ICSV14
Cairns • Australia
9-12 July, 2007

14th International Congress on Sound & Vibration

HEALTH AND SAFETY EFFECTS OF VIBRATIONS IN HELICOPTERS

Anthony Wagstaff[1] and Jan Ivar Kåsin[1]

[1] Norwegian Defence Medical Services - Institute of Aviation Medicine, 0313 Oslo, Norway
Anthony.wagstaff@flymed.uio.no (email address of lead author and presenter)

Abstract

Helicopter operations imply Whole-Body Vibration (WBV), primarily due to the motions of the main rotor system. Health effects of WBV in general have primarily been related to the spine and it's related structures. However, many other effects are present, some of them having potential health implications while others may affect safety by acting on the human operator's physiology.
METHODS AND DISCUSSION: Probable and possible vibration effects in helicopters are reviewed, both from possible mechanisms and epidemiological data. Low Back Pain (LBP) is possibly the best documented physiological effect, however, LBP in helicopters is only partly due to vibration. Other physiological effects, e.g on the neck and on the visual system may have safety consequences. The possible entity of Vibro-Acoustic Disease (VAD) is also discussed in relation to helicopter aircrew. Problem areas and possibilities in relation to reducing vibration in helicopters include considerations of the vibration levels and axes as well as crash protection

1. INTRODUCTION

Helicopter operations cover many different roles in Society. Depending on Geographical, Industrial and military needs, helicopters perform roles as diverse as search-and-rescue, offshore transport, power-line mounting, military/civilian transport or military wapons platform.
The helicopter is a fairly recent addition to our society's transport needs, arriving on the scene about half a century after it's fixed-wing counterpart the airplane. Consequentially, the attention to the working environment in helicopters has not been in the forefront compared to other workplaces. The basic working position for helicopter pilots is the same as when the helicopter was first introduced – helicopter flying includes using the Cyclic (in the centre in front of the pilot seat), the Collective (a lever on the pilots left side) and the pedals . These controls must be used simultaneously, employing all limbs at the same time – apart from periods in flight where any autopilot may be employed (a feature which is only present in some helicopters and that has limited use depending on the operation at hand. At the same time, helicopters are doing more and more complex jobs in areas where no other means can offer similar capabilities. This has spurred the introduction of an increasing array of equipment that pose further challenges to the

working environment. This equipment includes night-vision goggles, infra-red devices and safety equipment such as underwater breathing devices as well as other survival equipment.

In this complex working environment, Whole-Body Vibration WBW and noise is an inherent characteristic.

2. CHARACTERISTICS OF HELICOPTER VIBRATION FROM A HUMAN PERSPECTIVE

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 primary main rotor rotor rotation frequency (1R) is fairly constant under normal operations for a given helicopter type, typically 4-5Hz. The 1R frequency multiplied by the number of main rotor blades also provides for a peak in vibration intensity. These are the main vibration sources in a helicopter from a human perspective.

In Helicopters, the commonly used xyz axis system for orientation and direction of vibration for a human subject shows substantial vibrations in all axes simultaneously, with levels that vary according to flight profile. The Z axis is, however, usually the dominant one for most flight profiles in most helicopters.

3. HELICOPTER VIBRATION EFFECTS ON FUNCTION AND SAFETY

Fine coordination and speech is affected by helicopter vibration, Thus, writing activities and other functions requiring a certain level of dexterity may be affected. A typical situation where this may be the case is in flight profiles at or near to hovering, where finger coordination may be significantly hampered. Manual tasks as, for example, cyclic, collective and pedal movement are not so easily affected in normal situations.

An interesting practical detail is how the 4-5 Hz fundamental frequency of the helicopter coincides with the one of the dominant resonance frequencies in the human body, thus producing diaphragmatic fluctuation causing a vibrating effect on speech. Thus, most pilots will readily recognize that a fellow airman is speaking on the radio from a helicopter due to a flutter effect particularly in vowel sounds.

The human eye does not seem to be affected in practice at normal operating conditions, although relative movement of helicopter structures (e.g. instrument panel) may cause visual problems in some flight conditions. It has been argued that vibration may cause an increase in susceptibility to sensory disorientation in flight. Although this seems intuitively probable, the scientific evidence is lacking.

The musculoskeletal system is affected, the fluctuating small movements in musculature partly being contained by muscular contraction. This might be some of the reason for the much-reported problem of helicopter aircrew fatigue, although many other in-flight stressors also play a role here. Low Back Pain is a well documented problem in helicopter aircrew [1], leading to an aching, in-flight pain that usually arises after about 1 ½ hours of flight or so . These problems do not seem to cause a lot of long term ill-health. However, the implications to flight safety are important, as such pain may be an important distraction that may cause changes in how a mission is handled. Often, seats and other ergonomic factors have been attributed more of the reason for these problems than vibration. Similarly, the use of survival equipment such as e.g. life vest may induce ergonomic challenges that may lead to neck problems. More specifically, vibration may cause increased strain in neck muscles when using Night Vision Goggles or other helmet-mounted devices which increase the helmet weight and a forward-shift of the centre of gravity(c.g.) of the head and helmet. In order to alleviate this c.g. forward shift, counterweights might be used on the back of the helmet, but with the side-effect of increasing the total weight further.

4. LONG-TERM HEALTH EFFECTS OF HELICOPTER VIBRATION

It is documented that people exposed to WBW over a longer period are affected in the lower part of the spine including related tissues [3]. The relevance of these findings to possible long-term health effects in helicopter pilots has not been established.

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 [4], [5].
The contribution of vibration versus low-frequency noise is not clear, likewise any definite dose-response relationship that may be applied to helicopters.

5. VIBRATION ATTENUATION IN HELICOPTERS

Vibration attenuation in helicopters pose specific problems. Although some passive means may be utilized, spring systems as used in e.g. trucks may be hazardous in a crash or hard landing situation, as peak impact loads may be higher than without such systems. This is due to the helicopter’s often high sink rate in a crash situation.
However, active systems may be designed which incorporate crash safety factors. Some helicopters, like the EH101, incorporate active attenuation of the vibration at or near the rotor head. Some have looked at retrofit vibration attenuating seats – however suchsolutions, although technologically feasible, have not been possible on a large scale. This may be due to both a cost- and weight-conscious helicopter market and certification costs.

6. CONCLUSIONS

A relationship in humans between helicopter vibration and long-term health has not been adequately studied to provide any clear conclusions apart from a probable effect on the lower part of the spine. As such, the European Directive concerning whole-body vibration limit values is based on Spine-related problems only [6].

The problems related to function and flight safety are well known by helicopter aircrew and are in themselves a good reason for further study, as are the problems of possible long-term effects on other organs than the spine.

If further research provides clearer evidence of detrimental effects due to helicopter vibration, further development of vibration attenuating systems in helicopters might follow.

References:

[1] Hansen Ø, Wagstaff AS. Low Back Pain in Norwegian Helicopter Aircrew. Aviat Space Environ Med 2001;72:161-4.
[2] Griffin MJ. Handbook of human vibration. 1990;ISBN 0-12-303040-4:988.
[3] Dupuis H, Zerlett G. Whole-body vibration and disorders of the spine. Int Arch Occup Environ Health. 1987;59(4):323-36.
[4] 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.
[5] 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
[6] P. Cox JMIP. Directive 2002/44/EC of the European Parliament and the council of 25 June 2002. ed: 2002.