

REFLEX HYPERACTIVITY OF PARASPINAL MUSCLES IN ETIOLOGY OF BACK PAIN IN HELICOPTER PILOTS

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Abstract The position of the helicopter pilot can be described as a forced seated posture in relation to the seat and controls. The aim of this study was to detect reflex hyperactivity of the paraspinal muscles in test subjects resulting from prolonged uncomfortable sitting. Electromyographic activity was registered from paraspinal muscles during sustained paraspinal contraction. This activity was recorded by surface electrodes on four levels, from both sides on the *erector spinae* muscle with an eight-channel oscilloscope using integrated EMG signals. The results indicated a significant rise ($p < 0.05$) in electromyographic activity of the paraspinal muscles for five test subjects on both levels and sides investigated and compared to a raw signal recorded just before being placed in a sitting position. Findings made during this study suggest the possibility of existence of a reflex spasm in the paraspinal muscles, provoked by an awkward, fixed sitting position. This reflex is believed to be a potential generator of low back pain.

Keywords: Electromyography; paraspinal muscles; pilots.

1. INTRODUCTION (MAIN HEADINGS 12 PT, BOLD, CAPS LOCK)

Many well-documented studies report a significant prevalence of back pain in helicopter pilots, ranging from 21 - 95% [1-4]. In 32-64% of the pilots the pain is transient and directly related to flying [5-6]. The back pain usually occurs on flight missions. A large number of pilots experience this pain two hours after the onset of flight and immediately following the missions. Only under exceptional situation does the pain persist beyond 48 hours after the flight. The time required for the occurrence of the pain differs and is dependent on the sensitivity of each pilot, the type of helicopter, the type of flight mission and the number of hours flown. The back pain is dull (usually localized in the lumbar spine) and may evolve to a severe pain. In most pilots the pain withdraws after a post-flight rest. The two leading factors in the etiology of back pain in helicopter pilots have been confirmed by numerous authors as vibration and very awkward forced seated posture [3, 5, 7]. Our previous studies have shown that vibration at frequencies and amplitudes measured in all axis had an insignificant or played no part in the etiology of the back pain experienced by pilots during or immediately after flight [8-9].

Some authors tend to attribute the awkward sitting position of helicopter pilots as the leading role for the occurrence of this back pain [3, 7, 10]. The posture of helicopter pilots can be described as a forced seated posture in relation to the seat and controls. The task of flying a helicopter necessitates the continuous usage of all four extremities: hands on corresponding controls (the right hand on the cyclic and the left on the collective control) and the feet on the pedals. The cyclic control (placed directly in front of the pilot) necessitates utmost operating precision. To avoid any rough movements of the right hand due to vibrations, pilots (particularly those that are younger and inexperienced) tend to lean the right elbow on their thigh. As a result, the right hand is partially isolated from vibrations,

enabling higher precision in the handling of the control. However, this maneuver is usually accomplished by moving the whole body to the front resulting in a position referred to as "helicopter hunch".

Some authors suggest that the enforced, fixed position and the static loading of the pilot during the operation of the aircraft are the main factors for the occurrence of back pains. These have been made objective by the assessment of spinal muscles fatigue. Great postural tension, provoked by an inadequate sitting position, has a greater percent of maximal voluntary contraction, which produces higher electrical activity in paraspinal muscles.

The aim of our study was to detect reflex hyperactivity of the paraspinal muscles induced by prolonged awkward sitting.

2. METHOD

The study comprised 8 helicopter pilots who suffer from back pains during or after flying missions. An original helicopter seat was used in the laboratory to simulate flying conditions. A permanent body anteflexion with a semi-rotation to the right was induced by the enforced sitting position. In addition, the right hand was engaged through the semi-flexuous position in handling the cyclic control, while the left hand took a position similar to using the collective control. The lower extremities were in the semi-flexed position during the seated position, with a constant active participation of the dorsal and plantar feet flexors during the use of foot controls. A helicopter flight simulator on a PC (with a joystick used to simulate the cyclic control) was used to create as much of the natural flying conditions as possible and to achieve the required concentration and attention level of the pilot during flight.

The electromyographic activity of paraspinal muscles was registered before and immediately following the "flight" by placing the subjects in a lying position on their stomachs onto a firm bed. The activation of *m. erector spinae* was done through static contraction, which was caused by the horizontal abduction of the upper arm, with the mutual placement of hands on the back of head and retraction of shoulder blades. The movement was controlled by visual feedback when the subject moved their elbows from the base up to a certain level. The subject pilot was required to maintain that upper extremities position for a given time interval. The electromyographic activity was registered from paraspinal muscles during sustained paraspinal contraction. Registration of the electromyographic activity was performed using surface electrodes placed on four levels (third and fourth lumbar vertebra, L₃ and L₄, respectively) from both sides of the *erector spinae* muscle with an eight-channel oscilloscope using integrated EMG signals. The incoming signal time base was set at 80 ms, the amplitude declination was at 500 mV, and the incoming signal filter range was at intervals between 10 Hz and 500 Hz. The raw EMG signal was registered on the first four oscilloscope channels, while an integrated EMG signal with a ΔT value of 10 ms was registered at the same time on the other four channels.

The EMG activity was examined as a function of the amplitude change in the integrated signal during the given static contraction time interval of paravertebral muscles (which in this case was 60 seconds) and individual signal samples registered at 15 second intervals.

The electromyographic activity recorded immediately before placing the body in an enforced position in the helicopter seat represented the baseline signal (i.e., before fatigue), while the immediate activity after a 90-minute simulated flight represented the signal after the fatigue. The average of the five-recorded amplitudes of the integrated EMG signal from every channel (L₃ and L₄ on the right, and L₃ and L₄ on the left, respectively) represented the activity on the current level. Any increase in the electromyographic activity of paravertebral muscle was considered abnormal and was manifested through the rising amplitude of the integrated EMG signal. The gained values were used for further statistic analysis.

Central tendencies were determined for the measurement data. Student's T-test was used for determining significant differences between the means in relation to the null hypothesis at a significance level of 95%.

3. RESULTS

Tables 1 and 2 show results of the electromyographic activity in subjects, at controlled paravertebral musculature static contraction, immediately before and after taking the enforced sitting position.

Table 1. Recorded amplitude values of integrated EMG signal (I-EMG) for test subjects before (baseline) and after fatigue.

Test Subject	Baseline		After fatigue	
	L ₃ right (I-EMG)	L ₄ left (I-EMG)	L ₃ right (I-EMG)	L ₄ left (I-EMG)
1	47.4	60.9	73.3	69.4
2	38.4	42.7	32.6	32.3
3	28.4	35.8	17.3	25.7
4	26.1	29.2	42.3	40.0
5	68.5	68.2	63.3	68.6
6	55.5	54.6	62.5	65.0
7	27.9	26.3	38.8	41.1
8	40.6	47.1	43.9	48.7

By analyzing the values of examined levels, after fatigue in an enforced sitting position, a significant activity increase ($p < 0.05$) was recorded in five subjects on both examined levels (L₃ and L₄). An activity decrease on both examined levels was recorded in two subjects, while only one subject had an activity decline on the L₃ level. However, in the latter case, there was no change in values on the L₄ level after fatigue in an enforced sitting position.

Table 2. Summary recorded amplitude values of integrated EMG signal (I-EMG) for each test subject before (baseline) and after fatigue.

Test Subject	Baseline (I-EMG)	After fatigue (I-EMG)
1	54.2	71.4
2	40.6	32.5
3	32.1	21.5
4	27.7	41.2
5	68.4	66.0
6	55.1	63.8
7	27.1	40.0
8	43.9	46.3

Amplitude values of the recorded signal during 60 seconds of static paravertebral musculature contractions, with amplitude values at every 15 seconds during a set time interval are presented in Figures 1 - 3.

A significantly higher level of uniform activity ($p < 0.05$), at every registration, was obtained (with minor value oscillations) after sitting in an enforced position (Figure 1). During a 60-second period of static contraction, the recorded activity (after sitting in an enforced position) exhibited an increasing trend from the 15th second through the 60th second.

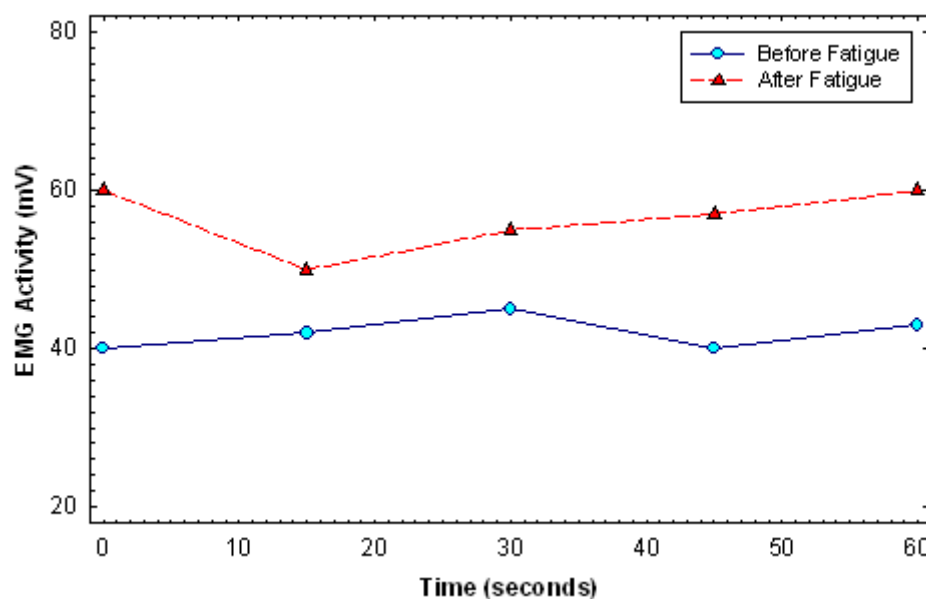


Figure 1. EMG activity registered as a function of time for test subjects with rising muscle activity recorded after fatigue.

The recorded activity after sitting in an enforced position had a slightly lower amplitude value of the integrated EMG signal in 2 subjects, with a decreasing trend through the 60th second in relation to the initial value recorded as the first measurement (immediately before taking the enforced position). The obtained values did not differ significantly in respective comparisons (Figure 2).

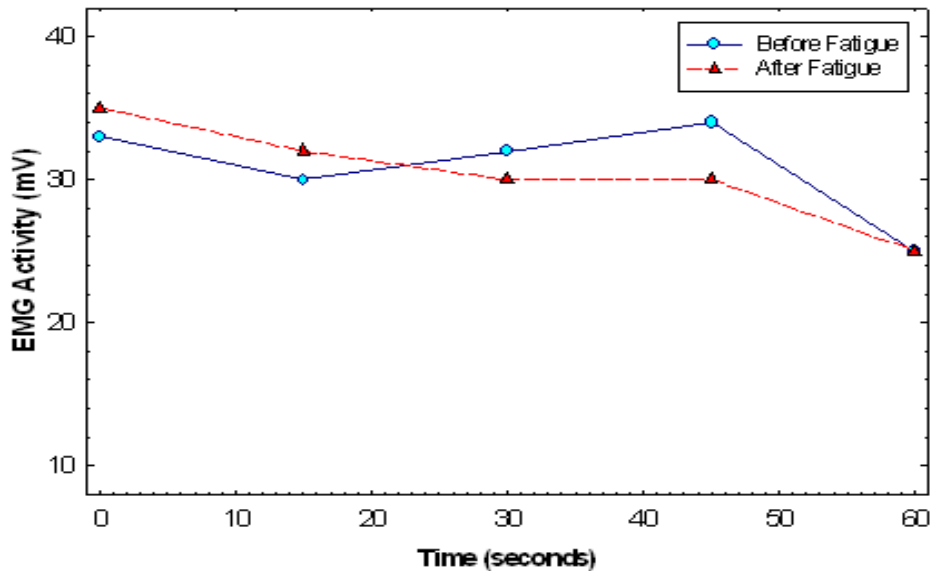


Figure 2. EMG activity registered as a function of time for test subjects with falling muscle activity recorded after fatigue.

While observing the activity curve of the electromyographic signal as a function of time, practically identical values were achieved before and after getting into the enforced position, during the 60-second test. Overall, a slightly increasing trend was observed from the 15th to the 60th second of static contraction (Figure 3).

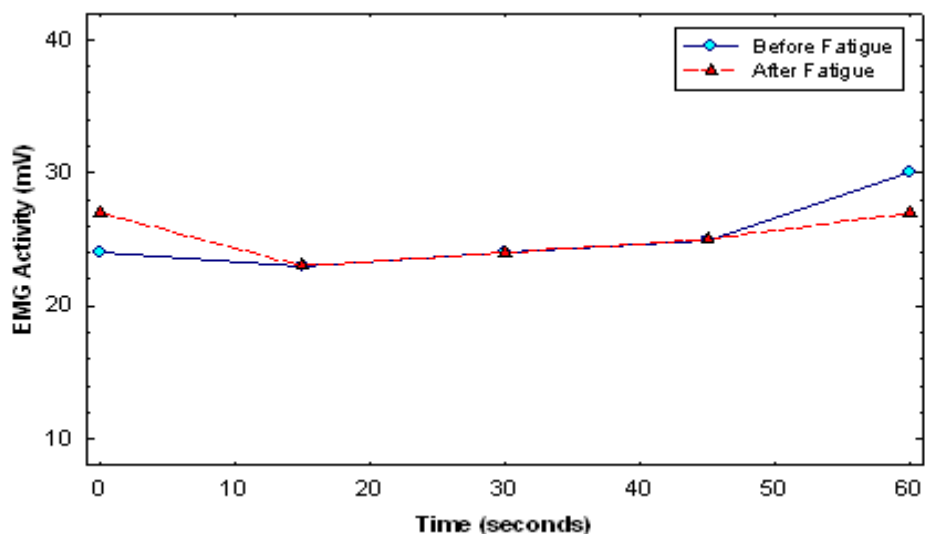


Figure 3. EMG activity registered as a function of time for test subject with no recorded change in muscle activity after fatigue.

4. DISCUSSION

There are very few electromyographic studies concerning back pain in pilots [10, 11-13]. The specific quality of the dynamic lumbar vertebral segment, the most mobile spinal segment, also encompasses the existence of a large number of possible primary back pain causes of nondiscal genesis.

In long-lasting static loadings that are conditioned by body position, the paravertebral ligament, nervous and muscle structures are exposed to continuous stress that can result in pain development of static origin. While bending the body forward, in an upright position and in a sitting position, as well as during active sitting, a load force occurs, caused by the force of gravity. At the moment the body is driven out of the middle line, the *m. erector spinae* starts its activity in order to control the position of the body and the head. The paravertebral musculature loading of the above mentioned part is indicated through continuous muscle activity with the aim of keeping the body position in a new, enforced position [14]. A prolonged stimulation, caused by the position of the body, will condition fatigue occurrence of the continuously active paravertebral musculature muscle groups. Within this situation, the development of local fatigue is possible resulting in an active muscle group dysfunction until the body position is changed to lower the effects of gravity. Thus, muscular strain of the paravertebral musculature (induced by altered biomechanical references in a specific, forced body position, within a longer period of time) may be the cause of back pain development.

The posture that was taken by test subjects resulted in the lumbar lordosis erection. Under such situations, a permanent distension of the aforementioned structures in an enforced sitting position causes a prolonged reaction to the stretching reflex that is noticed as a long-lasting intersegmental muscle contraction with the desire to control the body position. This distension is of changing intensity and occurs as a reaction to gravity effect and is manifested through a continuous body tendency of falling forward.

The electromyographic activity, which was observed in the test subjects as an increasing trend, suggests the possibility of the occurrence of paravertebral muscles reflex spasms which are caused by pain in the lumbar region and develop due to a prolonged enforced position. As the functional capacity of maintaining static contraction quality is compromised by the intensive local cellular metabolism (leading to the consumption of glycogenic reserves), the byproducts of this decomposition represent a reflex pain stimulation, which with the aim to protect, conditions the occurrence of a prolonged contraction. This explains the rise in amplitude from the first to the 60th second.

Along with such a mechanism, there is a possibility of a reflex static pain occurrence after a longer lasting enforced position that can be interpreted through energy reserves consumption in active muscles as well as through a consequential distension of posterior ligament structures, which take up a greater part of the loading. There exists also the possibility of static pressure development on smaller nervous branches of the current vertebral segment (e.g., the dorsal branches of the intervertebral nerve). A reflexive spasm and pain of a changing intensity may also occur [15]. In such situations, reflexive symmetrical or asymmetrical muscle activity inhibition can occur, leading to its bilateral or unilateral quality fall. The condition of subjects with registered electromyographic activity fall can be explained based on this mechanism. A possibility exists that the test subjects

reacted with a similar mechanism, either with the reflexive inhibition activity, or on the other hand, with the incapability of maintaining the same quality of the initial (at the first second) muscle activity level because of local fatigue.

The most extensive activity of the *m. erector spinae* is shown at ipsilateral rotation, whilst the rotators and multifidus show their highest activity level during contralateral rotation. It has also been observed that the increased activity occurs during the tendency of bringing the body back to its primary (upright) position. This finding leads to the conclusion that the body is moved by a disbalanced activity of the *m. erector spinae* from both sides, with a permanent tendency of resisting the force of gravity. It is interesting to note that during body rotation the absolute level of paraspinal muscle activity of the examined area (in a seated position) was higher than during the same movement in an upright position. This can be explained with a permanent, but also efficient attempt to increase the body stability within this posture. By taking all of these factors into account, it can be stated that the activity of the aforementioned muscle structures occurs in all movements during which the body is driven out of the middle line with the tendency of reverting to its initial position.

5. CONCLUSION

In studies that have been conducted so far, evidences have been presented showing that static stretching may be the reason for various types of muscle pain occurrences. It has been stated that static stretching provokes an inverse myotatic reflex, and through this mechanism the local tonic muscle spasm is initiated resulting in pain. The paravertebral muscle spasm develops as a reaction to pain in order to form a safety "blockade" of the affected area and to prevent further injury to that part. The reflexive spasm has the tendency prolonging the pain. This can lead to a heightened intensity of pain and result increase intensity of the protective reflex. Under these conditions a vicious circle develops and lasts up until the position is changed resulting in a relaxation of the tense paraspinal muscles. The available evidences suggest that every enforced postural loading requires a higher percentage of maximal voluntary contraction, increasing the electrical activity in those muscles. This will eventually lead to a decrease in the functional potential of the paravertebral musculature. The results observed during this study support these conclusions regarding back pain genesis during a long-lasting enforced position.

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