

# Listen to the Brain to Suss Out Concussions

By Nina Kraus, PhD, and Travis White-Schwoch

**A**n estimated 2 million to 4 million sports-related traumatic brain injuries (TBI) occur annually in the United States (*J Head Trauma Rehabil.* 2006;21[5]:375). The Centers for Disease Control and Prevention estimates that about 5.3 million Americans are living with long-term disabilities associated with TBI (*J Head Trauma Rehabil.* 2006). A major subclass of these injuries is concussion, defined as a diffuse, non-penetrating brain injury following a sudden impact (*Nat Rev Neurol.* 2015;11[4]:230). A person can get a concussion in any circumstance, but those suffered a concussion from playing sports have received tremendous public interest. Prominent athletes have retired following serious concussions, and a growing number of reports link repeated concussions or subconcussive head impact to lasting brain damage. Even former President Barack Obama weighed in, famously saying that if he had a son, he would not let him play professional football (CBS Sports, Jan. 2014).



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This public attention has motivated increased research into concussion science. However, there is currently no single test to identify a concussion. A clinician must consider an array of potential symptoms. And what is perhaps even more challenging is the lack of a gold standard test to indicate when an individual has completely recovered from a concussion.



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## FFR FOR CONCUSSION IDENTIFICATION

We tested a new approach to identify concussions: the frequency-following response (FFR), an electrophysiological measure of sound-evoked synchronous neural activity.

Making sense of sound is one of the brain's most difficult tasks, and an individual suffering from a concussion struggles to understand sound in complex listening environments. These observations motivated the hypothesis that measuring fine-grained neural processes could indicate the presence of a concussion.


To test this hypothesis, we measured the FFRs of adolescents diagnosed with a concussion in a sports medicine clinic (*Nature: Sci Rep.*

2016;6:39009). We found that neural responses to the fundamental frequency (F0) were disrupted after a concussion—they were about 30 percent lower and more sluggish than in healthy controls. The F0 is an important pitch-bearing cue for identifying sounds. For example, male and female voices are distinguished by their F0s; thus, tracking a speaker's F0 can facilitate speech understanding in a difficult listening situation. It makes sense, then, that the neural processing of this sound feature, and not others, is disrupted by a blow to the head. And discussed in previous columns in *The Hearing Journal*, the strength of coding the F0 tracks the ability to understand speech in noise (*Hear Res.* 2013;300:18).

We then tried to use the FFR to identify individuals with concussions, and found that the FFR accurately identified 90 percent of concussion patients and 95 percent of control patients. The FFR also tracked the symptom severity of a concussion; children, who reported the greatest symptom

loads from injuries, had the lowest F0 responses. Additionally, we found that the FFR to the F0 improved as patients recovered, suggesting that FFR can be used to track recovery.

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Concussion management is best tackled by an interdisciplinary team, including physicians, athletic trainers, and speech-language pathologists. But with the introduction of this measure of brain sound processing, audiologists may be able to collaborate with these health professionals in identifying and managing concussions. Our hope is that this discovery provides a new tool for clinical teams to make the best health decisions for athletes and sports enthusiasts. 

### FFR FOR CONCUSSION MANAGEMENT

The FFR has many features that make it an attractive approach to augment concussion management. It is a fast and portable test, with available norms for patients of different ages (*Cereb Cortex*. 2015;25[6]:1415). It also has a good test-to-test reliability. Perhaps the most useful feature of FFR for concussion management is that it does not require patients to do anything during the test—patients may sleep or watch a movie while the test is going on. Compared with other cognitive and behavioral tasks, FFR testing assures objective monitoring of concussions as patients cannot will themselves to perform at a certain level when undergoing this test. This is notably a distinctive and beneficial feature of FFR. Moreover, this test indicates meaningful individual differences in sound processing, making it an excellent approach for longitudinal monitoring. For example, an athlete could receive a baseline FFR prior to engaging in activities and be tested for deviations whenever a concussion is suspected.

While these results are promising, it is important to acknowledge that this study was just a proof of concept. The next step is to replicate these findings in a larger and more diverse sample. Should the FFR pan out as an approach to identify concussions, there are many potential outlets for its use. For example, the FFR could be used to track an individual's recovery from the concussion. When the brain response normalizes to a patient's pre-injury baseline, it might signal that it is safe for that individual to resume full participation in sports. The FFR could also be an approach to arbitrate between different concussion management strategies. For example, brain rest might be the best approach for some patients, whereas other patients might need exercise or cognitive rehabilitation.