inter-noise 2004
Prague • Czech Republic • August 22-25

The 33rd International Congress and Exposition on Noise Control Engineering

Vibroacoustic Disease in a Ten Year Old Male

N.A.A. Castelo Branco[a], A. Araújo[b], J. Joanaz de Melo[c] and M. Alves-Pereira[c]

[a]Center for Human Performance, Scientific Board, Apartado 173, 2615 Alverca Codex, Portugal
[b]Coronary Intensive Care Unit, Santa Maria University Hospital, Lisbon University, Portugal
[c]Dept. Environ. Sci. & Eng., DCEA-FCT, New University of Lisbon, 2825-315, Caparica, Portugal
[a]n.cbranco@netcabo.pt; [c]mariana.pereira@oninet.pt; [c]

Abstract [634] Background. Restelo is a suburb of Lisbon, Portugal, located on the northern hillside margin of the River Tagus. Directly across the river is a grain cargo-ship docking site where grain in bulk is poured into merchant ships. Until 2003, this site would operate for days at a time, including at night. This team was contacted by a family residing in Restelo, who complained about the noise during the grain-site operation. Low frequency noise (LFN) was measured at the house during operation, and the entire family received volunteer medical tests because vibroacoustic disease (VAD) was suspected. This report describes the LFN-induced pathological medical findings observed in this family. **METHODS.** Mr. F., 39-year-old architect, Mrs. F., 42-year-old Forestry Engineer and P., 10-year-old son, all received an echocardiogram to determine if characteristic LFN-induced cardiac thickening was present. **RESULTS.** All exhibited some degree of pericardial thickening. Among the adult parents, the father exhibited a thicker pericardium than the mother. However, 10-year-old P. disclosed very thickened pericardium and mitral valve leaflets. No diastolic dysfunction was identified in any member of this family. **DISCUSSION.** There is no history of rheumatic fever, nor is pericarditis present, nor is asbestos an issue. As in other LFN-exposed individuals, this family exhibited thickening of cardiac structures that is characteristic of VAD patients. The severity of the cardiac pathology seen in P. is related to the fact that his exposure began *in utero*. This family has been diagnosed with environmentally-induced VAD.

1 INTRODUCTION

Mr. F. is a 39-year-old architect who lives with his family in Restelo, a suburb of Lisbon, Portugal. Restelo is located on the hillside of the northern margin of the Tagus River. Directly in front of Restelo, on the other side of the river, operates a grain cargo-ship docking site. Until 2003, this industrial complex could function at any hour of the day or night. In February 2003, Mr. F. contacted our team complaining about low frequency noise (≤500 Hz, including infrasound) (LFN) in his home.

Mr. and, Mrs. F., a 42-year-old forestry engineer, had moved into their home in August 1992. Today they have two children, P. their 10-year-old son, and an 18-month-old baby. He explained:

"Some time ago I became aware of a vibration that interfered with my concentration, although for a very long while I was unable to determine the source. I began to suspect that the vibration came from the cereal silos when I noticed that each time I felt the vibration throughout my home, a ship was docked at the site. However, no one in my home shared my perceptions of a vibration, and this left me unsure as to the external source of the disturbance. Only when the consequences of the vibration became more evident, as seen and heard in the rattling of our front door, did my wife agree that something was indeed very wrong. Whether we noticed it then, or if the rattling increased

EXHIBIT Int. I-3(k)

for some reason, is unknown. I recognized that I *felt* the disturbance more than I *heard* it."

1.1 Noise Measurement

Noise was measured at Mr. F.'s home with a real time frequency analyser (Bruel&Kjaer, 2260 Observer) equipped with a ½" microphone (Bruel&Kjaer, 4189). Sound pressure levels were documented in dBA and dBLin, and frequency distributions were obtained in 1/3 octave bands, with a lower limiting frequency of 6.3 Hz.

Measurements were made on different days, with and without the "noise" present in the home. Figures 1 and 2 show the L_{eq} for the 1/3 octave band analysis (in dB_{Lin}), as well as the overall levels, in both dBA and dB_{Lin} (Table 1). These graphs are representative of the values obtained to date.

All frequency spectra presented are compared to the cockpit of the Airbus-340. The acoustical environment within an airline cockpit is rich in LFN components (1). Both pilots and flight attendants are at risk for developing vibroacoustic disease (VAD) (2), a systemic pathology caused by excessive exposure to LFN, and characterized by the abnormal growth of the extra-cellular matrices (3). Since no standards yet exist for LFN, and specific frequency bands have not yet been linked to specific lesions, it became pertinent, among VAD-researchers, to compare other LFN-rich environments with the airline cockpit. Hence, all graphs also contain comparative information regarding this acoustical environment.

There is an increase in the acoustical energy within the home (Figures 1 and 2), that seemed to be directly related with what Mr. F. describes as the operation of the site. However, other frequency bands below 16 Hz also disclose non-trivial levels. These acoustical events were also present when the acoustical phenomena associated with the site's operation were not present (See Figure 1).

The difference in dBA vs. dBLin values is due to the predominance of LFN components. The dB-value does not provide reliable information on the lower frequency bands (<500 Hz) (4,5). The dBLin value does not reflect the differences observed in the frequency distribution of these acoustical environments (4,5).

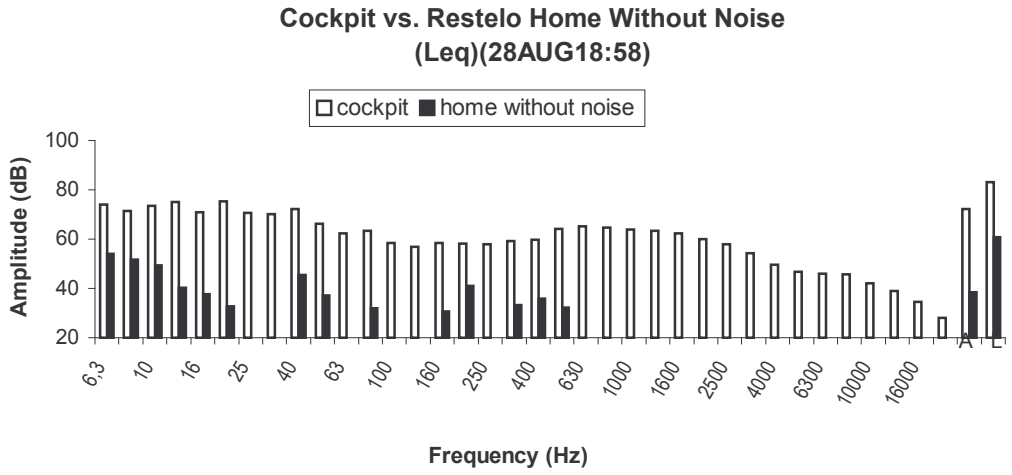

Figure 1: *Comparison of the frequency distribution obtained in the cockpit of the Airbus-340 (see text) with that obtained in the Restelo home, when the acoustical phenomena were not present (L_{eq} values). Overall dBA and dBLin levels are labelled A and L, respectively.*

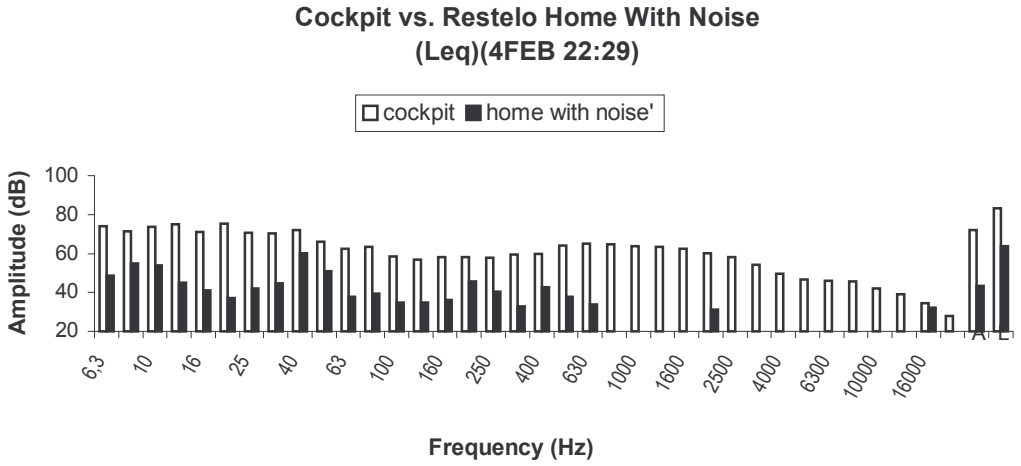

Figure 2: *Comparison of the frequency distribution obtained in the cockpit of the Airbus-340 (see text) with that obtained in the Restelo home, when the acoustical phenomena was present (L_{eq} values).Overall dBA and dBLin levels are labelled A and L, respectively.*

	Cockpit	Without Noise	With Noise
dBA	72.1	38.4	43.4
dBLin	83.2	60.7	63.7

Table1: *dB-levels values for all locations*

As a final note, even though the acoustical phenomena were very evident within the home, no confirmation was obtained from the silos authorities, attesting to the actual operation of the facility. However, each time the acoustical phenomena were present, a ship was, indeed, docked. And when no ship was seen at the facility, no similar acoustical phenomena were present in the home. The fact that other LFN components exist within the home when the silos are not in operation (Figure 1), is an indication that the silos are not the only source of LFN in this home.

1.2 Brief Medical Histories

Mr. F. is apparently asymptomatic. He complains of a lack of concentration and overall irritation, and has severe bouts of rosacea. He has always lived the suburbs of the city of Lisbon, and has been working in the center of Lisbon for the past 10 years.

Mrs. F. has been diagnosed with hepatitis A, mononucleosis and allergic rhinitis. While still a student in university, she was diagnosed with vestigial epilepsy. She complains of body aches, particularly in the right shoulder, left knee, back and neck. X-rays have not revealed any abnormalities. She has always had headaches, mostly in the back of the neck. Approximately 4 years ago, while in a shopping mall supermarket, Mrs. F. suffered a violent tachycardia, with feelings of faintness. She was taken to the hospital where a subsequent EKG did not disclose abnormalities. Mrs. F. works in governmental administrative offices, in the center of Lisbon for 16 years.

P. suffered from asthma until the age of 1 year. At the 5–8 months of age, he was medicated for reflux, and then again until he was 1 year old. At 8 months he suffered pneumonia. After the age of 1, he began to develop repeated ear infections that were not responsive to antibiotics. At age 3 he underwent ear surgery. At the age of 5, while at school, he lost his vision, and was taken to the hospital where the EKG revealed vestigial epilepsy. Nose bleeds without an apparent cause used to be frequent, but have subsided with age.

There is no history of rheumatic fever, nor is pericarditis present, nor is asbestos an issue. Given the above acoustical and medical data, the entire family received an echocardiogram because VAD was suspected.

2 METHODS

Echocardiogram was performed on this family using HP 1500 SONOS, 2-D, M mode, color Doppler analysis and spectral Doppler. All echocardiograms were recorded on VHS video tape, focusing on pericardial, aortic and mitral valve thickening, and qualitatively evaluated using a score system from 0 to 3 points: 0 points for no thickening, and 3 points for maximum thickening (6,7).

3 RESULTS

Pericardial thickening (the hallmark of VAD (8)) was identified in all family members: Mr. F. disclosed a 2 point pericardial thickening; Mrs. F. disclosed a 1 point thickening, and P. disclosed a 3 point pericardial thickening. E > A in all cases. Mrs. F. also exhibited thickened mitral valve leaflets (1 point), as did P. (3 points).

4 DISCUSSION

This family has been diagnosed with VAD, and is currently undergoing additional testing. This cardiac pathology is common to all LFN-exposed individuals, and was first observed, through echocardiography by Prof. T. Matoba (Japan), in 1983 (9). Today it is considered VAD-specific (8). The LFN response of biological tissue is associated with the abnormal proliferation of the extra-cellular matrices. This has been observed by this team in VAD patients through autopsy (10), echocardiography (2,6,7), electron microscopy of pericardial fragments (11-14), respiratory tract biopsy material (15,16), and in LFN-exposed animal models (17,19).

Neurological damage associated with VAD were the initial observations that triggered research into LFN-induced pathology among aeronautical workers (20). Epilepsy (20,21), rage reactions (22), balance (23) and movement disorders (24) have all been observed among VAD patients. Some have been associated with brain damage, as visualized through magnetic resonance imaging and event-related potentials P300 (25), and brainstem auditory evoked potentials (26).

Immunological changes induced by LFN have been documented in LFN-exposed workers (27), as well as in LFN-exposed rodents (28). Previous studies have suggested that noise-exposed workers are more prone to develop auto-immune disease (29-33). Among VAD patients, lupus (2,7) and vitilligo (7) are common findings. In lupus-prone mice, LFN-exposure accelerated of the onset of lupus and increased mortality (34).

Respiratory pathology, in smokers and non-smokers alike, is one of the most prominent features among LFN-exposed individuals (3,35,36). Electron microscopy studies of the respiratory tract of LFN-exposed rodents has already demonstrated that LFN targets the respiratory system (17-19,37). *In utero*, LFN-exposure causes irreversible damage to the respiratory epithelium, even after the animals are kept in silence for one year post-birth (17,18). Thus it is not surprising that P. would exhibit a more severe case of VAD than his parents, especially since he continues to be exposed post-birth.

The chronological evolution of signs and symptoms of VAD, as set forth for aircraft technicians, is based on an occupational exposure, i.e., 8 hours/day, 5 days/week (3). However, when the exposure is in the home, the occupational exposure schedule is not applicable. Exposure in the home can be more severe because of the amount of hours normally spent in the home, particularly when one sleeps, and for children. In other LFN environments, such as those found in submarines, on oil rigs, and in space, the occupational-schedule is also not directly applicable.

Although VAD was initially diagnosed in LFN-exposed workers, such as aircraft technicians (3,22) military (38) and commercial (2) pilots and flight attendants, a growing number of individuals are being diagnosed with VAD due to environmental LFN exposure (7,22,39). The issue of LFN-induced pathology can no longer remain restricted to the domain of Occupational Health, but must be included in Public Health concerns.

5 SUMMARY

VAD has been diagnosed in a family whose home is exposed to environmental LFN. These are not the first documented cases of environmentally-induced VAD. The results presented herein bring the issue of LFN-induced pathology into the realm of Public Health concerns.

ACKNOWLEDGEMENTS

The authors would like to thank all patients who have voluntarily contributed their time to our studies. Additionally, INVOTAN and the Escola Superior de Tecnologia de Setúbal (IPS) for continuous support. M. Alves-Pereira and J. Joanaz de Melo also thank IMAR (Instituto do Mar) for hosting project POCTI/MGS/41089/2001 and FCT (Fundação para a Ciência e Tecnologia) for its funding.

REFERENCES

[1] M. Alves-Pereira, M.S.N. Castelo Branco, J. Motylewski, A. Pedrosa and N.A.A. Castelo Branco, “Airflow-induced infrasound in commercial aircraft”, *Internoise 2001*, The Hague, Holland, pp. 1011-14, (2001).

[2] A. Araujo, F. Pais, J.M.C. Lopo Tuna, M. Alves-Pereira and N.A.A. Castelo Branco, “Echocardiography in noise-exposed flight crew”, *Internoise 2001*, The Hague, Holland, pp. 1007-10, (2001).

[3] N.A.A. Castelo Branco, "The clinical stages of vibroacoustic disease", *Aviation Space Environmental Medicine*, **70** (3, Suppl), pp. A32-9, (1999).

[4] M. Alves-Pereira, “Extra-aural noise-induced pathology. A review and commentary. *Aviation Space Environmental Medicine*, **70** (March, Suppl), pp. A7-21, (1999).

[5] M. Alves-Pereira, J. Reis Ferreira, J. Joanaz de Melo, J. Motylewski, E. Kotlicka and N.A.A. Castelo Branco, “Noise and the respiratory system”, *Revista Portuguesa. Pnumologia*, **IX**, pp. 367-79, (2003).

[6] W. Marciniak, J. Nóbrega, A. Bordalo e Sá, J.M.C. Lopo Tuna, M.S.N. Castelo Branco, M. Alves-Pereira and N.A.A. Castelo Branco, “Vibroacoustic disease induced by long-term exposure to sonic booms”, *Internoise 2001*, The Hague, Holland, pp. 1095-98, (2001).

[7] R. Torres, G. Tirado, A. Roman, R. Ramirez, H. Colon, A. Araujo, F. Pais, W. Marciniak, J. Nóbrega, A. Bordalo e Sá, J.M.C. Lopo Tuna, M.S.N. Castelo Branco, M. Alves-Pereira and N.A.A. Castelo Branco, “Vibroacoustic disease induced by long-term exposure to sonic booms”, *Internoise 2001*, The Hague, Holland, pp. 1095-98, (2001).

[8] B.D. Holt, “The pericardium”. In: *Hurst's The Heart*, (V. Furster, R. Wayne Alexander, & F. Alexander, eds.), McGraw-Hill, New York, 2001, pp. 2061-82.

[9] T. Matoba, “Increased left ventricular function as an adaptive response in vibration disease”, *American Journal Cardiology*, **15**, pp. 1223-6, (1983).

[10] N.A.A. Castelo Branco, "A unique case of vibroacoustic disease. A tribute to an extraordinary patient", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A27-31, (1999).
[11] N.A.A. Castelo Branco, A.P. Águas, A. Sousa Pereira, E. Monteiro, J.I.G. Fragata, F. Tavares and N.R. Grande, "The human pericardium in vibroacoustic disease", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A54-62, (1999).
[12] N.A.A Castelo Branco, A. Águas, A. Sousa Pereira, E.Monteiro, J.I.G. Fragata and N.R. Grande, "The pericardium in noise-exposed individuals", *Internoise 2001*, The Hague, Holland, pp. 1003-6, (2001).
[13] N.A.A. Castelo Branco, J.I.Fragata, A.P. Martins, E. Monteiro and M. Alves-Pereira, "Pericardial cellular death in vibroacoustic disease", *Proceedings 8th Intern. Conf. Noise as Public Health Problem (ICBEN)*, Rotterdam, Holland, pp. 376-377, (2003).
[14] N.A.A. Castelo Branco, J.I. Fragata, E. Monteiro and M. Alves-Pereira, "Pericardial features in vibroacoustic disease patients", *Proceedings 8th Intern. Conf. Noise as Public Health Problem (ICBEN)*, Rotterdam, Holland, pp. 380-381, (2003).
[15] J. Reis Ferreira, C.P. Mendes, N.A.A. Castelo Branco, E. Monteiro and M. Alves-Pereira, "The human trachea in vibroacoustic disease", *Proceedings 8th Intern. Conf. Noise as Public Health Problem (ICBEN)*, Rotterdam, Holland, pp. 388-389, (2003).
[16] J. Reis Ferreira, C.P. Mendes, N.A.A. Castelo Branco, E. Monteiro and M. Alves-Pereira, "The human lung and pleura in vibroacoustic disease", *Proceedings 8th Intern. Conf. Noise as Public Health Problem (ICBEN)*, Rotterdam, Holland, pp. 386-387, (2003).
[17] N.A.A. Castelo Branco, M. Alves-Pereira, J. Martins dos Santos and E. Monteiro, "SEM and TEM study of rat respiratory epithelia exposed to low frequency noise". In: *Science and Technology Education in Microscopy: An Overview, Vol. II* (A. Mendez-Vilas ed.) Formatex, Badajoz, Spain, 2003, pp. 505-33.
[18] N.A.A. Castelo Branco, E. Monteiro, A. Costa e Silva, J. Reis Ferreira and M. Alves-Pereira, "Respiratory epithelia in Wistar rats born in low frequency noise plus varying amount of additional exposure" *Revista Portuguesa Pneumologia*, **IX** (6), pp. 481-492, (2003).
[19] N.A.A. Castelo Branco, E. Monteiro, A. Costa e Silva, J. Martins dos Santos, J. Reis Ferreira and M. Alves-Pereira, "The lung parenchyma in low frequency noise exposed Wistar rats", *Revista Portuguesa Pneumologia*, **X**(1), pp. 77-85, (2004).
[20] N.A.A. Castelo Branco and E. Rodriguez Lopez E, "The vibroacoustic disease – An emerging pathology", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A1-6, (1999).
[21] GIMOGMA. [Epilepsy of vascular etiology, a clinical picture of vibration disease?] *Revista Portuguesa Medicina Militar*, **32**, pp.5-9, (1984). (In Portuguese)
[22] N.A.A. Castelo Branco, E. Rodriguez Lopez, M. Alves-Pereira and D.R. Jones, "Vibroacoustic disease: some forensic aspects", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A145-51, (1999).
[23] A.J.F. Martinho Pimenta, M.S.N. Castelo Branco and N.A.A. Castelo Branco, "Balance disturbances in individuals with vibroacoustic disease", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A96-99, (1999).
[24] A.J.F. Martinho Pimenta and N.A.A. Castelo Branco,"Facial dyskinesia induced by auditory stimulation. A report of four cases", *Aviation Space Environmental Medicine*, **70** (3, Suppl), pp. A119-121, (1999).
[25] M.G. Pimenta, A.J.F. Martinho Pimenta, M.S.N. Castelo Branco and N.A.A. Castelo Branco, "ERP P300 and brain magnetic resonance imaging in patients with vibroacoustic disease", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A107-114, (1999).
[26] M.S.N. Castelo Branco, N.A.A. Castelo Branco, A. Entrudo and J. Marvão, "[A standardization method of the brainstem auditory evoked potentials]", *Revista Sociedade*

Ciências Médicas de Lisboa, **149**, pp.214-220, (1985). (In Portuguese, Awarded the 1984 Ricardo Jorge National Public Health Award)

[27] A.P. Castro, A.P. Aguas, N.R. Grande, E. Monteiro and N.A.A. Castelo Branco, "Increase in CD8+ and CD4+ T lymphocytes in patients with vibroacoustic disease", *Aviation Space Environmental Medicine*, **70** (3, Suppl), pp. A141-4, (1999).

[28] A.P. Águas, N. Esaguy, A.P. Castro, N.R. Grande and N.A.A. Castelo Branco, "Effect low frequency noise exposure on BALB/C mice splenic lymphocytes", *Aviation Space Environmental Medicine*, **70** (3, Suppl), pp. A128-31, (1999).

[29] Y. Matsumoto, T. Yasue, N. Mizuno and I. Yoshida, "An immunoserological study of patients with vibration syndrome", *Occupational & Environmental Health*, **63**, pp. 357-9, (1992).

[30] Y. Matsumoto, M. Kawabe, T. Yasue, M. Yuguchi and I. Yoshida, "Two cases of scleroderma associated with vibration syndrome", *Japanese Journal Dermatology*, **99**, pp. 155-61, (1989).

[31] R.N. Jones, M. Turner-Warwick, M. Ziskind and H. Weill, "High prevalence of antinuclear antibodies in sandblasters' silicosis", *American Review Respiratory Diseases*, **113**, pp. 393-95, (1976).

[32] C.A. Soutar, M. Turner-Warwick and W.R. Parkes, "Circulating antinuclear antibody and rheumatoid factor in coal penumoconosis", British Medical Journal, **3**, pp. 145-7, (1974).

[33] M. Lippmann, H.L. Eckert, N. Hahon and W.K.C. Morgan, "Circulating antinuclear and rheumatoid factors in coal miners. A prevalence study in Pennsylvania and West Virginia", *Annals Internal Medicine*, **79**, pp. 807-11, (1973).

[34] A.P. Águas, N. Esaguy, A.P. Castro, N.R. Grande and N.A.A. Castelo Branco, "Acceleration of lupus erythematosus-like processes by low frequency noise in the hybrid NZB/W mouse model", *Aviation Space Environmental Medicine*, **70** (3, Suppl), pp. A132-6, (1999).

[35] J. Reis Ferreira, C.P. Mendes, M. Antunes, J. Martinho Pimenta, E. Monteiro, M. Alves-Pereira and N.A.A. Castelo Branco, "Diagnosis of vibroacoustic disease - preliminary report", *Proceedings 8th Intern. Conf. Noise as Public Health Problem (ICBEN)*, Rotterdam, Holland, pp. 112-14, (2003).

[36] J.M. Reis Ferreira, A.R. Couto, N. Jalles-Tavares, M.S.N. Castelo Branco and N.A.A. Castelo Branco, "Airflow limitations in patients with vibroacoustic disease", *Aviation Space Environmental Medicine* **70** (3, Suppl), pp. A63-69, (1999).

[37] N.A.A. Castelo Branco, P. Gomes-Ferreira, E. Monteiro, A. Costa e Silva, J. Reis Ferreira and M. Alves-Pereira, "Respiratory epithelia in Wistar rats after 48 hours of continuous exposure to low frequency noise," *Revista Portuguesa Pneumologia*, **IX**(6), pp. 474-9, (2003).

[38] N.A.A. Castelo Branco, E. Monteiro, M. Alves-Pereira, A.P. Águas, A. Sousa Pereira and N.R. Grande, "Morphological changes in the pericardia of military helicopter pilots", Proc. Microscopy Barcelona 2001, pp. 318-19 (2001).

[39] N.A.A. Castelo Branco, J. Reis Ferreira, M.C. Marques and M. Alves-Pereira, "Vibroacoustic disease: the impact of low frequency noise on quality of life", *ECQual-Journal European Commission on Quality of Life*, 2004 (In Press).