSION

This RCT investigated the effect of self-kinematic training using VR on neck pain, related disability, neck motion kinematics, and isometric neck strength. Findings showed a positive effect on kinematic performance in the training group as compared to the controls, and a positive relationship between exercising time and improvement in neck associated disability. This kinematic improvement in the intervention group was expected as this was the focus of the training program. However, results showed no change in self-reported measures such as pain intensity and disability.

There may be a few explanations for the lack of effectiveness of the investigated intervention in changing pain and disability. Unfortunately, only 41% of participants exercised at least once a week. On one hand, even this partial compliance had a positive impact on the dynamic parameters of kinematics. On the other hand, the low compliance probably contributed a great deal to the lack of change in self-reported measures. Some indication for this explanation relies on the correlation results showing the ones who invested more time in exercising experienced higher improvement in their NDI. Compliancy issues with independent self-exercise programs have been previously detected as problematic in pilots with neck pain.[18] Murray et al.[18] conducted a similar RCT in military pilots, which included a self-administered training program group. Subjects were instructed to perform neck- specific exercises aimed at strength, endurance, and coordination three times a week for 20 min each time during working hours. Similarly to our study, there was no supervision or designated time for training, and only 28.57% ($N = 35$) of the subjects complied and reported training regularly (1–3 times/week).

Other researchers did not rely on self-training alone; for example, Lange et al.[13] combined self-training with supervised sessions every 4 wk and reported better compliance—58% of subjects trained regularly (1–3 times/wk). Similarly, Ang et al.[2] investigated supervised exercises and reported a 77% compliance with a daily regimen performed during working hours. Therefore, our conclusion for future studies in combat pilots is that training plans should include built-in schedules and supervised programs to ensure compliance.

The lack of significant change in clinical measures could also have been affected by flight timing that was not controlled, as neck pain onset was strongly associated with flight timing. In addition, baseline results showed that pilots with FANP reported a mild to moderate level of neck pain and mild disability, which was in line with previous studies conducted in this population.[2,13,18] The majority of the pilots continued flying regularly and did not report a significant decline in their health status due to their neck pain. It is assumed, based solely on subjective concern of the investigating clinicians, that the self-reported measures were possibly under-reported, i.e., that some pilots reported lower levels of pain and disability than the real ones they experienced due to subjects' caution of a potential effect on flying status or qualification. This could have potentially created a flooring effect in these results.

Objectively, physical baseline measurements demonstrated acceptable kinematic performance for neck motion, showing good ability to perform fast and accurate neck movements

Table IV. Spearman Correlation Results Between Total Exercise Time (min) During the 4 wk and the Post-Minus Preintervention Difference in Outcome Measures.

MEASURE POST-PRE INTERVENTION	VAS PAIN	NDI	EQ5D-VAS
r	0.22	0.61	−0.02
P-value	0.43	0.02*	0.94
	GLOBAL MEAN VELOCITY	**GLOBAL ACCURACY**	**GLOBAL TTP%**
r	−0.32	0.21	−0.12
P-value	0.24	0.45	0.68

This correlation analysis was conducted only in the intervention group ($N = 22$).

NDI: Neck Disability Index; VAS: Visual Analog Scale; EQ5D: European Quality of Life Questionnaire, health status VAS; r: Spearman's correlation coefficient; TTP%: time to peak velocity. *$P \leq 0.05$.

through a large range of motion in spite of the reported FANP. The presented pilots' performance seems overall better than our findings in individuals with neck pain in the general population and is comparable with asymptomatic data from a young, healthy population group.[24,26] This was a limitation of our study design that should be addressed in future research by defining a kinematic impairment inclusion criteria.

Isometric strength was not trained and was not affected by kinematic training. The strong evidence from interventional research established a consensus that strengthening should be an integral part of treatment in neck pain.[10] However, further research is needed to examine this in pilots and to understand whether strengthening can also improve kinematics, or maybe kinematic training combined with strengthening can lead to a stronger therapeutic effect.

Another important factor that distinguished our findings from others was the outcome measure for change in neck pain. Similarly to Murray et al.,[18] we measured pain intensity and associated disability at the time of assessment.[4,20] Others preferred following neck pain frequency over a 3- to 6-mo period.[2,13] Pain frequency may be more relevant than pain intensity as the episodes of flight-related neck pain are often acute following flight and recover after a few days, until the following sortie. Our future recommendation is to include all flying pilots and follow them prospectively for neck pain frequency, rather than including only those reporting pain, which limits the inclusion criteria and biases the change with spontaneous recovery that often occurs in between flights.

A few limitations have been identified in this study. The poor compliance in self-exercising was a major factor that limited our ability to draw conclusions on the efficacy of the investigated intervention. Unfortunately, only 41% of subjects exercised at least once a week. Participants explained they were very busy and did not find the time to practice. Lack of compliance in independent self-exercise programs has been previously identified to be a problem in pilots with neck pain.[18]

This training protocol, which was adapted from the general population, may not be challenging enough for this high-end population whose initial ability was very good; we did not define kinematic impairment as an inclusion criterion. This may explain why some participants demonstrated a ceiling effect as kinematic ability was too good to be improved with the prescribed training. Further investigation is needed with an inclusion criterion that relates to the impairment aimed at in the intervention. A more challenging and supervised protocol addressing strengthening and kinematic training within working time should be considered.

A lack of RCT publications in this field can only be addressed by the international research community sharing their knowledge to advance therapeutic solutions as a joint effort. Lastly, more development is needed to address the contributing ergonomic and biomechanical contributing factors to FANP.

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Authors and affiliations: Hilla Sarig Bahat, PT, Ph.D., Dmitry German, BPT, M.Sc., Galia Palomo, BPT, M.Sc. candidate, and Hila Gold, BPT, M.Sc. candidate, Department of Physical Therapy, Faculty of Social Welfare & Health Sciences, University of Haifa, Mount Carmel, Haifa, Israel; and Yael Frankel Nir, M.D., Aerospace Medicine Unit, Israel Defence Force, Tel Hashomer, Israel.

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