Does Soccer Ball Heading Cause Retinal Bleeding?

William F. Reed, MD; Kenneth W. Feldman, MD; Avery H. Weiss, MD; Alan F. Tencer, PhD

Objectives: To define forces of youth soccer ball heading (headers) and determine whether heading causes retinal hemorrhage.

Setting: Regional Children’s Hospital, youth soccer camp.

Patients: Male and female soccer players, 13 to 16 years old, who regularly head soccer balls.

Measurements: Dilated retinal examination, after 2-week header diary, and accelerometer measurement of heading a lofted soccer ball.

Results: Twenty-one youth soccer players, averaging 79 headers in the prior 2 weeks, and 3 players who did not submit header diaries lacked retinal hemorrhage. Thirty control subjects also lacked retinal hemorrhage. Seven subjects heading the ball experienced linear cranial accelerations of 3.7 ± 1.3g. Rotational accelerations were negligible.

Conclusions: Headers, not associated with globe impact, are unlikely to cause retinal hemorrhage. Correctly executed headers did not cause significant rotational acceleration of the head, but incorrectly executed headers might.


Soccer has been reported to cause between 146,000 and 160,000 injuries requiring emergency department care in the United States annually.1 In Orlando, Fla, 13 youths had eye injuries caused by soccer balls. One had retinal hemorrhage and 5 had retinal edema.2 However, all 10 who had a clear injury history had sustained direct blunt impact to the globe. Because of these concerns, the American Academy of Pediatrics Committee on Sports Medicine and Fitness1 has recommended caution with soccer ball heading (headers) and use of protective eyewear for youth soccer players.

Brief periods of repetitive whiplash, during which the brain is accelerated in one and then the opposite direction, with or without accompanying impact, are believed to be the mechanism causing concussion and subdural bleeding in infants and toddlers with inflicted head injury.3,4 Retinal hemorrhage has been reported to accompany brain injury in 30% to 100% of these children with inflicted head injury.5 Motor vehicle passenger injuries, which include cranial whiplash, also are a rare cause of retinal hemorrhage.6 Adult primate head injury studies of single cranial whiplashes, both with and without cranial impact, did not establish thresholds for retinal damage.7 The mechanics of soccer ball heading might induce cranial whiplash events sufficient to cause retinal hemorrhage.

The primary purpose of our study was to determine whether there is a significant incidence of retinal hemorrhage among adolescents who head the soccer ball. We chose to study young adolescents because they have the strength to generate kicked balls of high velocity but might not yet have fully developed neck muscle strength or header technique. They also still have sufficient vitreous fibril, firmly adherent to the retina, to allow vitreoretinal traction to cause retinal bleeding.8 A second purpose of the study was to determine the forces that are experienced by youths heading the soccer ball.

RESULTS

PLAYER RETINAL EXAMINATIONS

Twenty-one players kept a 2-week header diary and underwent a retinal examination immediately at the end of that period. Eighteen were adolescent boys and 3 were adolescent girls. The “U” group-
SUBJECTS AND METHODS

PLAYER RETINAL EXAMINATIONS

Youth soccer players aged 13 through 16 years who regularly performed headers were recruited. The players played predominately on upper-skill level teams. For 2 weeks prior to a dilated retinal examination, they kept a diary of header frequency and whether these headers were performed during practice or game conditions. Thirty youths from the same age group coming to the ophthalmology clinic for evaluations of conditions not known to be predisposed to retinal disease were used as controls. Players and controls were evaluated from January 1, 1998, through December 31, 2000.

ACCELEROMETER STUDY

Biomechanical testing was conducted while youths headed a soccer ball. They were highly motivated participants at a summer youth soccer camp conducted by W. Dean Wurzberger, coach of the University of Washington men’s soccer team. A size 4 soccer ball was lofted to the players from 3 m away by one of the camp’s coaches. The players performed the header from an initial standing position.

They were fitted with light, inelastic plastic headgear to which accelerometers were attached (Figure 1). Two uniaxial accelerometers (PCB Piezoelectronics Inc, Depew, NY) were attached to a circumferential plastic band near each temporomandibular joint (TMJ), which is close to the center of gravity of the head in the sagittal plane. One accelerometer of each array recorded local vertical (Z) and the other measured horizontal (X) acceleration. Additionally, a triaxial accelerometer was fixed to a sagittal band of the plastic headgear near the apex of the head so that it formed a vertical plane with the TMJ accelerometers. Signals were filtered and collected at a 2-kHz sampling rate by a laptop computer (PowerMac G3; Apple Computer Co, Cupertino, Calif) with an 8-channel analog/digital converter, PCMCIA card, and Labview software (National Instruments, Austin, Tex).

Raw accelerometer signals were forward and reverse filtered using a fifth-order Butterworth digital filter implemented in Labview according to standard protocols (SAE J211; Society of Automotive Engineers, Detroit, Mich) with a cutoff high-pass frequency of 600 Hz. From the filtered data, the peak X linear acceleration was determined. Because the TMJ accelerometers were located at approximately the center of gravity of the head, any difference in X acceleration between the TMJ and the crown of the head could be divided by the known distance between the instruments to obtain angular acceleration. However, angular accelerations were small, as confirmed by video recording of each test. The video showed the subjects tensing their neck muscles and moving the head and torso in unison toward the ball. The linear accelerations of the left and right accelerometers were averaged, then averaged again for the 5 test runs conducted on each subject.

HUMAN SUBJECTS

The institutional review board of The Children’s Hospital and Regional Medical Center approved all aspects of the study. These study players received a $20 reimbursement for their participation in each study phases. Results were evaluated by simple descriptive statistics.

ACCELEROMETER STUDY

Seven adolescents, including six 13-year-old boys and one 16-year-old girl, participated in the biomechanical study. The lofted ball speed, estimated from videotapes of the header trials, was 6.7 m/s. The mean peak linear, horizontal cranial acceleration subsequent to ball impact was $3.7 \pm 1.3 g$ (range, 1.7-8.8g). Based on the impact duration and greatest peak linear acceleration observed, this would result in a Head Injury Criteria score of 61. Cranial rotational acceleration was negligible. The tested players used proper heading technique of tensing the neck muscles and meeting the ball with the upper body as a single unit. Body rotation was centered at the hips.

A previous photoanalysis of a skilled adult performing headers confirmed that the player’s head was fixed in line
with the trunk by tensed neck muscles. The player’s head met the ball in essentially a straight line, and the body’s flexion point was at the hip. We observed a similar technique in adolescents (Figure 2). An improperly executed header uses only rotation of the head on the neck to meet the ball; the neck muscles are not tensed. In the first case, the entire mass of the upper body meets the ball, whereas in the latter, the head mass alone strikes the ball. With correctly performed headers, cranial acceleration is indirectly related to the ratio of the player’s upper body mass to the ball’s mass and deformability and directly related to the ball’s velocity. An adolescent’s cranial mass is about 9% of total body weight, while body mass from the hip to the crown of the head is about 70%.

“Light heading” is first introduced into basic soccer skills training at the U10 level in Washington State. Children aged 8 to 10 years play with a 240- to 300-g number 3 ball. Through the U13 level, the game is played with a number 4 ball, weighing 330 to 390 g. From the U14 level and up, adolescents play with a number 5 ball, weighing 420 to 480 g. This would result in a head-to-ball mass ratio of 12 for an average sized 13-year-old boy. If the same player used the entire upper body to meet the ball, the upper body to ball mass ratio would be 93. Compared with the header using the head alone, this is nearly an 8-fold shift of the mass ratio in favor of reduced cranial acceleration. It would then be predicted that an improperly executed header would be more likely to cause brain and retinal injury than a properly executed one.

Kicked soccer balls have been reported to travel at 7 to 36 m/s.10-13 The ball speed of our accelerometer study is at the low end of these kicked ball speeds. Computer simulation has suggested that adults heading a soccer ball traveling at 10 m/s experience a 19g linear cranial acceleration and 366 radian/s² angular acceleration.10 No estimates are reported for children. Schneider and Zernicke10 suggested that the upper limit of adult brain tolerance for rotational cranial acceleration induced by a headed soccer ball would be 1800 radian/s². Since injury thresholds are extrapolated from the animal data based on cranial mass and are lower for larger masses, the injury thresholds for rotational acceleration in adolescents should be slightly higher than for adults.7 In primate studies, prevention of cranial rotation by a cervical collar, which allowed only linear or translational acceleration, increased the head injury thresholds by 50%.7 Current US Department of Transportation Head Injury Criteria specific to translational cranial acceleration involve a complex association of the integral of the cranial acceleration pulse and its time course.14 The greatest translational acceleration we recorded resulted in a Head Injury Criteria of 61; this is negligible compared with the threshold for brain injury of a score of 1000 or more.

The current leading proposed mechanism for retinal injuries in rotational head trauma is that whiplash acceleration forces are translated through the vitreous body. Vitreous fibrils are attached along the inner retina where the retinal vessels are located. They are most dense at the posterior pole and ora serrata retinae. As the vitreous humor moves away from the retina, tension shears the vessels resulting in retinal bleeding and, at the extreme, retinoschisis. This is suggested to be a direct result of the acceleration exerted on the globe by cranial whiplash with or without impact, not an indirect consequence of brain injury, intracranial hemorrhage, and/or increased intracranial pressure.6 Fibrils connecting the retina to the vitreous humor degenerate with increasing age.13 However, young adolescent soccer players still have firm vitreous attachments,8 so they might be at risk for retinal bleeding from whiplash acceleration forces from heading the soccer ball. The relatively small number of players who had retinal examinations after 2 weeks of play leaves an upper statistical possibility of a 12.5% incidence of retinal hemorrhage.16

By intention, our subjects are likely to include the most motivated and skilled players for their age. We chose

Figure 2. A, A 12-year-old boy soccer player assumes a tensed stance in preparation for ball impact. B, Neck muscles are tensed and hips flex immediately prior to impact. C, After impact, the neck muscles remain tensed and hips straightened owing to entire upper body being used to accelerate the ball.
Although eye injuries occur in soccer due to direct globe impact, it was unknown whether headers indirectly cause retinal hemorrhage. Players performing headers were prospectively evaluated. Headers could not be documented to cause retinal hemorrhage. Forces of youth soccer headers were evaluated. The relatively low-velocity balls studied did not cause rotational cranial acceleration. The accelerations we observed are unlikely to cause eye or brain injury.

Our biomechanical study demonstrates only linear cranial acceleration with headers; we can surmise that greater forces than those of lofted balls would be required to cause significant rotational acceleration of the player's head. These results and the direct retinal examinations are reassuring that headers are unlikely, barring globe impact, to cause retinal injury in youth.