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Soccer STAR Methodology

Laboratory Tests

A custom impactor was used to test soccer headgear under head-to-head conditions which are known to be associated with the highest risk of concussion in soccer (Figure 1) [1]. The impactor consists of two NOCSAE head and Hybrid III neck configurations on 16 kg sliding masses to represent the head, neck and torso of 50th percentile males. Test conditions were based off video recorded by Withnall [1] and include two locations (Table 1) and three velocities (2, 3, and 4 m/s). Headgear samples were positioned according to package directions on the struck head which was also instrumented with three linear accelerometers and a triaxial angular rate sensor. Each test configuration was repeated twice with two headgear samples. Data were sampled at 20,000 Hz and filtered using a 4-pole Butterworth low pass filter with a cutoff frequency of 1650 Hz (CFC 1000) for accelerometer data and 256 Hz (CFC 155) for angular rate sensor data.

The same test conditions (two locations and three velocities for two trials each) were performed without headgear to be used as the control scenario. Results of the headgear impacts were compared to the bare head impacts in determining the final STAR rating.

Figure 1: Head-to-head impactor include two head and neck assemblies on sliding masses. An additional sliding platform is located behind the striking head to propel the sliding torso mass and prevent neck extension during acceleration down the rail. The striking headform is attached to a cable and pulley system that accelerates the torso mass by a set of connected falling weights.

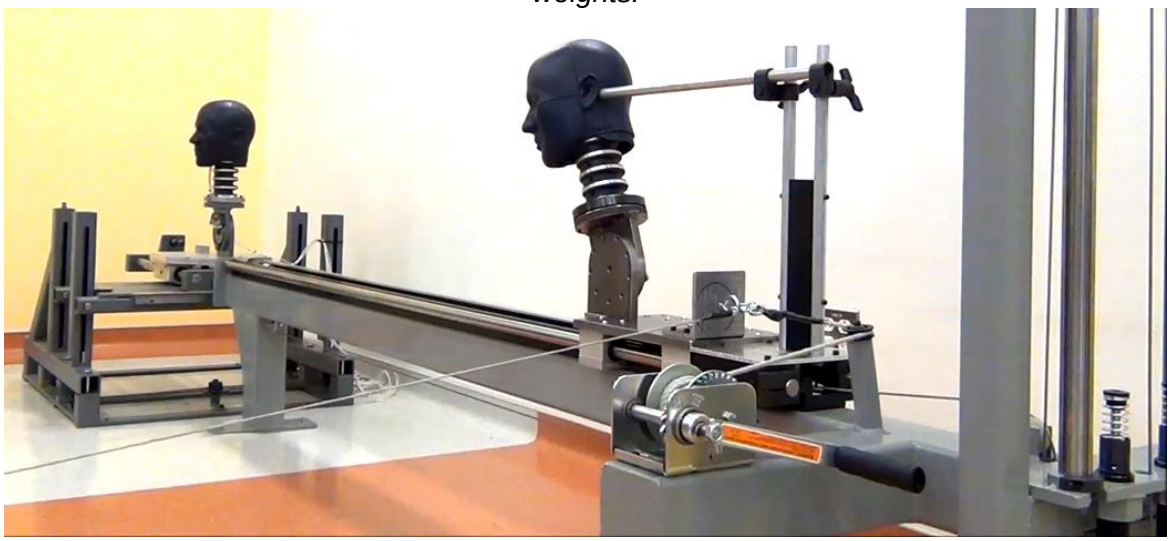

Table 1: NOCSAE headform translations and rotations on the linear slide table for each test condition.

Headform	Location	Y (cm)	Z (cm)	Ry (deg)	Rz (deg)
Struck (instrumented, headgear worn)	Side	+1	+3.5	0°	+90°
	Back	+3.8	+5	0°	+157.5°
Striking (not instrumented, no headgear worn)	Front Boss	0	0	+20°	-50°

Note: All measurements were made using the SAE j211 coordinate system in relation to a "zero" condition in which both headforms were in a position of 0° Y and Z-axis rotation and the median (midsagittal) and basic (transverse) plane intersection of the headforms were aligned with headforms facing each other.

STAR Ratings

The following equation describes the STAR value used to rate each headgear. This equation was developed to represent the predictive concussion incidence of one player over a season [2]. It has been adapted to instead provide the amount of reduction of concussion incidence when wearing headgear compared to a bare-head condition. The equation uses laboratory tests that represent the range of on-field impacts seen in soccer, and associates with each impact the amount of times it would occur over one season (exposure) as well as the associated probability of a concussion (risk). The STAR value is found by multiplying the predicted on-field exposure (E) at each impact location (L) and velocity (V) by the risk of concussion (R) for that impact using the peak resultant linear acceleration (a) and rotational acceleration (α) from laboratory impacts (Equation 1).

$$STAR = \frac{\sum_{L=1}^{2}\left(\sum_{V=1}^{3} E(L,V) \bullet R(A,\alpha)\right)_{HG}}{\sum_{L=1}^{2}\left(\sum_{V=1}^{3} E(L,V) \bullet R(A,\alpha)\right)_{BARE}} \quad \text{(Eq. 1)}$$

Each impact was given an exposure value of 1, indicating that each impact is rare in soccer and each has an equal chance of occurring at any time. Risk of concussion was obtained from a multivariate logistic regression analysis of instrumented American football player data paired with diagnosed concussions (Equation 2) [3]. The risk of concussion (R) takes into account both linear (a) and rotational (α) components of acceleration which are both known to be associated with brain injury [4].

$$R(a,\alpha) = \frac{1}{1 + e^{-(-10.2 + 0.0433*a + 0.000873*\alpha - 0.00000092*a\alpha)}} \quad \text{(Eq. 2)}$$

Headgear results were summed together and divided by the summed results of the bare head condition. The resulting STAR values range from 0 to 1, with 1 being the bare head condition. The STAR values were further broken into number of stars (1 to 5) for ease of understanding for consumers (Table 2).

Table 2: Thresholds to match STAR values to number of stars in a 5-star rating scale.

STAR Value	Number of Stars
0.0 – 0.3	5
0.3 – 0.5	4
0.5 – 0.7	3
0.7 – 0.9	2
0.9 – 1.0	1

References

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