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Computational simulation of the cupula behavior in vestibular pathologies of the inner ear

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Vertigo is reported as one of the most common symptoms in the world, commonly related with vestibular disorders. It is considered the third most frequent complaint in medicine, transmitting a sense of inadequacy and insecurity, mainly in elders. The aim of this work is to contribute to a better understanding on how the vestibular system works, mainly during vestibular rehabilitation process. This knowledge will help in the development of new techniques that will facilitate a more efficient rehabilitation. Vestibular rehabilitation consists in a set of exercises, known as maneuvers, that can reduce and even eliminate the symptoms of dizziness and imbalance associated with a vestibular disorder.

The finite element method (FEM) is a computational tool that allow the development and simulation of biological structures such as the inner ear. The FEM aim is to find solutions for a complex problem, usually dividing the problem domain into small parts called elements, with the same mechanical properties; which allows the analysis of displacements, stresses, torsions or other measurements in the structure after the simulation with the defined conditions.
The complexity of the vestibular labyrinth structures is a challenge for the model development, additionally, the fluid-structure interaction due the endolymph inside the canals is one of the main concerns in the simulation process.

A three-dimensional computational model of the vestibular system, containing the bio-fluids that promote the body balance, as the endolymph, will be built using the smoothed-particle hydrodynamics (SPH) method to simulate the fluid behavior. In SPH the domain is discretized by particles possessing constant mass. The other vestibular components, as the semicircular canals structure, the cupulas in each canal and the otoconia debris, in the case of a pathological case, which simulate the benign paroxysmal positional vertigo disease, will be discretized using the finite element method. The components will be meshed accordingly and boundary conditions will be applied mesmerizing the inner ear environment. All the considered material properties for the vestibular system components including the endolymph were obtained from the literature.
After all the conditions defined it will be possible to obtain all the biomechanical results related with the model simulation. Using ABAQUS software the numerical model of the vestibular system will be analyzed. The final computational model will be built using images from Magnetic Resonance Imaging (MRI), that will help to obtain a more realistic model, which allow to get more accurate results.

The vestibular numerical model will be used to optimize the standard maneuvers, which will permit to reduce the number of maneuvers and modify the intensity of the movements involved, and consequently attenuate the unbalance symptoms. Additionally, it will be studied the influence of the otoconia migration in the cupula behavior.

Keywords: Biomechanics, Vestibular System, Computational, Finite Element Method

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W276S/W276S mutation in KCNQ4 causes vestibular dysfunction after acceleration stimulation via hair cell degeneration

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Objective

KCNQ4 mutation causes autosomal dominant progressive hearing loss. A vestibular phenotype of this kind of mutation have not been clearly identified. This study was performed to investigate if a mutation of W276S/W276S in KCNQ4 causes vestibular dysfunction in animal model and human.