Frequency Response of the Human Brain Substructures During Helmeted Side Impacts

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Sport-related mild traumatic brain injury (mTBI) is one of the causes of morbidity in athletes, which can be prevented by using protective headgears such as helmets [1]. Helmets are designed to mitigate the head kinematics during an impact [1], while the recent studies have emphasized the importance of the brain substructure dynamics in concussion mechanism [2]. Characterizing the dynamics response of the brain during impacts has shown the existence of localized modes and multi-modal behavior in the brain [2]. Therefore, it is crucial to consider the differential brain substructure biomechanics in helmet design instead of focusing only on head kinematics. Here, we performed side impact tests to a Hybrid III anthropomorphic head-neck system. We tested a bike helmet and a hockey helmet three to compare their effectiveness in mitigating the head kinematics, and the resultant frequency response of the brain. The head kinematics were imported to the Global Human Body Models Consortium (GHBMC) skull-brain model in the LS-Dyna environment to simulate these impacts. We analyzed the modal behavior of the corpus callosum, brainstem, and the brain based on the relative displacement of each region with respect to the skull [2]. In corpus callosum and the brain, the first dominant mode frequency was at the frequency regime of 20-30 Hz in both helmets. This range of frequency is important to us, since in previous studies, it was reported that the brain is more susceptible to injury for vibrations within this frequency [2, 3]. The dynamic range of the bike helmet was larger compared to the hockey helmet. Looking into the dynamic frequency response of the brain, our results showed that in the corpus callosum and the brainstem, which have been reported as vulnerable regions in injury, the modal amplitude around the frequency regime of 20-30 Hz was higher in hockey helmet compared to the bike helmet. In the brainstem, the first harmonic of the bike helmet was at the same frequency regime. In all regions, the second harmonic in the bike helmet was not visible, but in the brainstem and the brain, it was around 60-70 Hz for the hockey helmet. Our results suggested that the tested hockey and bike helmets cannot dissipate frequency components of the brain around 20-30 Hz.

References:

[1] Hoshizaki, T. B, & Brien, S. E, *Neurosurgery*, 2004.

[2] Laksari, K, et al., Physical Review Letters, 2018.

[3] Abderezaei, J, et al., Physical Review Applied, 2019.