ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

ACUTE EFFECT OF A HELICOPTER FLIGHT ON CELLULAR TISSUE BIOCHEMICAL MARKERS

Jan Ivar Kåsin[1], John Kjekshus[2] and Anthony Wagstaff[1]

[1] Norwegian Defence Medical Services - Institute of Aviation Medicine, 0313 Oslo, Norway
[2] Rikshospitalet University Hospital – Department of Cardiology- 0027 Oslo, Norway
jik@flymed.no (email address of lead author and presenter)

Abstract

Whole-body vibration and noise are inherent characteristics of helicopter operations. The helicopter pilot is affected by vibration from both low-frequency noise and mechanical vibration sources. The way this energy is transmitted to different tissues and organs depends on intensity, frequency and resonance phenomena within the body. Whole body vibration is known to affect the muscular and skeletal system in the lower part of the spine. How each single cell responds to this stimulation is, however, less known, but some studies have described chronic pathological changes in different types of tissue in persons exposed to low-frequency noise and vibration. The aim of the present study was to investigate possible cellular reactions to an acute exposure to low frequency noise and vibration in a helicopter. 13 male subjects were subjected to a 3.5 hr helicopter flight in a in a Westland Sea King Rescue helicopter. Blood tests were taken before and after the flight and analyzed for more than 80 parameters including cytokines and other biochemical markers of low-level tissue irritation. Subjects were their own controls. No statistically significant changes in cytokines or other indicators of low-level tissue irritation were found after controlling for normal variation in the control blood tests. Some blood values changed significantly, however different explanations are possible for these findings. An acute exposure to helicopter noise and vibration caused no statistically significant changes in known sensitive tissue biochemical markers. Further studies are needed to explain chronic pathological changes found by other researchers

INTRODUCTION

Whole-Body Vibration (WBV) and noise is an inherent characteristic of helicopter operations. The vibrations of helicopters are dominated by combinations of frequency components associated with the revolution rate of the rotors, gearboxes and similar items. The vibration is mainly in the low frequency band, 4-80Hz [1]. The human body is sensitive to frequencies within its resonance area between 4-100Hz, depending on body part. The helicopter pilot is affected by vibration energy from both noise and mechanical vibration sources. This energy is transmitted to different tissues and organs and ultimately leads to an influence on each single cell. How each cell responds to this stimulation is not known. It is documented that people exposed to WBV over a longer period are affected in the lower part of the spine including related tissues [2].

Long term exposure to Low frequency noise <90dB sound pressure level (SPL) and vibration (LFNAV) (<500 Hz) has been studied by a Portuguese group for more than 20 years. Their studies suggest that people with long term exposure (>15 years) for LFNAV develop thickening of pericardial walls, artery walls and cardiac valvular tissue, both in aortic and mitral valves as well as the tricuspid valve. These findings are termed Vibroacoustic Disease, pericardial thickening being the most common sign. The changes in pericardial structures are evaluated through Echocardiography [3] Histologically examinations are further performed on four patients who underwent cardiac surgery [4]. Inflammatory processes in the affected areas are not established. The thickening is suggested to be a possible adaptation to LFNAV influence. The described changes had developed over 10-15 years. To our knowledge there was no control for other possible causative agents. A noise survey was conducted at Oficinas Gerais de Material Aeronautico (OGMA) the place was the major population for their research is recruited. They found levels between 100-130 dB(A) in their working environment.[5]

Although increases in CD8+ and CD4+ T Lymphocytes has been observed in patients diagnosed with Vibroacoustic disease exposed to LFNAV for more than 10 years [6]. A controlled study in Wistar mouse arterial endothelial cells demonstrates cellular changes after only 4 hours of vibration exposure, by increased levels of NFATc3 (nuclear factor of activated T-cells) [7]. Another study from the same group has demonstrated morphological changes as fibrosis deep in rat lung parenchyma [8].

Most studies demonstrate changes after long exposure time, although in the human studies there are also some uncertainty associated with the exposure dose/levels and the response. If influence of noise and vibration during a 10-15 years period results in tissue changes, we would believe that it is possible to detect the acute effect of these environmental factors if the detection methods are highly accurate and sensitive enough.
Analyzing cytokines and different biochemical markers is a well established procedure to demonstrate cellular damage in clinical practice.

The aim of the present study was to examine the acute effects during a representative working day for a helicopter pilot in order to establish a connection between LFNAV and if biochemical indices of tissue changes.

METHOD

The study was approved by the regional ethics committee.

Subjects
The subjects consisted of 13 males in two groups. Group A consisted of 7 non helicopter crew, and group B of 6 persons in the Sea-King Helicopter rescue crew setup; 1.pilot, 2.pilot, system operator, technical engineer, rescuer and doctor. All were subjected to the following exclusion criteria:
-been in helicopter the last 4 weeks (not applied for group B), smoked/snuffed, used alcohol or exercised the last 24 hours, uses any remedy, high blood pressure, under 18 years, ongoing infection disease, any atherosclerotic disease or motion sickness problems.
All subjects signed informed consent form.

Noise and vibration Environment

A Westland Sea King Mk43B helicopter from 330 rescue squadron was made available by the Royal Norwegian Air Force (RNoAF) for this study. The vibration environment was recorded using a Brüel & Kjær, Multi analyzer system 3560 with Pulse software version 9.0 (Brüel & Kjær, Nærum, Denmark). The noise environment was recorded using a Brüel & Kjær 2260 Investigator. The vibration levels were recorded in the pilot seat in 3 orthogonal axes (x,y,z) according to ISO 2631-1. Vibration recordings were made for 3 hours and 14 minutes in about 10 minutes intervals in the frequency range 1,25 – 100 Hz. Sound recordings were made for 1 hour and 44 minutes in 1/3 octave band logged every 11s in the frequency range 12,5 – 20 000 Hz.

Methodological considerations
The helicopter was operational for search and rescue operations during the flight. The capacity was for that reason restricted to seven persons (group A) in addition to the helicopter crew of six persons (group B). The flight period was restricted to 3,5 hours to standing operative procedures.

Study design
Blood samples were taken from the cephalic vein.
The first blood sampling was carried out for both groups at 8:00 am. Samples were taken from Group A (n=7) at Rikshospitalet, Oslo, Norway before transportation to Rygge Air Base approximately one hour drive from Oslo. From Group B (n=6), samples were taken at Rygge Air Base Clinic at the same time. The takeoff took place with both groups from Rygge Air Base at 11:00AM in the Sea King. The flight took 3,5 hours before the helicopter landed on Rikshospitalet Heli Pad. The second blood sampling took place for both groups immediately after landing. To validate the daily variations, group A where tested some weeks later at the same time points without helicopter vibration exposure.

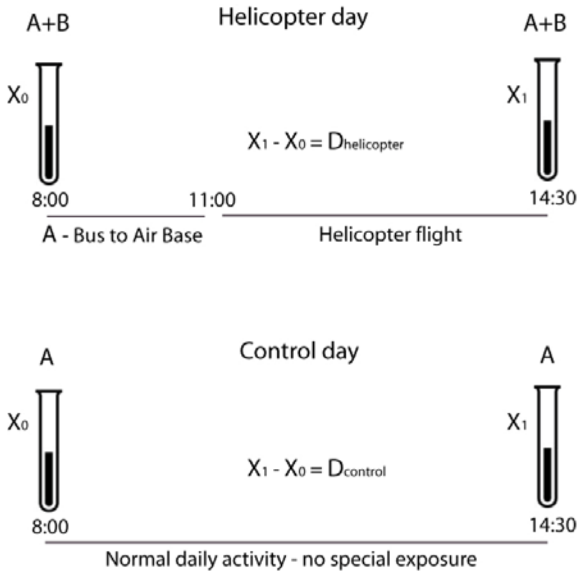

Figure 1: Study design. Group A (n=7), Group B (n=6), X_0 = morning sampled values, X_1= afternoon sampled values, $D_{(helicopter)}$=delta values helicopter flight, $D_{(control)}$=delta values control day.

Blood samples

Blood samples before and after each flight were analyzed for for the following cytokines and biochemical markers: cd4, cd8, cd40, TCC, PCRP, PACTH, ProBNP, IFNg, ILb, IL1ra, IL2, IL4, IL6, IL8, IL9, IL10, IL12p70, IL13, GCSF, MCP1, Eotaxin, IP 10, VCAM, ICAM MIP1a, MIP1b, PDGFbb, VEGF, ICAM, E-selectin, P-selectin, BTG, PAI-1, t-PA.

Results

The participants' age ranged from 19-69, with average 38.

Delta values are calculated from both helicopter day and control day. For each person values from the 08:00 am samples were subtracted from the 02:30 pm samples. The delta values from the helicopter day and the control day were computed in SPSS 13, choosing Wilcoxon signed rank test.

Vibration

The vibration levels for the whole helicopter flight was; 0,25 m/s^2 in the x-axis (front-aft), 0,21 m/s^2 in the y-axis (sideways) and 0,39 m/s^2 in the z-axis (up-down). The vibration levels are normally higher in the Z-axis than X and Y [9].

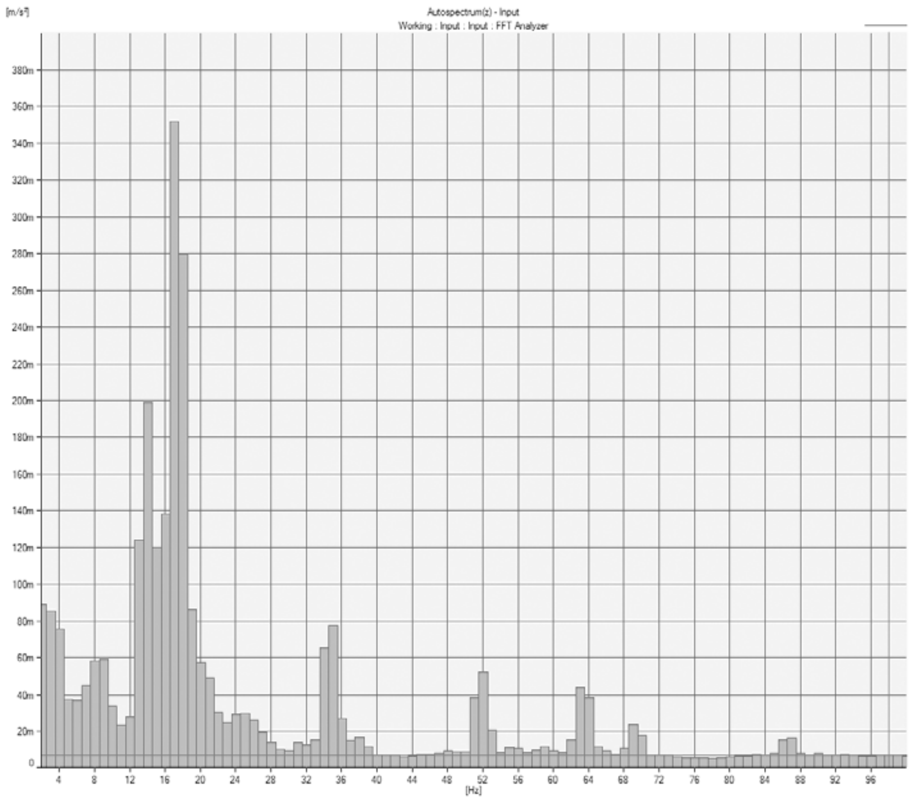

Figure 2: FFT analysis 2-100Hz in the Z-axis. The bars shows a 10 minutes interval average RMS (root mean square value) for each frequency and is w_k weighted.

Noise

The average noise level during the helicopter flight was 94,7 dBA [10]. The noise is distributed in the spectrum from 0.5-100 Hz as seen in figure 3.

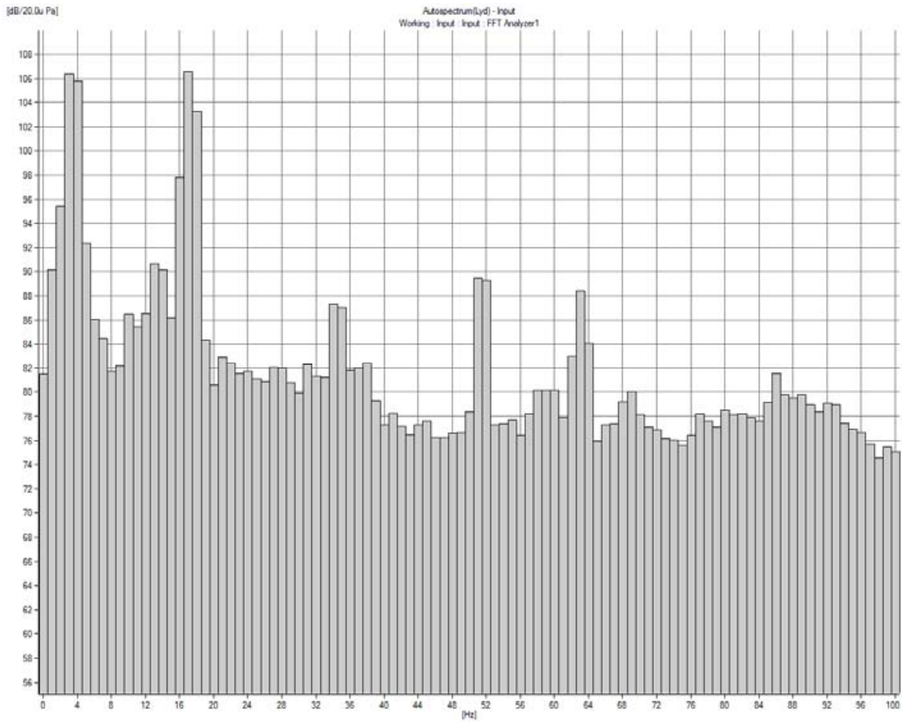

Figure 3: The cockpit noise between 1. and 2. pilot in head position. The helicopter is cruising at 100 knots. FFT analysis ranges from 0.5-100 Hz. The spectrum bars shows a 60 s average measurement in dB-linear.

Discussion

The present study demonstrates no difference between the basic morning and afternoon levels of group A and group B. Furthermore, we found no significant differences when we compare the delta values from flight with control day. We can therefore not demonstrate any link between LFNAV and effects on cellular tissue revealed by biochemical markers. One possibility is that sound and vibration exposure has no effect on cellular tissue. Another reason is that the detection methods or the detection methods are not sensitive enough.

The acute effects on NFAT 3C levels in mice found by Curry et al [7], where vibration caused increased levels, are not confirmed by our study on similar tissue markers on human subjects. However, vibration levels in this study were over ten-fold as high and over much longer periods.

The noise environment in our experiment averaged 94,7 dBA (Leq). In the major Portuguese studies the population worked at OGMA and the noise levels varied from 100-130 dBA. However, based on the frequency spectra in the OGMA studies, the helicopter environment has substantially more low frequency noise content [5]. In addition, vibration levels are probably higher in the helicopter, however not documented in the Portuguese studies. The lack of findings in our study still only shows a lack of acute response based on the biochemical markers we have chosen. Chronic changes as found by the Portuguese group may have other mechanisms that do not affect these markers in an acute setting.

Our results are useful as a mapping of the helicopter working environment in order to evaluate possible indications of health effects caused by noise and vibration. The duration of the flight is realistic for typical Sea King helicopter operations, such as search and rescue or emergency medical evacuation. The results may however also be applicable to other working environments with similar noise and vibration patterns.

If the noise and vibration dose in this helicopter study has minor effect on the cellular tissue, a larger population may be needed to detect any possible changes. The knowledge about LFNAV levels and possible cellular effects are limited. Still, our findings do not indicate any acute changes to this real work environment setting causing some reassurance to helicopter personnel. Further research is warranted in order to clarify the degree and possible mechanisms of chronic changes that have been described by other workers.

[1] Griffin MJ. Handbook of human vibration. 1990;ISBN 0-12-303040-4:988.
[2] Dupuis H, Zerlett G. Whole-body vibration and disorders of the spine. Int Arch Occup Environ Health. 1987;59(4):323-36.
[3] Marciniak W, Rodriguez E, Olszowska K, Atkov O, Botvin I, Araujo A, et al. Echocardiographic evaluation in 485 aeronautical workers exposed to different noise environments. Aviat Space Environ Med. 1999 Mar;70(3 Pt 2):A46-53.
[4] Castelo Branco NA, Aguas AP, Sousa Pereira A, Monteiro E, Fragata JI, Tavares F, et al. The human pericardium in vibroacoustic disease. Aviat Space Environ Med. 1999 Mar;70(3 Pt 2):A54-62.
[5] Bento Coelho JL, Ferreira A, Serano J, A.A. CB. Noise Assessment During Aircraft Run-up Procedures. Aviat Space Environ Med. 1999 Mar;70(3 Pt2):A22-6.
[6] Castro AP, Aguas AP, Grande NR, Monteiro E, Castelo Branco NA. Increase in CD8+ and CD4+ T lymphocytes in patients with vibroacoustic disease. Aviat Space Environ Med. 1999 Mar;70(3 Pt 2):A141-4.
[7] Curry BD, Bain JL, Yan JG, Zhang LL, Yamaguchi M, Matloub HS, et al. Vibration injury damages arterial endothelial cells. Muscle Nerve. 2002 Apr;25(4):527-34.
[8] Grande NR, Aguas AP, De Sousa Pereira A, Monteiro E, Castelo Branco NA. Morphological changes in rat lung parenchyma exposed to low frequency noise. Aviat Space Environ Med. 1999 Mar;70(3 Pt 2):A70-7.
[9] P. Cox JMIP. Directive 2002/44/EC of the European Parliament and the council of 25 June 2002. ed: 2002.
[10] Bento Coelho JL, Ferreira A, Serrano J, Castelo Branco NA. Noise assessment during aircraft run-up procedures. Aviat Space Environ Med. 1999 Mar;70(3 Pt 2):A22-6.