THE EFFECT OF KINESIOTHERAPY ON CERVICAL MUSCULOSKELETAL SYMPTOMS OF FIGHTER PILOTS

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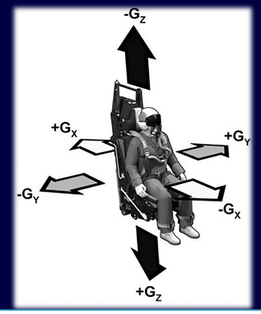
Introduction: During flying, fighter pilots are exposed to extreme working conditions (high G-forces in a combination of rotation, lateral flexion, and extension of the neck), which increase the risk of musculoskeletal injuries and disorders. 83% of fighter pilots experience chronic neck pain, while in the general population, the percentage is 37% (1-10). The flight-induced cervical musculoskeletal symptoms (F-ICMSs) are related to lack of concentration and readiness during the flight, reduced motor control, inability to perform manoeuvres and landings, reduced flight hours, increased use of medical services, and early retirement (1- 10).

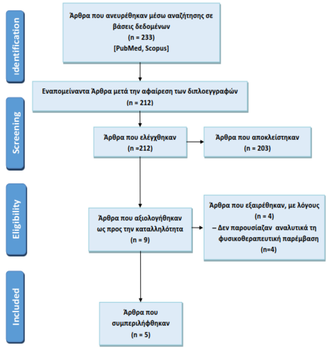
Purpose: The review of the existing literature for studies in which physiotherapy exercise programs (PTP) were used to treat F-ICMSs.

Material & Method: The literature review was performed on Pubmed and Scopus databases, using appropriate keywords: Fighter pilots, flight-induced cervical disorders, neck pain, musculoskeletal disorders, and exercise training. The selection criteria were: RCTs or clinical studies to be written in English language and to describe in detail the physiotherapy intervention. Reviews and meta-analyses were excluded.



Gravitational (Gx, Gy, and Gz) axes with respect to aircraft pilot.

Figure1



Result: 233 articles were initially identified; 20 were evaluated for eligibility, and finally, 10 of them were included in the present study (Figure 1). The implemented PTPs were lasted from 6 weeks(3,4) to 12 months(2) and included various interventions: active exercises with the use of helmets with additional weight(1,2), resistance bands(4-9), hand weights(1,5,9), medical balls(9), trampoline exercises(3), and mechanical passive neck traction device(10). The outcomes showed that PTPs aimed at reducing pain(2,4-7,10), improving neck muscles' strength(1,3,4,8,9), volume(8), and endurance(1,9), increasing the range of motion(10) and the functionality(2,4,5) of the fighter pilots.

Conclusions: All PTPs were found to be effective in reducing F-ICMSs. However, further research is needed to fully clarify the pathomechanism and the optimal way to strengthen the muscle groups involved and design new exercise programs for fighter pilots.

Table 1_ Characteristics of studies included in the systematic review

Authors (Year)	Groups & Number Of Participants	Type of Physiotherapy Intervention	Duration and Frequency of Intervention	Results of Assessment Tools
Hamalainen et al (1998)	Total number of participants (Fighter pilots) N=20 Training group 1: N=10 Training group 2: N=10	Training group 1 (dynamic neck and shoulder muscle training group): Warm-ups, stretches and active resistance exercises that targeted cervical and shoulder girdle muscles with 4, 6 and 8 kg dumbbells. Training group 2 (helmet training with additional weights group): Helmet training with additional weight that was equivalent to 10 and 20% of the maximum isometric contraction of the cervical spine's extensors, utilizing the full range of motion of the neck.	Total duration: 12 months 1st quarter: 3 times/week 2nd quarter: 1 time/week 3rd quarter: 3 times/week 4th quarter: 1 time/week (Exercises were performed at home the 3rd and 4th quarter) 30 minutes/intervention	Training group 1: (before intervention) 9/10 pilots lost flight hours, (after intervention) 4/10 pilots lost flight hours * Training group 2: (before intervention) 8/10 pilots lost flight hours, (after intervention) 7/10 pilots lost flight hours *
Alricsson et al (2004)	Total number of participants (Fighter pilots) N=40 Training group 1: N=20 Training group 2: N=20	Training group 1 (reinforced group): Neck muscle stretches with supervision,. Flexion–extension of the neck with weights (1.2 and 4 kg), which were fitted either directly on the head or on a training helmet. Weights were used in combination to provide extra resistance. Training group 2 (non reinforced group): Carrying out the same exercise program as training group 1, with the only difference being that there was no supervision.	Total duration: 8 months 3 times/week 4 sets/exercise 10 repetitions /set	Training group 1: INSMS [Change in strength before and after the intervention (Nm)]: Flexion (+3.9Nm)*, Extension (+5Nm)* Borg CR-10 Scale [Change in endurance before and after the intervention (s)]: Extension (+53s) Training group 2: INSMS [Change in strength before and after the intervention (Nm)]: Extension (-11.5Nm)* Borg CR-10 Scale [Change in endurance before and after the intervention (s)]: Extension (-33s)
Sovelius et al (2006)	Total number of participants (Fighter pilots) N=16 Training group 1: N=8 Training group 2: N=8	Training group 1 (strength training group): Active neck flexion and extension exercises and isometric rotational exercises. Resistance to approximately 15-30% of maximal isometric contraction in the neutral position. Repetitions and resistance were gradually increased after each successful week of exercise. In addition, to avoid intense strain on the cervical spine, low-intensity exercises were chosen aimed at increasing muscle endurance. Training group 2 (trampoline training group): Trampoline training program (diameter 4.3 m). The program included upper limb, knee and back exercises. Exercises were performed until subjectively assessed fatigue, normally 30 – 60´´/set and there were similar recovery times, 30 – 60´´ between sets.	Total duration: 6 weeks 2-3 times/week (of increasing difficulty) 2-4 sets/exercise 20-40 repetitions/set	Training group 1: INSMS [Change before and after the intervention (%)]: Flexion (+2.3%)* , Extension (+6.0%)*, %MVC of sternocleidomastoid muscles (-50.3%)*, %MVC of cervical trunk extensor, during CLT: -15.7%* Training group 2: INSMS [Change before and after the intervention (%)]: Flexion (+3.2%)* , Extension (+6.4%)*, %MVC of sternocleidomastoid muscles (-40.8%)*, %MVC of cervical trunk extensor, during CLT (-22%)*
A'ng et al (2009)	Total number of participants (Military helicopters pilots) N=68 Training group: N=34 Control group: N=34	Training group (supervised neck/shoulder exercise regimen group): Bed exercises: Low-load active flexion of the craniocervical spine at 5 pressure levels, avoiding the activation of superficial neck flexors. Prone position: Isometric scapular adduction. Sitting position: Low-load active flexion of the craniocervical spine at 5 pressure levels, avoiding the activation of superficial neck flexors. Full-range head rotation with simultaneous scapular contraction, with mid-position hold and active craniocervical flexion. Endurance-strength exercises: Active scapular contractions with load, through pull-ups aimed at the initial concentric phase and vertical trunk positions. Active exercises, with moderate resistance, turning the neck, in a vertical position, through elastic straps. These exercises started with a small craniocervical flexion, then a small neck extension, followed by neck rotation. Control group: Regular physical activity.	Total duration: 6 weeks 2 times/day or 1 time/day, if there was no pain in the last 3 months Active craniocervical flexion: 10 repetitions/set, 10´´/repetition Scap retraction: 10 repetitions/set, 10´´/repetition Head turn: 3 sets, 20-30 repetitions/set Scap contraction through traction: 3 sets, 15 repetitions/set 10-15 minutes/intervention	Training group: mFABQ (before intervention) 6.0/24 (after intervention) 1/24, (follow up) 1.5/24 * EMG (nRMS30) sternocleidomastoid activity: (before intervention) 40%RVE, (after intervention) 20%RVE * NMQ (%percentage of people referring pain) (before intervention): 38% (13/34 pilots), (follow up): 15% (5/34 pilots) * Control group: mFABQ (before intervention) 6.5/24 (after intervention) 3.5/24 * EMG nRMS30 sternocleidomastoid activity (before intervention) 40%RVE, (after intervention) 30%RVE * NMQ (%percentage of people referring pain) (before intervention): 32% (11/34 pilots), (follow up): 32% (11/34 pilots) **
Lange et al (2013)	Total number of participants (Fighter pilots F-16) N=55 Training group: N=27 Control group: N=28	Training group: Warm-up exercises: 3 exercises activating the deep cervical flexors. Slow and controlled flexion-extension of the neck in the upright anatomical position. Movement of the head in a cephalic and caudal direction while in supine position (at first the head was supported). In upright position, both hands were placed on the side of the head for resistance while the neck was rotating, so as the flexors and extensors co-contract. Strengthening exercises: While seated, static pull in 8 directions (central, dorsal, right, left, diagonally 45o) with resistance that came from an elastic strap. In upright position, shoulder elevation (shrugs) while holding dumbbells. In seated position, the participants leaned the upper body 45o forward with a straight bag, the arms pointing toward the floor with a dumbbell in their hands. The dumbbells were raised until the arms were horizontal. Endurance exercises: Standing on both feet, participants were holding the bodyblade with both hands and with shoulders 90% flexed and elbows 5% flexed. Small shoulder extensions and flexions were performed to make the bodyblade oscillate. Resistance ranged at 70 – 85% of 1 RM. Control group: Encouragement for regular physical activity.	Total duration: 24 weeks 3 times /week 20 minutes/intervention Flexion – extension of the neck: 15 repetitions Anterior and posterior movement of the head: 15 repetitions Head rotation: 5 repetitions/side	Training group: NRS (pain levels) (before intervention) 1/10, (after intervention) 0.3/10* NMQ (% percentage of people referring pain) (before intervention): 30% (8/27 pilots), (follow up): 7% (2/27 pilots)* Control group: NRS (pain levels) (before intervention) 1.2/10, (after intervention) 1/10 ** NMQ (% percentage of people referring pain) (before intervention): 25% (7/28 pilots), (follow up): 18% (5/28 pilots) **
Salmon et al (2013)	Total number of participants (Military helicopter pilots) N=29 Endurance training group: N=11 Coordination training group: N= 10 Control group: N=8	Training group 1 (Endurance training group): Participants used elastic rubber tubing to resist the dynamic movements of cervical flexion, extension, right neck flexion and left neck flexion. Resistance was approximately 30% of 1 RM. Resistance was determined and increased by 5% (1.3 Kg - 1.8 Kg -2.2Kg), if a participant successfully performed 12 consecutive repetitions of an exercise. Training group 2 (Coordination training group): Low-load exercises focused on muscle control through three stages were used to train and re-establish coordination between the deep and superficial layers of the neck musculature. Stage 1: Isolation of the deep segmental stabilizers of the cervical spine using isometric contractions to maintain a neutral cervical spine while supine, standing and sitting. Stage 2: Maintenance of a neutral cervical spine while integrating limb motion into the exercises. Stage 3: Strengthening of the superficial muscles on the neck through resisted flexion, extension and right neck flexion and left neck flexion using controlled segmental movement patterns which incorporated the deep cervical muscle through the maintenance of proper posture and a slight chin nod. Resistance was applied using the same mode employed as the one used in training group 1. Control group: No intervention.	Total duration: 12 weeks 3 times/week 3 sets 10 repetitions/set 1´ break/set	Endurance training group: EMG [Change before and after the intervention in MVC (N)]: Right neck flexion (+23.4 N)* Change in time achieving 70% muscle fatigue (s): Flexion(+3.27s)**, Left neck flexion (+12.98s)**, Right neck flexion (+5s)** Coordination training group: EMG [Change before and after the intervention in MVC (N)]: Right neck flexion (+26.96 N)*, Flexion (+21.44 N)* Change in time achieving 70% muscle fatigue (s): Flexion (+26.34s)*, Left neck flexion (+23.54 s)*, Right neck flexion (+28.72s)* Control group: EMG [Change before and after the intervention in MVC (N)]: Right neck flexion (+0.09 N),** Flexion (+6.18 N)** Change in time achieving 70% muscle fatigue (s): Flexion (+0.68s)**, Left neck flexion (-27.44 s),* Right neck flexion (-15.96 s) **
Mike Murray et al (a) 2015 and (b) 2017	Total number of participants (Pilots and crew of military helicopters) N=69 Training group: N=35 Reference group: N=34	Training group: Warm-up exercises: Participants were instructed, while in supine position, to perform an upper cervical spine extension, moving the head backwards in a cephalic direction. When fully extended, the head was returned performing an upper cervical spine flexion in a caudal direction. Main focus was the superficial muscles to be relaxed and not to contract. The other exercise was performed seated with the head held in an anatomical neutral position and one hand placed on the side of the head. The exercise was to rotate the head against a gentle pressure created by the hand. The exercise was done for both the right and left side. Training exercises: Resistance came from a head harness using different color-coded elastic resistance bands (Thera-Band®). Cervical flexion: Seated position, straight back, head in an anatomically neutral position, arms held straight with hands placed underneath the knees and the trunk leaned forward 20o – 30o, participants performed lower cervical spine flexion followed by lower cervical spine extension. Cervical extension: (participant's position -> same as cervical flexion). Exercise was performed with lower cervical spine flexion followed by lower cervical spine extension against resistance. Lateral flexion: Standing erect, with the head in an anatomically neutral position, one hand was placed horizontally against a wall and a Thera-Band was stretched between the hand and side of the head harness. Exercise was performed with a low lateral spine flexion followed by a low lateral spine extension against resistance (for each side). Shoulder elevation (shrugs): In an upright position, shoulders were elevated as high as possible toward the ears and lowered again against resistance. Reverse flies: While seated, participants had their back straight, their head in an anatomically neutral position and leaned their trunk forward 20-30o and both arms were pointing towards the floor while holding the bands. Both arms were raised toward a horizontal level and lowered again. (after six weeks of training an additional exercise was introduced) Stimulation of flexed and rotated positioning: Seated position, with straight back and trunk leaned forward (~20o), head was held in an anatomically neutral position and rotated approximately 45o (right or left), the hips were flexed and the body flexed (against resistance) followed by an extension (for both sides). Reference group: Encouragement for regular physical activity.	Total duration: 20 weeks 3 times/week 20 minutes/intervention Warm up exercises: 6 sets 15 repetitions/set Strengthening exercises: 2-4 sets/intervention 12-20 repetitions/set	Training group: NRS (pain levels) (before intervention) 1/10, (after intervention) 0.6/10* PPT [pain tolerance (kPa)] (left trapezius) (before intervention) 434, (after intervention) 381* Reference group: PPT [pain tolerance (kPa)] (left trapezius) (before intervention) 405, (after intervention) 332*, (right trapezius) (before intervention) 416, (after intervention) 342*, (left extensors of the upper cervical spine) (before intervention) 335, (after intervention) 292*, (right extensors of the upper cervical spine) (before intervention) 334, (after intervention) 295*
Chumbley et al (2016)	Total number of participants (Fighter pilots F-15C) N=12 (Cross-over study) Intervention – Control group: N=7 Control – Intervention group: N=5	*Intervention was implemented with Saunders Home Cervical Traction Unit* Intervention – Control group: 1st phase: Application of traction force 9-11Kg, in 15o cervical flexion. 2nd phase: Recovery. 3rd phase: No exercise Control – Intervention group: 1st phase: No exercise. 2nd phase: Recovery. 3rd phase: Application of traction force 9-11Kg, in 15o cervical flexion.	Total duration: 14 weeks Intervention – Control group: 1st phase (6 weeks): 3 times /week, 10 minutes/intervention, 15 repetitions 2nd phase (2 weeks): recovery 3rd phase (6 weeks): No exercise Control – Intervention group: 1st phase (6 weeks): No exercise 2nd phase (2 weeks): recovery 3rd phase (6 w): 3 times/week, 10 minutes/intervention, 15 reps	Intervention groups: NRS (Change in pain levels before and after the intervention) (r=-0.729)* ROM [Change in degrees before and after the intervention (°)], Right rotation(7o)*
Rausch et al (2021)	Total number of participants (Fighter pilots) N=18 Training group: N=12 Control group: N=6	Training group: The program contained flexion, extension, lateral flexion and extension and neck rotation exercises. Intensity was monitored by the equipment, which consisted from sandbag, medicine balls, bands and small weights. Control group: Encouragement for regular physical activity.	Total duration: 12 weeks 3 times/week 60 minutes/intervention 12-15 repetitions/set	Training group: INSMS [Change before and after the intervention (%)]: Flexion(+17.7%)* , Extension(+6.8%)*, Right neck flexion (+6.9%)*, Left neck flexion (+7.3%)*, Right rotation (+22.7%)*, Left rotation (+23.2%)* EMG [% MVC of cervical muscles (sternocleidomastoid, trapezius and trunk extensor) using helmet] (before intervention): 30% (follow-up): 23%* [% MVC of cervical muscles (sternocleidomastoid, trapezius and trunk extensor) using helmet and night vision goggles] (follow-up): 30%* MRI (muscle volume measurement) [Change before and after the intervention (%)]: Sternocleidomastoid (+7.4%)*, Trapezius (+8.3%)*Deep cervical muscles (+6.6%)* Control group: INSMS [Change before and after the intervention (%)]: Flexion(+10.5%)* EMG [% MVC of cervical muscles (sternocleidomastoid, trapezius and trunk extensor) using helmet and night vision goggles] (follow-up): 40%*

* Results where statistically significant difference was found before and after the intervention (p<0.05)
** Results where no statistically significant difference was found before and after the intervention
NMQ: The Standardised Nordic Musculoskeletal Questionnaire; INSMS: Isometric Neck Strength Measurement System; Borg CR-10 Scale: The level of fatigue is assessed each 15s.; MVC: Maximal Voluntary Contraction; mFABQ: Modified Fear-Avoidance Belief Questionnaire (min: 0 / max: 24 - higher score indicates greater pain-related fear); EMG: Electromyography;
PPT: Pressure Pain Threshold (Low score ppt means high pain sensitivity. High ppt means low pain sensitivity); RVE: Reference voluntary electricity; CLT: Cervical Loading Test (assesses cervical radiculopathy); NRS: Numerical Rating Scale, assesses pain levels (min: 0 / max: 10 – worst pain imaginable); ROM: Range of motion; MRI: Magnetic resonance imaging

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