MODIFIED METHODOLOGY TO DETERMINE HEAD ACCELERATION IN HEAD-TO-BALL COLLISIONS IN SOCCER

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INTRODUCTION

The cumulative effect of repetitive subconcussive head impacts with the soccer ball may lead to neurological dysfunction and permanent brain damage. Accurate information on head acceleration is therefore essential in reaching the ultimate goal of designing appropriate head protection devices. This paper proposes a set of features to be added to the test models in order to better predict the dynamics of the head/neck ensemble for the real conditions seen in a soccer game. The new features include the capability to adjust the elastic constant of the neck under bending loads in the sagittal plane and the inclusion of added linear resistance simulating the torso participation in the impact.

METHODS

The experimental evaluation was performed on a Hybrid III male head/neck model instrumented with a linear, single-axis accelerometer placed in the center of gravity of the head. The direction of impact was restricted to the front of the model's head only. By tilting the model, the elevation angle varied between 0 and 30 degrees. In some tests, the head model was removed from the neck and mounted on a rotating plate fitted with a spring opposing its rotation. In others, it was mounted on a sliding carriage that simulated the added resistance of the torso in the process of heading the ball. To account for the skill level, muscle strength, and heading technique, the resistance opposed to head movement was simulated by a spring attached to the carriage.

Acceleration data was recorded using a data acquisition system. Baseline data was initially gathered using the head/neck model without headgear. Some of the impact tests were also replicated using a commercially available headgear.

Data analysis was performed on the experimentally generated acceleration curves. A computer code was developed to estimate the following parameters: (*i*) peak acceleration; (*ii*) characteristic time length of the impact; (*iii*) average slope for the rising portion of the curve, and (*iv*) the similarly defined average slope for the descending portion of the curve.

TABLE 1 Head rotation, spring, 0 degrees

Speed (m/s)	Acceleration Peak (g)		
	No spring	Spring	% Decrease
3	8.0	7.6	5.0
9	15.6	14.1	9.6
15	24.8	23.4	5.6

RESULTS

Table 1 shows the acceleration peaks recorded on the head model that first rotated freely in the sagittal plane, and then was fitted with a spring opposing its rotation. Addition of the spring reduced the acceleration peak between 5.0% and 9.6%. The acceleration rate did not change significantly.

A different set of results was generated for tests where the ball approached the head model at a 30-degree elevation angle (table not included in this abstract). The relative decrease in peak acceleration was between 8.6% and 19.5%, always lower when the spring was used. Acceleration rates were also decreased between 0 and 12.5%.

With the model mounted on the sliding carriage, acceleration was compared between spring and no-spring cases (Table 2). Adding the spring reduced peak acceleration between 2.0 and 14.2% and acceleration application rate between 13.8 and 24.0%. Relative differences were higher at higher ball speeds.

The tests were repeated with a protective soccer headgear mounted on the head model. Compared to no-gear cases, acceleration peak decreased between 8.4% and 32.1% while acceleration onset rate decreased between 6.0% and 34.7%.

CONCLUSIONS

1. Addition of a spring limiting head rotation in the sagittal plane (strength, prepared player) reduces head acceleration.

2. Addition of a spring opposing translation (upper body added mass, prepared player) reduces head acceleration.

3. The maximum head acceleration occurred for the setup with no resistance to head rotational motion and no resistance to upper torso translation.

4. It is proposed to modify the existing models to account for different player's strength and skill level. New features include ability to control resistive torque at the head pivot as well as upper body dynamics.

TABLE 2 Base of neck translation spring, 0 degrees

Speed (m/s)	Acceleration Peak (g)		
	No spring	Spring	% Decrease
3	10.2	10.0	2.0
9	26.6	23.0	13.5
15	43.6	37.4	14.2