

FLUID SHIFTS: OTOACOUSTIC EMISSION CHANGES IN RESPONSE TO POSTURE AND LOWER BODY NEGATIVE PRESSURE

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INTRODUCTION

The purpose of the NASA Fluid Shifts Study is to characterize fluid distribution and compartmentalization associated with long-duration spaceflight and to correlate these findings with vision changes and other elements of the visual impairment and intracranial pressure (VIIP) syndrome. VIIP signs and symptoms, as well as postflight lumbar puncture data, suggest that elevated intracranial pressure (ICP) may be associated with spaceflight-induced cephalad fluid shifts, but this hypothesis has not been tested. Due to the invasive nature of direct measures of ICP, a noninvasive technique of monitoring ICP is desired for use during spaceflight. The phase angle and amplitude of otoacoustic emissions (OAEs) have been shown to be sensitive to posture change and ICP (1, 2), therefore use of OAEs is an attractive option.

OAEs are low-level sounds produced by the sensory cells of the cochlea in response to auditory stimulation. These sounds travel peripherally from the cochlea, through the oval window, to the ear canal where they can be recorded. OAE transmission is sensitive to changes in the stiffness of the oval window, occurring as a result of changes in cochlear pressure. Increased stiffness of the oval window largely affects the transmission of sound from the cochlea at frequencies between 800 Hz and 1600 Hz. OAEs can be self-recorded in the laboratory or on the ISS using a handheld device.

Our primary objectives regarding OAE measures in this experiment were to 1) validate this method during preflight testing of each crewmember (while sitting, supine and in head-down tilt position), and 2) determine if OAE measures (and presumably ICP) are responsive to lower body negative pressure and to spaceflight.

METHODS

Distortion-product otoacoustic emissions (DPOAEs) and transient evoked otoacoustic emissions (TEOAEs) were recorded preflight using the Otoport Advance OAE system (Otodynamics Ltd., Hatfield, UK). Data were collected in four conditions (seated, supine, 15 degrees head down tilt (HDT), and 15 degrees HDT with lower body negative pressure (LBNP)) to produce a range of ICP in each subject and test the susceptibility of OAEs to LBNP. LBNP was induced using the Russian Chibis suit to produce the same fit and pressures that would be experienced inflight during Chibis LBNP trials. Similar trials have occurred inflight on the ISS. A comparative analysis of preflight and inflight phase measurements and magnitudes was completed in both broad and narrow band frequency ranges.

RESULTS

TEOAE data demonstrated notable phase shifts from 859-1640 Hz when the seated baseline condition is compared to supine, HDT, and HDT plus Chibis conditions. Changes were particularly pronounced at low frequencies and were consistent with the expected ICP changes.

Preflight DPOAE magnitude data revealed changes consistent with increased ICP in two conditions at 1414 Hz, where a magnitude change (relative to the seated condition) was seen in the HDT position and in HDT plus Chibis.

DISCUSSION

OAEs revealed systematic changes in phase and magnitude throughout all test conditions (including use of Chibis LBNP) that were consistent with ICP changes. Results indicate that OAEs may provide a rapid noninvasive means of monitoring ICP changes. The first two subjects are projected to complete inflight testing on the ISS in early 2016, with the full complement of 10 subjects scheduled to be complete in 2018. Supported by NASA NNX13AK30G, NNX13AJ12G, and the Human Health and Performance Contract (HHPC).

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