Cycling and the Motor Sports

Cycling, high-speed-non-motor, and the motor sports are significant causes of visual problems from intracranial injuries to the optic nerves, chiasm, and optical pathways from extreme impact energy to the head. BMX bikers are primarily males (74%) in the 6 to 17 year age group, Of the 3.7 million BMX bikers, 1.1 million participate more than 52 times a year. Mountain biking participants number 7.4 million (70% male, 1.7 million more than 25 times a year). Bicycling as a primary fitness program involves 1.9 million (52% females), and there is a huge, uncounted population of recreational cyclists and motorcyclists. Snowmobiling has 6.8 million participants (56% male, 1.5 million more than 15 times a year). [1]

Cycling

Each year, about 900 people in the United States are killed by bicycle crashes, which occur once for about every 4,500 riding miles. Of the 567,000 (350,000 under age 15) emergency room visits because of bicycle injuries, 130,000 were to the head. [2] Eye injuries, including ocular contusion injuries, luxation of the ocular globe, [3] foreign bodies, traumatic optic neuritis, [4, 5] result from flying debris, crashes and falls. The USEIR database has six eye injuries: one open globe from falling on a stick, one shot with a BB while riding a bicycle, two serious lid lacerations, one orbital fracture, and one vitreous hemorrhage. [6] Cyclists, especially children who suffer the majority of serious head injuries from bicycling accidents, would avoid most head, face and eye injuries if they wore adequate head protection whenever they rode. Bike helmets reduce the risk of head injury by 85%. The universal use of helmets by all bicyclists would prevent one death every day and one head injury every four minutes. [7-15]

A layer of stiff foam in the helmet reduces the peak energy of a sharp impact by crushing. The spongy foam inside a helmet is for comfort and fit, not for impact. The helmet should be brightly colored for visibility and must fit level on the head, touching all around, comfortably snug but not tight. The helmet should not move more than about an inch in any direction, and must not pull off no matter how hard the cyclist tries. A helmet should not have: snag points sticking out, a squared-off shell, inadequate vents, excessive vents, an extreme "aero" shape, dark colors, thin straps, complicated adjustments, or a rigid visor that could snag in a fall.

A sticker inside the helmet tells what standard it meets. Helmets made for US sale after 1999 must meet the US Consumer Product Safety Commission standard. ASTM's standard F-1447 is comparable. Snell's B-95 and N-94 standards are tougher but seldom used. The weak ANSI Z90.4 standard is inadequate. Replace any helmet if you crash. The Bicycle Helmet Safety Institute (http://www.bhsi.org/), from which the above paragraphs were abstracted, constantly updates helmet information.

Many cyclists have constant gritty eye irritation from wind and sun exposure, especially when traveling at high altitude in arid regions. Although a lubricating ointment will give temporary relief from dry eye symptoms, the best protection is a good pair of polycarbonate lenses that shield the eyes from dust, dirt, wind, and UV light. Eye protection certified to the high-velocity/high-mass specifications of ANSI Z87, the specifications of ASTM F803, or the military eyewear fragment specification would protect from flying road debris and would add to the protective effect of the helmet for the eyes in case of a crash.

Most bicycle injuries could be prevented if bicyclists (1) avoid loose sand or gravel, especially when turning or going downhill; (2) avoid riding double; (3) properly maintain their bicycles; (4) wear protective clothing, including helmets; (5) obey basic traffic laws; and (6) use lights and reflectors and wear light-colored clothing. [16, 17] Cyclists should be separated from motor vehicles as much as possible and children should delay cycling until developmentally ready. [18] Long, competitive races require an extensive medical support network with safety regulations, such as the mandatory use of helmets. The US Cycling Federation (USCF) requires that riders wear helmets. In 8 years of competition, 606 riders broke many helmets in crashes each year but only two serious head injuries were recorded. [19]

Batteries

Common to most vehicles is the storage battery, which can explode and cause open globe injuries, surface and intraocular foreign bodies, and chemical burns. [20-25] Strict adherence to Prevent Blindness America jump-start instructions could prevent almost all battery explosion eye injuries, which also could be life saving if the vehicle is an all-terrain or snowmobile in a remote location. To safely jump-start a dead battery:

a. keep sparks and flames away from batteries at all times;

b. wear safety goggles conforming to ANSI Z87;

c. be sure vent caps are tight (if available place a damp cloth over the vent caps), battery fluid is not frozen, both electrical systems are of the same voltage, and the vehicles are not touching;

d. using cables and clamps specifically designed for jump starting a battery, clamp in the sequence (1) one end of first cable with care to only touch the battery terminal, to positive (+) terminal of dead battery, (2) other jumper end of first cable to positive (+) terminal of good battery, (3) one end of second cable to negative (-) terminal of good battery, (4) make final connection on engine block of stalled engine (not to battery negative post) away from battery, carburetor, fuel line, any tubing or moving parts;

e. start vehicle with good battery then the disabled vehicle;

f. remove cables in reverse order, starting by first removing cable from engine block or metallic ground. [26]

Batteries explode because a spark ignites the hydrogen gas that is often present in the vicinity of a battery and in the battery cells. Remembering that the last connection in the jump start sequence always sparks, and that the last connection is always to a ground away from the potentially explosive hydrogen gas will help one remember the proper sequence. Safety goggles and the jumper cables should be kept together.

All-terrain vehicles

The vast majority of all-terrain vehicle accidents involve males younger than the age of 30. Because of the high incidence of injuries to the face and head, and accidents associated with poor judgment and alcohol, protective headgear, as well as training and abstinence from alcohol while driving, are advised. [27, 28] Because of increasing catastrophic spinal injuries to children, it has been suggested that the use of off-road vehicles should be limited to those who hold a valid driver's license or who have passed a test certifying that they understand the risks associated with these vehicles. [29] Helmets with integral face and eye protection would decrease the incidence of facial fracture and ruptured globes. [30]

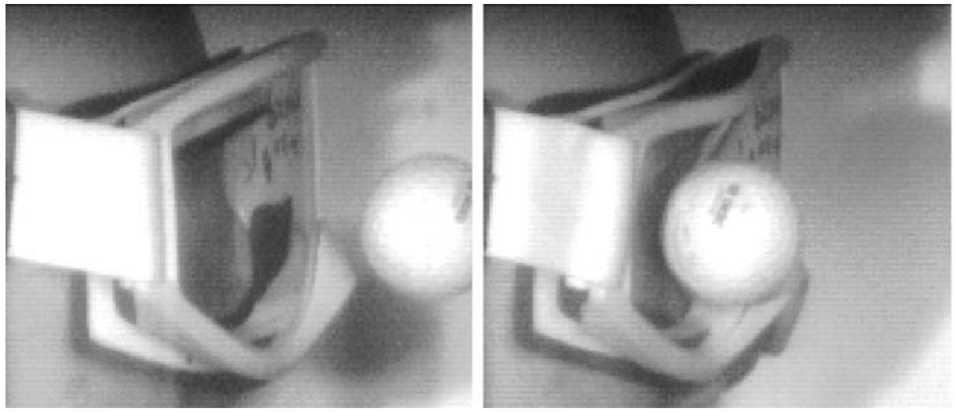
Automobile racing

Championship Auto Racing Teams (CART) have an accident frequency of one per 1,414 miles of racing with one injury per 9.5 accidents. The rate of accidents at the Indianapolis Motor Speedway is less at one per 3000 miles raced, but the frequency of injury was higher at one injury per 3.2 accidents. Despite speeds of 200 miles per hour, most automobile racing injuries are limb, rather than life, threatening. [31] This is due to sophisticated race car design and safety equipment, which includes a driver's helmet in compliance with the Snell Institute standards [32] fire-retardant clothing, restraining harness, fire extinguisher system, and (optional) compressed air supply to create positive pressure within the helmet to keep out smoke and fumes. [33] The combination of high gravitational forces plus harness compression in car-flipping accidents has resulted in acute retinal angiopathy, with minimal injury elsewhere, to five drivers. Although good visual acuity recovered, these drivers had evidence of permanent retinal vasculature and anatomic changes that resulted in scotomas, color vision defects, and changes in contrast sensitivity. [34] Considering the magnitude of the forces involved, it appears that the potential for eye injury has been reduced to an acceptable minimum with present safety equipment.

Motorcycling

Mandatory helmets reduce head injuries to motorcyclists. [35-38] Faceguards attached to the helmet add a significant degree of eye and face protection. [39] Motorcycle goggles ***figure 32*** decrease the incidence of pingueculae, pterygia, keratitis, and ocular foreign bodies in motorcycle riders. [40, 41] The US Supreme Court in the 1972 case of Simon v. Sargent upheld the concept that society has the right to mandate protective equipment that appears, on the surface, to affect only the individual. "From the moment of injury, society picks the person up off the highway; delivers him to a municipal hospital and municipal doctors; provides him with unemployment compensation if, after recovery, he cannot replace his lost job, and if the injury causes permanent disability, may assume the responsibility for his and his family's subsistence. We do not understand a state of mind that permits a plaintiff to think that only he himself is concerned." [42]

Figure 32. Motorcycle goggles



Impact on a motorcycle goggle by a golf ball at 60mph. This simulates hitting a flying piece of gravel. The goggle remains intact and there is no eye contact.

Snowmobiling

Most eye and facial injuries to snowmobilers can be avoided by a combination of safe driving, avoidance of alcohol and drugs while driving, and full face protection. [43, 44] Protection against snowblindness and ocular windburn is available with shatter-resistant face masks or goggles. As more snowmobilers are wearing head and face protection, the leading anatomic site of injury, in Wisconsin, shifted from the head and face to the extremities over 15 years. [45]

Other Active Sports

Exercise, running, and jogging

Elastic cords (used for repetitive resistance exercises) may snap or release from a handle or hook and cause an eye injury. [46] The rapid deceleration associated with bungee jumping causes a sudden rise in intraocular pressure and intravenous pressure that may cause retinal hemorrhage [47-56] and orbital emphysema. [57]

Eye injuries to runners and joggers usually result from striking branches, twigs, pipes, and so on while running in low light conditions in unfamiliar terrain. In sports, retinal detachment is usually caused by direct trauma to the globe. [58] Physical activity such as running and jogging do not increase the incidence of retinal detachment. [59, 60] Bird attacks, which caused a fatal accident to a bicyclist in Melbourne, usually are from birds of prey attacking the runner from the rear. Scalp lacerations, but no eye injuries, have been reported. Fake eyes affixed to the back of a jogger's cap may discourage a bird attack to the jogger or runner. [61, 62]

Inverted posture may be hazardous to some participants. The practice of hanging upside down by means of "gravity boots" was associated with a retinal tear in a highly myopic patient. [63] Inverted posture raised the intraocular pressure from a pre-inversion average of 19 mm Hg to an average of 35 mm Hg after inversion for 3 minutes; this returned to normal within one minute after seated posture was resumed. [64] Glaucomatous patients experience a higher rise in pressure to 37.6mm Hg ± 5.0 after inversion for only 30 seconds. The inverted posture probably raises intraocular pressure by increasing episcleral venous pressure which is closely related to increased venous pressure in the orbit. The episcleral venous pressure rise almost immediately follows posture inversion, with a typical normal subject's pressure, normally 16mm Hg sitting, increasing to 27mm Hg after 10 seconds of inversion, then increasing to 32mm Hg within 30 seconds, after which it remains unchanged. [65-67]

Patients with ocular hypertension, glaucoma, and retinal vascular disease should be discouraged from maintaining the inverted posture that doubles the intraocular pressure and the diastolic ophthalmic artery pressure; increases the systolic ophthalmic artery pressure by 60%; constricts the retinal arterioles; reduces pattern reversal visual-evoked potentials; and causes transient visual field defects in many subjects. [68, 69] Yoga exercises that use the shoulder-stand and headstand positions may contribute to field loss in glaucoma patients by significantly elevating the intraocular pressure while the participant is in the inverted position. [70]

Although the inverted posture may be harmful to those with glaucoma, other forms of exercise can be beneficial. Regular aerobic exercise is associated with a reduction in intraocular pressure and may represent an effective nonpharmacologic intervention for patients suspected of having glaucoma. [71-78] However, some young patients with advanced glaucomatous optic neuropathy may experience exercise-induced visual disturbance from an exercise-induced 'vascular steal'. These patients should be advised to limit activities which induce their symptoms. [79]

Glaucoma patients with pigment dispersion syndrome may experience symptomatic elevation of intraocular pressure (to 47mm Hg) after strenuous exercise, such as playing basketball for two hours. Pretreatment with 0.5% pilocarpine 30 minutes before the physical exertion prevents the pressure spike and the pressure lowers, as is usual in glaucoma patients who do not have pigment dispersion. Pressure rises in those with pigment dispersion may occur with exercises that involve jumping or jogging for several hours, [80] but not after comparable periods of equivalent cycling. It is believed that the jumping increases iris-zonule contact, which is prevented by pretreatment with pilocarpine. [81] Nd:Yag laser iridotomy prevents the bicycle ergometer induced iris concavity that results in pigment dispersion in some patients. [82]

Topical timolol (a nonselective $beta_1$ and $beta_2$-blocker) interferes with exercise endurance probably by reducing the maximal obtainable heart rate. [83] It is interesting that topical betaxolol (a selective $beta_1$-blocker) does not cause this side effect, despite the fact that betaxolol is a potent beta-blocker when administered systemically. There is most likely insufficient active drug in the blood after ocular administration to cause a measurable cardiac effect in normal persons. It would be prudent to attempt glaucoma control with betaxolol rather than timolol in those patients with glaucoma who require a beta-blocker but also happen to be endurance athletes. [84]

Weightlifting may cause extreme blood pressure elevations during and immediately after exertion. Five experienced body builders had a mean elevation of blood pressure to 355/281 mm Hg, with one subject reaching an alarming 480/350 mm Hg after a series of double leg presses. Even a series of single arm curls raises the mean blood pressure to 293/230mm Hg. Subarachnoid hemorrhage explained severe post-weightlifting headaches in two women, aged 16 and 25. [85] Patients with vascular eye disease in whom acute, severe elevations of blood pressure may be harmful, should train with lighter weights, using more repetitions.

Frisbee

Frisbees typically cause lid lacerations and hyphemas, but there is at least one open globe injury from shattered sunglasses that had glass lenses. Injuries to the eye can be avoided with shatter-resistant eyewear. It is probably impossible to make a Frisbee eye-safe without destroying desirable aerodynamic characteristics.

Mountaineering

Mountaineers at altitudes higher than 12,000 feet (3658 meters) are subject to retinal hemorrhages, probably secondary to hypoxic vasodilation combined with sudden rises in intravascular pressures. The hemorrhages resolve spontaneously with return of normal visual acuity on return of the climber to a lower altitude, but the climber may be left with permanent reduction in critical flicker fusion frequency, visual fields, and dark adaptation. [86-89] One climber, on a Mount Everest ascent to 5,909 meters, had a permanent visual loss to finger counting after an ischemic central retinal vein occlusion with vitreous hemorrhage. Higher baseline intraocular pressure and the use of non-steroidal anti-inflammatory drugs are risk factors for the development of altitude retinopathy. [90] The severity of high-altitude retinopathy is correlated with potentially fatal high-altitude cerebral edema—and progression of both conditions may be prevented with oxygen, steroids, diuretics, and immediate descent. [91] Hemoconcentration and hypoxia—the undlerlying factors of acute mountain sickness, high-altitude cerebral edema, pulmonary edema, thromboemebolism, and high-altitude retinopathy—should be treated in patients with high-altitude retinopathy. [92]

A 77-year-old man with low endothelial cell counts developed endothelial decompensation necessitating a penetrating keratoplasty when he drove to 12,500 feet. [93] A 15-year-old boy had the transient loss of light perception secondary to the expansion of a perfluoropropane gas bubble used to treat a giant retinal tear when he was driven over a 4,289-foot mountain pass. [94] Since this ascent is comparable to that of commercial airline jets reaching cruising altitude in which the cabin pressure is the equivalent of approximately 7,000 feet, patients with intraocular gas bubbles risk significant elevation of intraocular pressure due to expansion of the intraocular gas and probably should remain at lower altitudes and avoid aircraft flight until the bubble diminishes in size. [95]

The prevention of snowblindness secondary to overexposure to UV light is essential. Because the thinner atmosphere does not filter out as much of the sun's UV light as does the thicker atmosphere at sea level, and ice and snow reflect approximately 85% of UV light, the climber is twice exposed—by both direct and reflected UV light. A severe case of snowblindness may be asymptomatic for 8 to 12 hours after exposure, then be totally disabling for several days while the climber is unable to keep the eyes open because of extreme pain, photophobia, and lid edema. Mountaineering sunglasses or goggles should filter out at least 90% of wavelengths below 400 nm and be designed to block most reflected light coming from the sides and below. In an emergency, goggles may be made of cardboard with a thin slit. Sherpa and Balti porters have been known to protect their eyes by pulling their hair down over their faces. Mountaineers should understand that UV light protection is as important under overcast conditions as it is in full sunlight. Erythropsia (vision that is temporarily tinged red) is due to retinal overexposure to UV light and eliminated by the use of UV light-absorbing glasses. [96, 97]

Eyes that have radial keratotomy are prone to significant hyperopic shift that can impede vision and increase mountaineering risk. [98-103] Eyes that have had LASIK or PRK to treat myopia are less prone to visual fluctuation at high altitude, usually from a myopic shift. [101, 104, 105]

Equestrian Sports

There are over 1.2 million horse owners younger than age 20 and more than 27 million riders older than age 12 in the United States. Horseback riding is an extremely diverse sport including dressage and show jumping in arenas, cross-country endurance, fox hunting through wooded trails, 24-hour mountain endurance races, tetrathlons (races that combine riding with running, swimming, and shooting), calm trail riding, rodeo, polo ***(for polo, see Stick and Ball...Sports)***, racing on horseback or while mounted or in a sulky, activities for the handicapped, and the formal moves of the Spanish Riding School of

Vienna. [106]

Approximately ace 20% of equestrian injuries are to the head and face. There are between 105 and 257 deaths a year, mostly due to head injuries, a number which could be greatly reduced by the universal use of headgear that stays on the head in accidents, resists penetration, and prevents transmission of concussive forces. [107-111]

The risk of injury in US Pony Club (USPC) events in order of decreasing incidence is cross-country, horse/pony jumping, stadium jumping, dressage, hunter equitation, pony club games, gymkhana, hunter, and vaulting. The USPC has required mounted members to wear hats that have passed protective standards since June 1, 1983. [107] Protective standards have become more stringent with the advent of the ASTM standard Fl163 specification for headgear used in horse sports and horseback riding in 1990. Helmets are tested to the standard and independently certified by the Safety Equipment Institute (SEI). As more riders wear headgear that bears the SEI seal, it is expected that injuries will continue to decrease. [112] Most USPC riders' face and eye injuries result from jumping. The increased size of the ASTM helmet, which acts as a buffer, taking impacts first before they reach the face, has resulted in a decrease in eye and face injuries in USPC riders. [113] From 1990 to 1992 the USPC reported a decrease in head injuries by 26% and in face injuries by 62%. [114]

The mandatory use of helmets and face guards to prevent concussions and facial injuries in rodeo events that involve large animals is controversial, [115, 116] but more bull riders, the competitors most likely to suffer head and face injury, [117, 118] are voluntarily using the protective headgear.

Winter Sports

Skiing

Both cross-country and downhill skiers can suffer ski pole injuries [119] and snowblindness. Two perforated globes as a result of skiing were reported to NETS. The first occurred in a skier who was not wearing glasses or goggles and was struck in the eye by a piece of plastic on the end of a cord. The second occurred when a streetwear spectacle lens shattered on impact from the handle of a ski pole. Serious periocular injuries have occurred when ski goggles shattered. Ski eyewear should conform to the high-impact requirements of ASTM F659.

One death occurs per 1.6 million Alpine skier days. The fact that 82% of deaths involve head injuries, and that deaths are extremely rare in downhill ski racers who are required to wear helmets, [120] indicates that unniversal use of helmets would greatly reduce skiing deaths.

Sleds, toboggans, snowboards, and tubes

The incidence of eye and face injuries in these sports is unknown. It is believed that tubing may be the most dangerous of winter sports. [121] The close proximity of participants, excessive speed on slopes that are too steep, and fixed objects, such as rocks and trees, account for the majority of collision injuries. [122] Luge does not pose a significant eye injury hazard but is responsible for severe post-run headaches in the majority of participants. Although the cause of lugers' headaches, possibly due to the strain of holding up the head aggravated by jolts from an uneven track, is not yet known, they seem not to have permanent adverse effect. [123]

Blind Athletes

The year 1976 was a turning point for blind athletes: the United States Association for Blind Athletes (USABA) enabled blind and partially sighted athletes to participate in competition on a national level, and the Olympiad for the Physically Disabled was the first Olympiad with full competition for blind, paralyzed, and amputee athletes. [124, 125] Events included track and field, gymnastics, wrestling, the 10-km run, and goal ball—a fast-paced game developed especially for blind athletes in which a 4.5-lb ball containing bells is rolled on a 30x60-ft mat, past opposing players, across an end. To eliminate the advantage the partially sighted may have over the totally blind, all players, including the totally blind, wear blindfolds for the game. Athletes of all ages are divided by vision into three groups: Class A, totally blind or light perception with no acuity, with less than three degrees of visual field; Class B, 20/400 or less with 3 to 10 degrees of visual field; and Class C, less than 20/200 and/or between 10 and 20 degrees of visual field.

Due to encouragement from organizations such as the USABA, the blind are participating in more active sports—such as beep baseball, tandem cycling, golf, downhill and cross-country skiing, skating, wrestling, judo, track, and swimming—in addition to the usual activities of the blind such as bowling, nature hikes, boating and fishing, picnics, and dances. Beep ball was invented by the Telephone Pioneers of America and uses a sound-emitting softball with sound-emitting bases. All players wear head, face, and chest protection. The sport is so popular that the National Beep Baseball Association drew a crowd of 1200 spectators at a national tournament. [126] The US Blind Golfers Association (USGBA) is the oldest organization that promotes organized sport for totally blind athletes. Ski for Light, the Blind Outdoor Leisure Development (BOLD), and the American Blind Skiing Foundation promote skiing for the blind.

The sports achievements of the blind are impressive: Harry Cordellos, blind from diabetes, completed the Boston Marathon in under 3 hours with the help of a sighted companion. Craig MacFarlane is competitive with sighted golfers. Sky-diver Tom Sullivan pulls the rip cord at the signal (by helmet radio communication) from his sighted sky-diving companion. Tom O'Connor completed a triathlon in the remarkable time of 3:49:06 without being tethered to a guide. For the 0.9 mile swim, he swam in a lane formed by 20-ft tubes pulled by a kayak, he ran 6.2 miles with a guide alongside him, and cycled 25.1 miles guided only by verbal commands shouted from a guide car.

It is important to encourage those who become partially sighted or blind to pursue sports activities through one of the many organizations that are expert in promoting active sports that are challenging, and safe, bolster self-esteem, and especially are fun. [127-131]

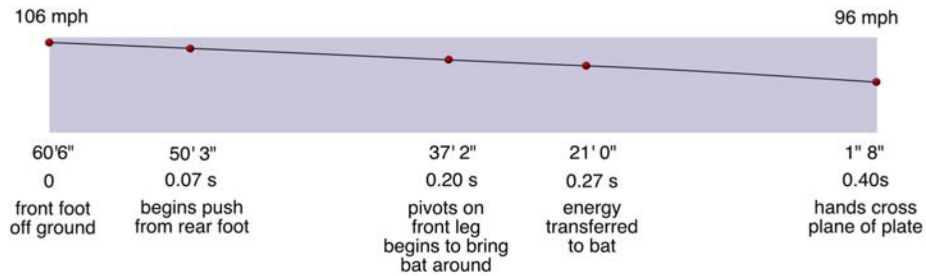
Vision Performance and Training

The use of visual training to improve athletic performance is increasing in popularity as more practitioners enter the field. The controversy surrounding visual training and athletic performance does not center around whether visual parameters that are not commonly measured—such as dynamic visual acuity (visual ability with the athlete, the object of regard, or both, in motion), eye tracking ability (the ability to maintain fixation on a moving target), glare recovery, visualization (the ability to see an image in the mind's eye), visual concentration (the ability to concentrate on the visual task at hand and exclude distractions), central-peripheral field awareness (the ability to be aware of or even concentrate on objects or players eccentric to fixation), speed and span of recognition (the ability to see, often separate, objects quickly and accurately) and quiet-eye time (the release of fixation on a target after the brain has sufficient information for the body to react appropriately)—are important for athletic performance, they clearly are. Yet to be determined is whether visual training can improve athletic performance, and , if so, what training is appropriate.

Personal observations of one-eyed athletes raise questions about some of the current concepts of visual performance and vision training and suggest areas for future research . Many people with severe limitations of vision in one eye function at the highest levels of sport in which it is commonly assumed that true stereopsis is essential. A few examples are: After enucleation of his dominent eye, a flight instructor continued a demanding career flying airplanes; A trap shooter remained a top competitor after losing sight in his dominant eye; A semi-pro baseball pitcher lost an eye to a line drive, then successfully continued his career ; A high school athlete lost an eye playing basketball, then excelled in college varsity baseball, football, and basketball; A football quarterback with dense amblyopia who also played basketball and baseball for a major university excelled in all three sports; A major league outfielder was an excellent batter despite mild macular degeneration and 20/30 vision in each eye with no measurable stereopsis. How can these players and others (such as Babe Ruth who had dense amblyopia) perform so well without vision skills that are usually considered essential for performance? Hitting a baseball is considered one of the most demanding athletic tasks, yet 5 of the 7 athletes mentioned above were able to play baseball at college, semi-pro, and professional levels without true stereopsis. A trap shooter, compensated for loss of his dominant eye in a sport in which sighting with the dominant eye is considered essential.

Studies on the physics of baseball and the visual activity of baseball batters give insight into the timing required to hit a baseball. [132, 133] The motion analysis of Mark McGuire's 70th home run in St. Louis on September 27, 1998, is depicted in ***Figure 33***. The ball left Carl Pavano's hand at 106 mph and slowed to 96 mph in the 0.4 seconds it

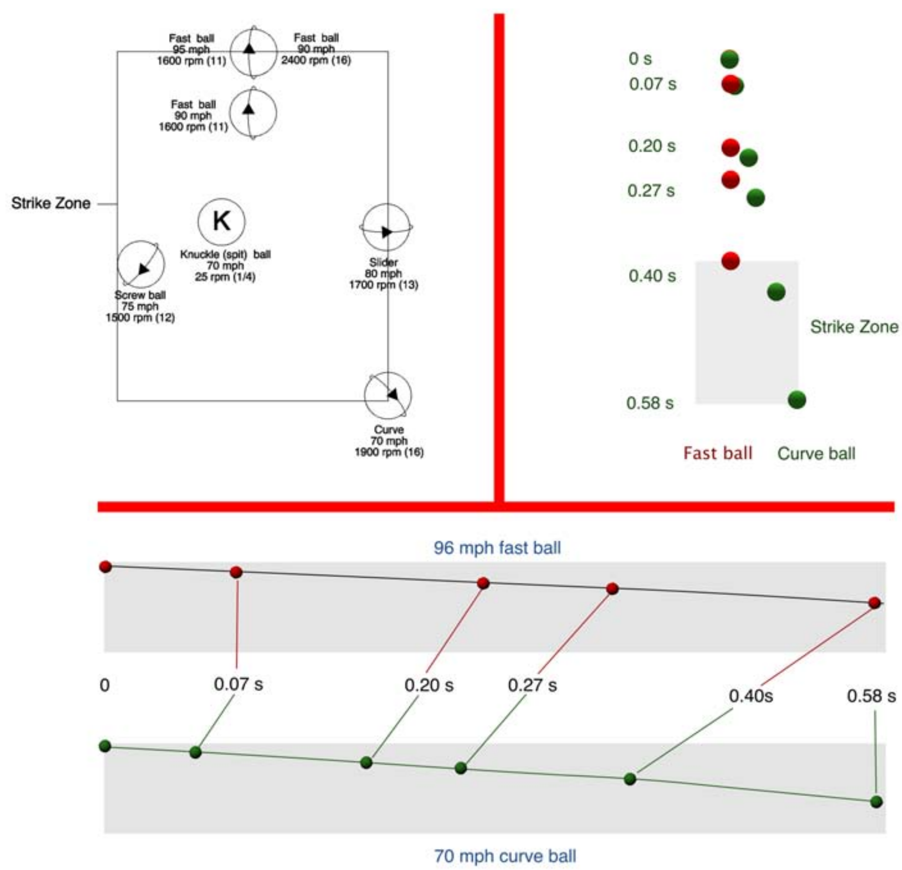
Figure 33. The timing of a home run swing



Analysis of mark McGuire's 70th home run by Paul lagace, professor of Aeronautics and Astronautics at MIT

took to reach home plate. McGuire had his front foot off the ground as the ball was released, started his swing when the ball was half way to the plate, and was essentially fully committed to the path of the swing when the ball was still 21 feet from home plate. The 34.5", 33-ounce bat had a tip speed of 80 mph when it collided with the ball and propelled the ball at 110 mph with 2,000 rpm back spin for a home run. Pavano, throwing the ball on the same initial trajectory, could have placed the ball almost anywhere in the strike zone by varying the speed and spin on the ball. ***Figure 34*** relates the ball speed, the ball revolutions per minute (rpm), (the revolutions of the ball between the pitcher

Figure 34. The effect of initial velocity and spin on the final position of a baseball in the strike zone, when thrown on the same initial trajectory by the pitcher



Upper left:The position ot the ball in the strike zone when thrown thrown by a right handed pitcher on the same initial trajectory with varying velocity and spin. mph = velocity of ball as it enters the strike zone; arrow = direction of rotation as seen by the batter; rpm = revolutions of the ball per minute; (xx) = revolutions of the ball between the itcher and home plate; rotation of knuckle ball varies.

Upper right: Fast ball (red) compared to curve ball (green) as seen by batter over time (s)

Lower: Fast ball (red) compared to curve ball (green) as seen by batter over time (s) as seen from the side. Note the distance from the plate the slow curve is when compared to the fastball as it crosses the plate in 0.40 seconds and how the batter would see the curve ball as "falling off the table" in the final 0.18 seconds. [132, 133] and home plate are in parenthesis), the direction of ball spin as viewed by the batter, and the final position of the ball in the strike zone. With all of these final ball positions possible from the same release point and the same initial trajectory, it was essential that McGuire predict the type of pitch to by thrown by analyzing both the speed and spin of the ball as Pavano was going through the delivery motions—before the ball was even released. A swing timed to hit a home run off of a 91 mph fast-ball will miss a 96 mph fast-ball completely. Minor variations in Pavano's delivery and arm speed would be a clue as to the ball speed. Seeing the grip Pavano had on the ball at the time of release would be a clue as to the type of spin the ball would have. McGuire did all of this subconsciously at the visual-motor memory level—the reflex reaction of an excellent batter. All batters analyze pitchers, their delivery, and the pitches they usually throw, but no batter I know of has said they consciously analyze any of this while at bat. They simply hit the ball with the bat.

To see how the ball is held in the pitcher's hand requires good visual acuity. Perhaps one reason that baseball batters usually have excellent static visual acuity (81% better than 20/15) is that good visual acuity is necessary to predict where the ball will be when it crosses home plate. Distance stereo-acuity and contrast sensitivity, which also measure significantly better in professional baseball players than the general population also probably play a major predictive role in final ball position. [134] If we put baseballs on thin poles, one 29 feet from home plate, and the other 30 feet from home plate, the batter cannot tell which ball is further away, unless one ball hides part of the other. As the ball approaches the plate, the angular velocity in relationship to the batter's eyes increases rapidly, so that when the ball is within 10 feet of the plate, the angular velocity exceeds 500 degrees per second and is impossible to track. The maximum smooth pursuit velocities in professional baseball players are 30 degrees per second for the head and 130 degrees per second for the eyes In the initial tracking of the ball, it has been shown that professional batters move their head as well as their eyes to track the ball as long as possible. [133]

McGuire was probably using distance stereopsis, but he was not using (usually measured and trained) near stereopsis to any significant degree when he started his swing. He was tracking the ball, moving both his head and his eyes until tracking became impossible within ten feet of the plate. Distance stereopsis could be used to modify the plane of his swing until the ball was 10 feet from the plate, but changing the plane of the swing after the batter has transferred energy to the bat at a ball distance of about 20 feet from the plate is very difficult.

Accommodation and convergence are too slow to have played any role in hitting the ball. The image was 34 degrees off McGuire's fovea when the ball was two feet in front of home plate. It is apparent that McGuire could hit a very blurry baseball out of the park because he has the gifts of natural ability and superior motor memory that have been fine-tuned with practice. If McGuire were rigidly trained to keep his head still and track the ball to the moment of contact from an early age [135] and he rigidly followed these instructions, he probably would not be very good at hitting a baseball. When we train athletes, we must be certain that what we are teaching actually will help and not interfere with performance. Analysis of many photographs of athletes hitting balls or pucks with bats, rackets, or sticks show that they almost never are looking at the point of contact between the ball and the racket, bat, or stick. It clearly is detrimental to performance to instruct an athlete to watch a fast-moving ball make contact with the bat, racket, or glove, etc.

Would McGuire be as good a batter if he hit fewer baseballs and spent more time doing various types of visual training in an eye care professional's office? While many visual abilities are trainable, the transfer to real-world tasks that are related to sports has not been demonstrated. [136] The essential factors needed to hit a baseball (and other sports balls) well are: innate ability, excellent visual and motor memory, total body timing, quick visual learning, concentration, and dynamic visual acuity. Important factors include, distance stereopsis, contrast sensitivity, peripheral awareness, and visualization. Not important are accommodation and vergence amplitude and speed.

A batter has to be a quick visual learner. He sees the pitched ball for less than 0.5 seconds per pitch. He has about 7 pitches per each at bat and 4 at bats per game. Each game, the batter has 14 seconds of learning about a particular pitcher. The batter learns the most from the last third of each pitch as he correlates how the final path of the ball relates to the delivery and release of the pitcher. Learning is a total system approach. To be effective in hitting the ball, the batter must see the pitcher's total motion, including the release of the ball. Then he must correlate the biomechanics of his own swing and his visual-motor memory, with the pitcher's delivery and release and the trajectory of the ball.

To help the athlete perform better, vision therapy research and practice should:

1. Be certain that the athlete has correction that allows the best possible vision and that there are no significant ocular abnormalities that will diminish input quality.

2. Use actual field conditions as much as possible. It is the constant motor feedback of the total game environment that will give the athlete the totality of information needed to put input and response into the subconscious and react quickly to rapidly changing game situations.

3. Use video replays in conjunction with coaching to help the athlete visualize effective technique.

4. Avoid evaluations and treatments that are probably not important for performance—they only take time from the important. It is probably possible to degrade performance by having the athlete spend time doing stupid training (Watch the ball hit the racket strings. Keep your head still. No, NO. Watch the ball hit the strings. Keep your head still. No, NO. Watch the ball hit the strings. Keep your head still. No, NO. etc, etc.) which detracts from true learning.

5. Learn what visual functions are important, and develop consistent and reliable diagnostic techniques, normal values, and standardized training protocols.

6. Set up test protocols that will give real answers as to the methodology by which performance actually can be improved. [137-147] Standardized test methods, normal values, and controlled studies,are needed. Before treatment is done on many people, the procedure should be proven effective—for example, the concept of biofeedback to treat ophthalmologic disorders, such as blepharospasm and voluntary torsions, has been applied to the treatment of myopia. [148, 149] However, a double-masked study of the effect of biofeedback on myopia showed no difference between the control and experimental subjects. [150]

7. We should keep an open mind on

this active area. Practitioners and researchers in the area of visual training should continue to develop standardized tests and gather data on the normal range of values. Visual training may not only prove a valuable technique for improving athletic performance, but the techniques learned may also help in other areas such as macular disease and field loss.

Legal Implications of Sports-Related Eye Injuries

Prescribing and/or dispensing eyewear for athletes is fertile ground for litigation because there is significant potential for injury and the sale of a product is frequently involved. Legal claims can be directed on the grounds of negligence as well as those of product liability. Negligence awards for the plaintiff have arisen from failure to prescribe the lens material of choice and failure to warn of the differences in impact resistance between various lens materials. Manufacturers of sunglasses and protective eyewear have had product liability judgments against them for defects in design that resulted in an otherwise preventable injury. [151, 152] It would be legally imprudent for anyone writing a prescription or dispensing eyewear to athletes not to prescribe polycarbonate [153] or Trivex lenses or not to be certain that prescribed sports eyewear meets applicable safety standards. [154] The dispenser should beware of the stylish sunglass with the CR39 or glass lens that could shatter if struck with a tennis ball, frisbee, or softball. It is apparent that malpractice negligence and product liability suits will remain a significant factor in sports-related eye injuries and that there are both good and bad aspects to the present legal situation.

The negative aspects—extravagant awards, capricious juries and judges, inconsistency in awards for apparently similar injuries in apparently similar circumstances, long delay in trials so that physicians and manufacturers are often held to a state of the art that has advanced since the time of the injury, escalating insurance premiums, a long "tail" on protective equipment that has become obsolete yet is still used by the athlete, lawyers' greed and tendency to instigate suit for high awards—are well known to physicians and manufacturers and must be corrected by the legal profession. Product liability suits concerning football helmets resulted in cancellation of the NOCSAE insurance, which would not be replaced by another insurer. This resulted in a withdrawal of NOCSAE from important organizations such as the NCAA, National Federation of State High School Associations, the National Junior College Athletic Association, and the National Athletic Trainers Association, because members of these organizations on the NOCSAE board withdrew to protect themselves from liability. [155] It seems counterproductive to the welfare of athletes that a standards setting organization that has done a great deal for sports safety can be radically changed by uninsurability. Rising insurance costs and huge liability awards are threatening some sports and recreation programs. [156]

However, the present legal climate, as much as it desperately needs improvement, does have a significant positive attribute—it is the most efficient check on the small fraction of manufacturers, retailers, and health care professionals who are incompetent or are without conscience and motivated solely by greed. The fact is that the potential of the injured athlete to obtain large awards from the courts has forced manufacturers to gather together to write voluntary consensus standards to upgrade protective devices and help keep inferior products off the market. Administrators are studying risk management, with resultant safer facilities. [157] Although suits against eye care professionals for improperly prescribing optical devices are uncommon, [158, 159] they certainly will increase in frequency as lawyers become aware of advances in eyewear protection that the professional should advise for athletic patients exposed to specific risks. Another area of significant liability risk appears to be failure to warn RK, PK, and other patients with increased risk of ruptured globe of the extra need for eye protection against traumatic rupture of the globe likely to occur from the energy used in many sports. The optician, dispensing optometrist, and ophthalmologist should take a sports, industrial, and hobby history and advise the use of appropriate protective eyewear. Manufacturers must participate in the voluntary standard-setting process and test their products before release to the general public. Sports officials must be certain that athletes under their supervision are properly protected. Devices that are advertised as protective then fail to give adequate protection will result in litigation.

The responsibilities of teachers and coaches of motor skill activities as well as the agencies that sponsor them were further defined in a $6.3 million award to an injured Seattle high school football player. [160] Although this case involved football, the legal principles would probably apply to all supervised sports. The student must be instructed in appropriate skills, be warned of potential dangers, and have available the latest safety precautions and techniques. The participants in sports are also not immune from litigation if they act with more aggression than permitted by the rules of the sport or use the sport as an excuse for acts of violence. Athletic administrators, coaches. doctors, and equipment manufacturers realize that injuries cannot be entirely eliminated from sports, but they must strive to at least minimize the risk of serious injury. [161] The best defense in a legal suit seems to be the ability to demonstrate that all concerned were acting responsibly, using state-of-the-art protective devices and playing surfaces, and using conditioning and training techniques to protect the athlete to an acceptable level of risk considering the nature of the sport. [162, 163]

Ethics

All who are in position of authority have a responsibility to act in a positive manner for the benefit and welfare of those under that authority. This responsibility is fuller and stronger when the responsible person is dealing with those who are in a position of diminished ability to be responsible for themselves. [164] Therefore, the athletic director or coach of a grammar school team is more responsible to ensure the safety of his or her charges than is the professional coach who is dealing with adults who can make an informed consent. A sport official is ethically responsible for the safety of the players especially in the school setting, in which the school official is acting in a parental role, supervising a minor who is under his or her care during the time of sports participation. To ignore a situation in which there is a preventable cause of injury and force participants to play without the benefit of a device that would greatly reduce the probability of injury is clearly unethical and irresponsible.[165]

It is vital to realize that to be beneficial to a child a sport must be fun. Children should have the right to: participate regardless of skill, ability or sex; decide whether they want to participate in sports at all; know that a failure in sports is not a failure in life; have a competent coach; safe facilities, and properly maintained equipment; have their fair share of public funds and facilities; be treated like children, not like miniature adults; competent medical treatment; stop playing when hurt or sick without fear of reprisals; their own individuality; have compassionate organized sports programs; play opponents who are carefully matched in age, weight and size; have a wide variety of sports to choose from. [166]

In colleges, football, hockey, and basketball are the income producers that support other sports programs. [167] There must be constant vigilance that college players are not viewed as income-producing assets with more attention paid to performance at the expense of safety. The college or professional coach must realize that persons should not have to go along with stupid things and that, while the informed adult may opt to take a risk for himself or herself, he or she should not put other persons at risk. College and professional team physicians must be extremely careful of the dilemma of divided loyalties—to the team that pays the physician's salary and expects winning performance from the athlete as opposed to the athlete who is, in fact, the patient. It is essential that the team physician avoid ambiguity at all costs. If the relationship differs from the customary physician-patient relationship, it is crucial to tell the patient. [165, 168-171]

Role of Eye-Care and Athletic Professionals in Eye Injury Prevention

In preventing and treating athletic eye injuries, the well-being of the athlete must be placed above all other considerations. Ophthalmology, optometry, and optician organizations should emphasize prevention as an important part of eye care practice. The ophthalmologist or optometrist can help the athlete protect his or her eyes by knowing what to advise, discussing the advice with the athlete, and writing a specific sports-eyewear prescription. A section of every optical dispensary should be a display of sports and industrial eyewear that meets applicable standards, as well as handouts that give specific advice on eye protection for various activities.

The school committee members should be sensitive to their responsibility to properly educate their interscholastic coaches and provide athletic trainers. The athletic trainer is the bridge between the medical staff and the athletes and is invaluable in monitoring the athletes for fitness to participate and ensuring that protective equipment complies with applicable safety-standards, fits properly and is properly maintained. Since it is only the coach who is with the athlete before, during, and after both practices and games, the coach assumes the role of everyman. In addition to producing winning teams and teaching proper playing techniques, the coach is expected to keep the athletes healthy and injury free. Since certified athletic trainers and physicians are not present at every game, the coach should have a basic knowledge of injury prevention, recognition, and first aid.

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