NOCSAE® IMPACT

"Commissioning research and establishing standards for athletic equipment, where feasible, and encouraging dissemination of research findings on athletic equipment and sports injuries."

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"MEETS NOCSAE STANDARD": What does it mean?

Football, lacrosse, baseball batters and catchers helmets must carry the NOCSAE logo if they are to be used in most organized contests. The NCAA, NAIA, National Federation of State High School Associations, ASA, Little League Baseball, Dixie Baseball, USA Baseball, U.S. Military, and other organizations require by rule that helmets used in sports administered by them meet the NOCSAE standard. But many people don't know what is involved in helmet certification or recertification to NOCSAE standards.

Manufacturer Certifies

In exchange for giving a license to a manufacturer or reconditioner to put our seal and logo on their helmets, NOCSAE requires in return that the licensee follow all NOCSAE standards and related documents. Licensees also participate in sharing test data with NOCSAE to provide us with significant test performance data, which allows us to constantly evaluate and improve the NOCSAE standards.

Helmet manufacturers utilize the NOCSAE test specifications both as final product tests and as research and development tools. The drop test equipment includes a specially developed headform, attached to a carriage, that is dropped from varying heights and guided by steel wires onto a polymer anvil. Highly sensitive electronics in the headform measure three acceleration parameters at the same time. All of this data is captured by a special software program designed to analyze and store drop test information. All of these tests are validated by check routines in the software, which will disqualify any data that does not meet valid limits. Baseball and softball helmets are tested with baseballs shot into the helmet from an air cannon, while measuring the impact results on the helmeted headform. Each helmet manufacturer and all NAERA member reconditioners perform their own test. NOCSAE provides any assistance requested to assist these licensees in performing the certification and recertification tests.

The NOCSAE seal on a new helmet means that a sufficient number of samples of that model and size helmet have been tested to the NOCSAE standard and all have passed all the tests. The seal on a recertified helmet means that the reconditioner has inspected the helmet, tested a sufficient number of helmets before reconditioning and tested the same helmets after reconditioning, and has concluded that the reconditioning process has restored the helmet to the point that it passes the same NOCSAE standard as when the helmet was new.

NOCSAE also has contracted with the Southern Impact Research Center (SIRC) in Knoxville, Tennessee to provide licensees a resource for testing questions, equipment set-up, software matters, parts and supplies support, and even some update training from time to time when requested. SIRC also helps NOCSAE with matters such as headform design and improvement, drop test data assessment, and related matters from time to time.

The NOCSAE seal means that the helmet meets or exceeds the gold standard for head protection in that sport. But it also means that your surcharge for the NOCSAE recertification is being reinvested to improve not only helmet standards, but also to fund research in the areas of sports medicine, injury mechanics and prevention, and public education.

Please consult our website for more information, or call us with your questions. If you would like to arrange an informational presentation about the NOCSAE standards, call us at 913-888-1340 to discuss the details.

On the Web: www.nocsae.org

Inside NOCSAE

Comprehensive Research Report - February 2000

Extramural Funding Levels

In 1994, Dr. Trey Crisco developed the first extramural research program for NOCSAE. Since that time, NOCSAE has committed over $650,000 in extramural funding. Actual funds dispersed to date are approximately $550,000. The difference is due to ongoing projects and previous projects that did not obtain significant progress. These funds have been awarded to 19 different principal investigators at 17 institutions throughout the United States. Over 40 abstracts and papers supported by NOCSAE have been published (Appendix A1).

Funding Guidelines and Process

The extramural research program was developed to provide the funding for qualified investigators who are engaged in basic science or applied research in the area of sports injury mechanisms and injury prevention through the use of protective sports equipment. Projects without a testable hypothesis, such as comparing helmet A to helmet B, or projects designed to develop new products do not fall within the NOCSAE guidelines for fundable projects.

Due to the diverse range of potential proposals, a two-tier review process has been in place since 1997. Prospective grantees are first asked to submit a one-page proposal. These proposals are presented to the Board at the NOCSAE Winter meeting, and reviewed to insure they meet a minimum level of scientific quality. Proposals falling within the Board's present area of interest and meeting minimum scientific criteria are identified, and the principal investigators are then asked to submit full grant proposals to NOCSAE. Full grant proposals are received by March and reviewed by the Research Director and experts in the appropriate field. The Research Director determines the need for expert review.

Funded Areas

NOCSAE has supported a diverse range of grants within the specified guidelines. The projects are grouped and summarized below by common injury types.

► Brain Injury

NOCSAE studies in the area of brain injury include studies on the impacts leading to traumatic brain injuries, studies addressing the definition of mild traumatic brain injuries (MTBI), and those evaluating the criteria for a safe return to play.

The most significant portion of funding in the area of brain injury has been awarded to studies assessing the severity of MTBI and studies on early prediction of MTBI severity Kaufamn (1995) proposed to study the early prediction of MTBI severity using standard neuropsychological testing as well as the advanced imaging modalities of MRI and PET scanning. The progress of this study was initially delayed due to problems with equipment and a lack of patients meeting the inclusion criteria. However, under the direction of a new principal investigator (Kuwarbara, 1999), this study has made significant early progress and we have seen some exciting preliminary data. In the progress report, investigators reported three football players who had experienced MTBI demonstrated greater regional variation in regional cerebral blood flow (rCBF) and regional cerebral metabolic rate of glucose (rCMRglc) than uninjured control football players (n = 6) and age matched, non-athlete controls (n = 6). This work may lead to fundamental advances in basic understanding of the MTBI mechanism.

Neuropsychological assessment remains the common approach for determining when return to play is safe after an MTBI, but remains difficult to define and is an area of intense interest. In a prospective study, Echmendia (1999) aims to assess the sensitivity, reliability, and practices of neuropsychological tests over a wide range of collegiate sports. This work should be enhanced by a parallel study in the NHL and a proposed study in the NFL

An alternative to neuropsychological assessment which may prove advantageous is the assessment of an injured player's ability to control their balance or sway. In his first NOCSAE grant, Guskiewicz (1996) developed the use of postural sway as a tool for assessing MTBI [9, 10, 11, 12]. The goal of the most recently funded study (Guskiewicz, 1999), was to validate a cost-effective and practical version of this method for assessing MTBI and return to play.

While the injury rate associated with severe brain injury has been significantly reduced to acceptable low levels, in large part due to Dr. Hodgson's and NOCSAE's efforts in the late 1970s [18, 19, 20], the MTBI injury rate continues to raise concern. While NOCSAE developed head acceleration criteria for the prevention of severe traumatic brain injuries, the level of head acceleration resulting in MTBI and the levels occurring in the field remain largely unknown. This has been a major area of interest since first recommended as a critical area by the Research Director in 1994.

Aerobatic freestyle ski jumpers experience an extremely high rate of falls when landing off balance leading to the head slapping back and MTBI. Johnson (1994) studied a group of Olympic skiers and recorded head acceleration during their on-slope practices. In the course of their study, 382 slap back falls (approx. 16% of all jumps) were recorded. The acceleration levels recorded in these falls were notably lower than the values typically believed to be associated with MTBI, and no injuries were recorded [7, 8]. These findings, or lack thereof, demonstrate the difficulty of documenting actual impacts during play due to the low percentage of injuries - even in a high risk sport.

Perhaps the biggest difficulty in measuring head acceleration during play has been the lack of small, accurate electronic sensing and recording systems. Over the last several years, there has been substantial progress in sensor and recording technology, but we are presently uncertain if this progress meets the specific needs of NOCSAE. Recently, NOCSAE funded the development of a prototype system for measuring head acceleration in automotive racers (Olvey, 1999). While this prototype may not be directly usable in team sports such as football, it is hoped that this work will provide sufficient knowledge of and an instrumentation base for applications in sports more traditionally associated with NOCSAE.

Of course, the design of sport helmets remains the final key to preventing injuries. While the designs of football helmets, for example, have changed in the last thirty years, there is little scientific information available to guide designers. Using theories developed for optimizing protective performance in the automotive and aviation industries, Pilkey (1996) performed a theoretical study of the limiting performance of sports helmets and developed guidelines for optimizing their performance. Manufactures may now determine if these guidelines are practical and if they can be implemented into helmet designs.

The only NOCSAE grant to study second impact syndrome did not meet its progress goals and was terminated after the initial funding period (Kindt, 1994).

► Commotio Cordis

Commotio cordis is defined as sudden death from a blow to the chest in which there is no structural damage to the vital organs. Commotio cordis is rare and has been limited to youths who have received non-remarkable blows.

The NOCSAE studies of Link (1996) were the first studies to correctly identify the fatal mechanism as ventricular fibrillation brought on by an unremarkable impact during a precise 15 msec window of time in the cardiac cycle [24, 25, 26, 27, 28, 29, 30, 31, 32]. Contrary to previous research by others, Link demonstrated that baseballs designed to reduce the risk of head injury also reduced the risk of commotio cordis. The current study by Link (1998) aims to develop a more complete understanding of commotio cordis as well as the potential efficacy of protective equipment.

Commotio cordis has only recently been appreciated and given detailed documentation. The national registry developed by Maron (1995) continues to serve as the primary source for information [33, 34, 35, 36]. Of note, these physicians have suggested that chest protectors may reduce the risk of commotio cordis. The Research Director believes the use of chest protectors is not yet supported by the data. One limitation is, unlike acceleration which is associated with brain injury, there are no mechanical variables presently associated with commotio cordis. Therefore, setting a performance standard would not be possible. A second limitation is that commotio cordis has not been documented at higher levels of impacts. A resulting a concern is that a chest protector might transform a high impact into one capable of producing commotio cordis.

An earlier study on the efficacy/resiliency of chest protectors to reduce the risk of injury due to baseball impacts in children used crash-test manikins and has provided useful data on impact attenuation (Jayaraman, 1994) [22, 23]. Given the more recent findings by Link (1996; [33, 34, 35, 36]), the applicability of the results of this study in the prevention of commotio cordis may need to be reexamined.

► Neck Injury

Catastrophic neck injury and fracture leading to paralysis remains a primary concern, however, it is well established that these injuries cannot be prevented using any helmet design which does not dramatically alter the sport and which does not raise the concern for other injury types. Regardless, a better understanding of the mechanisms leading to catastrophic neck injury and fracture is warranted.

In 1995, NOCSAE commissioned a review of cervical spine mechanics and cervical spine protection by Myers and Panjabi (1995). This effort resulted in what is believed to be the most extensive compilation and analysis of the literature in this area to date [40].

Another study, designed to evaluate the role of vertebral geometry and density and the effectiveness of neck protective devices in cervical impact injuries (Shea, 1995) has had minimal progress. Further progress is unlikely as both investigators have moved into other areas at other locations.

► Facial Injury

Facial injuries in sports occur most frequently from contact with a ball. The actual incidence and frequency of such injuries has not been well documented. Mueller (1996) developed a registry for facial injuries in youth baseball, part of a larger study of all types of injuries in youth baseball. He found the overall rate of injury in youth baseball very low at 8.45 per 1,000 players (95% confidence interval: 7.46 - 9.59). The most common types of injury were contusions, abrasions, and lacerations to the head region (19% of all injuries). The most common type of serious injury was most often associated with being hit by a ball (36%).

He concluded that youth baseball does not have a high rate of injury and prevention efforts should focus on increased protection for the head and greater support for the ankle [37, 38, 39].

More frequently than ever before, Youth baseballs of various softness are being used in Youth baseball leagues. However, the definition of "softness" and its association with reduction of injury had not been extensively studied. In a contract provided by NOCSAE, Greenwald (1995) studied the correlation between the static properties of various youth baseballs and their dynamic impact performance [14, 15, 16, 17]. This work lead to a better understanding of the relationships between the definition of "softness" and injury potential. In a current extensive study of all balls in use in Youth baseball and softball (NISSS Study of Youth Baseball and Softballs.) the novel methodologies developed in the Greenwald study are being used.

One concern with balls that are too soft is the potential for deeper intrusion into the orbit and thus an increased risk of eye injury. Vinger (1997) evaluated eye injuries caused by baseballs of varying hardness. He observed that softer baseballs decreased the risk of orbital fractures, and that balls that were extremely soft intruded significantly more into the orbit. He suggested however, that this increased intrusion may not be clinically significant and may not offset the overall benefits associated with the use of "softer" baseballs. He recommends the use of balls that are not "too soft" [41].

In the scholastic sport of girls lacrosse, Webster (1994) performed a prospective controlled study on the effectiveness of protective eye wear and reported that such eyewear reduced injuries by 51% [42, 43, 44]. While helmets are not generally permitted, this study has helped the acceptance and use of protective eyewear in girls lacrosse.

► Lower Extremity Injury

In the lower extremities, fractures and shin splint are a major concern. Garret (1996) developed a methodology for the comparison of shin guards and studied the likelihood of their ability to prevent tibia and fibula fractures in soccer. This work has lead to development of an apparatus which may potentially be used in the performance testing of shin guards [5, 6].

An ongoing study by Burr (1997) is examining the efficacy of shoe orthotics in reducing bone strain rate, and hence, the likelihood of stress fractures and shin splints.

► Wrist Fractures

Wrist fractures are the most common fracture in roller bladeing and snow boarding. In an ongoing study, Kim (1997) is looking at the biomechanics of wrist guards in an attempt to evaluate their effectiveness at preventing forearm injuries.

Ongoing Grants

Listed below are the ongoing NOCSAE grants. These grants are in their final year, have no cost extensions, or the second phase of funding has not yet been awarded. All progress reports are due by and will be available at the 2000 NOCSAE Summer Meeting. Funds for the budgets listed below have already been dispersed, minus those funds that are committed.

5-95 Early Prediction of Severity of Closed Head Injury in Football Accidents Using Neuropsychological Testing, MRI, and Pet Scanning. H. Kuwabara, M.D., Robert C. Byrd Health Sciences Center of West Virginia Univ. School of Medicine, Morgantown, WV. Total Budget: $16,275

3-97 Use of Shoe Orthotics to Reduce Bone Strain Rate. David B. Burr, Ph.D., Dept. of Anatomy, Indiana Univ. School of Medicine. Total Budget: $38,769

2-98 Biomechanics of Wrist Guards - Efficient Usage in Preventing Forearm Injuries. Kyu-Jung Kim, Ph.D. Orthopaedic Biomechanics Lab, Mayo Foundation., Rochester, MN. Total Budget: $29,576

3-98 Mechanisms and Prevention of Commotio Cordis: Use in an Animal Model. Mark S. Link, MD, New England Medical Center Hospitals, Boston, MA. Total Budget: $30,000

1-99 Prospective Investigation of Mild Head Injury in Sport: Alternative Assessment Techniques. Kevin M. Guskiewicz, Ph.D., ATC, University of North Carolina at Chapel Hill. Total Budget: $45,990 Committed '00-'01: $23,009

2-99 Commotio Cordis Registry. Barry J. Maron, M.D., Minneapolis Heart Institute Foundation, Minneapolis, MN. Total Budget: $34,820 Committed '00-'01: $17,410

3-99 The Use of Triaxial Accelerometers to Measure Head Motion and Energy Exposure During High Velocity Vehicular Impact. Stephen E. Olvey, M.D. University of Miami School of Medicine, Miami, FL. Total Budget: $16,988

4-99 Neuropsychological Assessment and Recovery of Functions Following Sports-Related Cerebral Concussion: A Prospective Multi-Sport Study in College and High School Athletes. Ruben J. Echemendia, Ph.D. Penn State Department of Psychiatry, University Park, PA. Total Budget: $78,732 Committed '00-'01: $38,972

2000 Preliminary Grant Proposals

This year we have received significantly fewer preliminary proposals for funding than in past years. Two proposals have been received by the specified deadline. An extension was granted to one additional group, but that proposal has not yet been received.

1-00 Sport Helmet Impact Attenuation Mechanisms: methodology to quantify spatial and temporal force distribution patterns. David J. Pearsall, PhD., McGill University, Canada Budget: $15,000 for one year.

2-00 Response Time as a Consideration in Design Constraints for Baseballs and Baseball Bats. Mark D. Grabiner, Ph.D. The Cleveland Clinic Foundation, Cleveland, OH Budget: $32,040 for one year.

Standard Performance Specification For Newly Manufactured Baseballs

The existing NOCSAE standard for the performance of baseballs was formulated to reduce the risk of head injury to youth players from ball impact. Revisions have been proposed by the Research Director in order accomplish two goals: 1. To simplify the laboratory procedures for testing baseballs, and 2. To broaden the scope of the standard to address a wider range of injuries. These proposed revisions incorporate methods described in ASTM F 1888-98: A Test Method for Compression-Displacement of Baseballs and Softballs.

The Research Director attended the December 1999 ASTM Meeting at which time there was a lengthy discussion and review of ASTM F 1888-98. During this discussion it became apparent, in the opinion of the Research Director, that ASTM F 1888-98 did not contain a well defined test protocol, nor was this test protocol supported by substantial data. The Research Director finds that a more detailed review of the test methodology is required.

NOCSAE Home Page (*www.nocsae.org*)

The NOCSAE web site has been expanded with an extensive library of articles related to sports injury in five sections:

- Concussion Epidemiology
- Concussion Etiology
- General Sports
- Head Accelerations/Injury
- Helmet Evaluations

Appendix A1

NOCSAE Grants and Contracts

Burr, David: (1997) Use of shoe orthotics to reduce bone strain rate. Indiana Univ. School of Medicine. NOCSAE Grant 3-97.

Echemendia, Ruben J.: (1999) Neuropsychological Assessment and Recovery of Functions Following Sports-Related Cerebral Concussion. Penn State College. NOCSAE Grant 4-99.

Garrett, William: (1996) Comparison of shin guards in preventing tibia & fibula fractures in soccer. Duke University Medical Center. NOCSAE Grant 7-96.

Guskiewicz, Kevin: (1996) Effect of mild head injury on cognition & postural stability. Univ. of North Caroloina at Chapel Hill. NOCSAE Grant 11-96.

Guskiewicz, Kevin M.: (1999) Prospective Investigation of Mild Head Injury in Sport. Univ. North Carolina. NOCSAE Grant 1-99.

Greenwald, Richard: (1994) Static & dynamic impact behavior of baseballs. Orthopaedic Biomechanics Institute. NOCSAE Contract.

Greenwald, Richard: (1997) Static & dynamic impact behavior of softballs. NISSS. NOCSAE Contract

Jayaraman, Gopal: (1994) Efficacy/Resilience of chest protectors to reduce the risk of injury due to baseball impacts in children. Michigan Technological University. NOCSAE Grant 8-94.

Johnson, Stephen C.: (1994) Mechanisms of head injury during freestyle ski jumping. Orthopaedic Biomechanics Institute. NOCSAE Grant 15-94.

Kaufman, Howard: (1995) Early prediction of severity of closed head injury in football accident using neuropsychological testing. West Virginia Univ. Research Corp. NOCSAE Grant 5-95.

Kim, Kyu-Jung: (1998) Biomechanics of wrist guards-efficient usage in preventing forearm injury. Mayo Foundation, Minneapolis. NOCSAE Grant 2-98

Kindt, Glenn: (1994) Biomechanics of 2nd impact catastrophic brain injury. Univ. of Colorado Health Sciences Center. NOCSAE Grant 3-94.

Kuwabara, Hiroto: (1998) Early Prediction of Severity of Closed Head Injury in Football. U. W. Va. NOCSAE Grant 15-98.

Link, Mark: (1996) Dev. of a biological model for commotio cordis: use in evaluating baseball injury & chest wall protection. New England Medical Center Hospitals. NOCSAE Grant 2-96

Link, Mark: (1998) Mechanisms and prevention of commotio cordis: use in an animal model. New England Medical Center Hosp. NOCSAE Grant 3-98.

Maron, Barry: (1995) Commotio Cordis Registry. Minneapolis Heart Institute Foundation. NOCSAE Grant 12-95.

Maron, Barry J.: (1999) Commotio Cordis Registry. Minneapolis Heart Inst Foundation. NOCSAE Grant 2-99.

Mueller, Frederick O.: (1995) Facial injuries in youth baseball registry. National Center for Catastrophic Sports Injury Research. NOCSAE Grant 11-95.

Mueller, F.O.: (1998) Conference entitled: High School Athletic Injury and National Surveillance Approach: Multiple Disciplinary Planning Conference. U. North Carolina. NOCSAE Grant 14-98.

Olvey, S.E. (1999). The Development of a System Using Triaxial Accelerometers To Measure Head Motion and Energy Exposure During High Velocity Vehicular Impact. Univ. of Miami. NOCSAE Grant 3-99.

Pilkey, Walter: (1996) Limiting performance studies of sports helmets. University of Virginia. NOCSAE Grant 8-96.

Shea, Marie: (1995) The role of vertebral geometry & density and the effectiveness of neck protective devices in cerebral impact injuries. Beth Israel Hospital, Boston, MA. NOCSAE Grant 10-95.

Vinger, Paul: (1997) Evaluation of eye injuries caused by baseballs of varying hardness. Vision Performance & Safety Service. NOCSAE Grant 2-97.

Webster, Dwight: (1994) Effectiveness of protective eye wear in scholastic girls' lacrosse: a prospective controlled study. SUNY Health Science Center. NOCSAE Grant 7-94.

NOCSAE Supported Publications

1. Crisco, J.J.: (1995) Impact characteristics of baseballs as altered by compliance, conference on commotio cordis. ASTM. Denver, CO., May 17, 1995.
2. Crisco, J.J. , Hendee, S.P. and Greenwald, R. M.: (1995) The influence of baseball modulus and mass on estimates of head and chest impact injury: a theoretical study. ASTM International Symposium on Safety in Baseball/Softball. Atlanta, GA, December 6, 1995.
3. Crisco, J.J. , Hendee, S.P. and Greenwald, R. M.: (1996) The influence of baseball modulus and mass on estimates of head and chest impact injury: a theoretical study. ASMI 14th Annual Injuries in Baseball Course, Birmingham, AL, January 18-21, 1996.
4. Crisco, J.J., Hendee, S.P. and Greenwald, R. M.: (1997) The influence of baseball modulus and mass on head and chest impacts: a theoretical study. Med. and Sci. in Sports & Ex., Vol. 29(1):26-36.
5. Francisco, A.C., Nightingale, R.W., Guiliak, F., Glisson, R.R., and Garrett, W.E.: (1998) Comparison of soccer shin guards in preventing tibia fractures. Presented at the annual meeting of the American College of Sports Medicine, Orlando, FL.
6. Francisco, A.C., Nightingale, R.W., Guiliak, F., Glisson, R.R., and Garrett, W.E.: (1999) Comparison of soccer shin guards in preventing tibia fractures. American J. Sports Medicine (submitted).
7. Mecham, M.D., Greenwald, R.M., Macintyre, J.G., Johnson, S.C.: (1996) Incidence and Severity of Head Impact During Freestyle Aerial Ski Jumping. 2nd World Congress for Sports Trauma, AOSSM Annual Meeting, June 1996.
8. Mecham, M.D., Greenwald, R.M., Macintyre, J.G., Johnson, S.C.: (1999) Incidence and severity of head impact during freestyle aerial ski jumping. J. Applied Biomech., 15(1):27-35.
9. Guskiewicz, K., Perrin, D., & Gansneder, B.: (1996) Effect of mild head injury on postural sway. Journal of Athletic Training. 31(4):300-306.
10. Guskiewicz, K., Riemann, B., Perrin, D., & Nashner, L.: (1997) Alternative approaches to the assessment of mild head injuries in athletes. Med. & Sci. in Sports & Exercise. 29(7), S213-S221.
11. Guskiewicz, K., Padua, D., & Myers, J.: (1998) Return to play decisions following mild head injury in collegiate and high school football players (Abstract). National Athletic Trainers' Association Annual Meeting, Baltimore, MD., Free Communications, June 1998.
12. Riemann, B. and Guskiewicz, K.: (1998) Objective mild head injury evaluation through a battery of clinical postural stability tests (Abstract). National Athletic Trainers' Association Annual Meeting, Baltimore, MD., Free Communications, June 1998.
13. Guskiewicz, K., & Perrin, D.: (1998) Effect of mild head injury on cognition and postural stability (Abstract). National Athletic Trainers' Association Annual Meeting, Baltimore, MD., Free Communications, June 1998.
14. Hendee, S.P., Greenwald, R.M., and Crisco, J.J.: (1998) Static and Dynamic Properties of Various Baseballs. J. Appl. Biomech., 14(4):390-400.
15. Hendee, S.P. and Greenwald, R.M.: (1995) Compression vs. hardness vs. functional components of balls. ASTM International Symposium on Safety in Baseball/Softball. Atlanta, GA, Dec. 6, 1995.
16. Hendee, S.P., Self, B. and Greenwald, R.M.: (1996) Impact characteristics of traditional and reduced stiffness baseballs. ASMI 14th Annual Injuries in Baseball Course. Birmingham, AL, January 18-21, 1996.
17. Hendee, S.P., Greenwald, R.M., and Crisco, J.J.: (1997) Correlations Between Static and Dynamic Properties of Various Baseballs. American Society of Biomechanics, 21st Annual Meeting, Clemson, South Carolina, September, 1997.
18. Hodgson, Voigt R.: (1975) National Operating Committee on Standards for Athletic Equipment football certification program.., Med. & Sci. in Sports , 7(3):225-231.
19. Hodgson, Voigt R. (1976) Head injury criteria and evaluation of protective head gear. ASME, 31:121-135.
20. Torg, J.S., Truex, Jr., R.C., Marshall, J., Hodgson,V.R., Quendenfield, T.C., Spealman, A.D. and Nichols, C.E.: (1977) Spinal injury at the level of the third and fourth cervical vertebrae from football. J. of Bone and Joint Surg., 59(8)1015-1019.
21. Hodgson, Voigt R. and Thomas, L. Murray: (1980) Mechanisms of cervical spine injury during impact to the protected head. Proc. of 24th Stapp Car Crash Conf., SAE, Troy, MI., pp.17-42.
22. Jayaraman, G.: (1995) Contact response characteristics of baseball chest protectors. Conference on Commotio Cordis, ASTM. Denver, CO., May 17, 1995.
23. Jayaraman, G., Grimm, T.R., Whipple, R.L., Hegg, T., Lehtola, J.A., Burkhouse, D.R.: (1998) Biomechanical efficacy of chest protectors against baseball injury. Presented at the Injuries in Baseball Course, American Sports Medicine Institute, Birmingham, Alabama. January, 1998.
24. Link, M.S., Wang, P.J., Pandian, N.G., Bharati, S., Udelson, J.E., Man-Young, L., Vechiotti, M.A., Vanderbrink, B.A., Mirra, G., Maron, B.J., Estes III, N.A.M.: (1998) An experimental model of sudden death due to low-energy chest wall-impact (commotio cordis). N. Engl. J. Med. 338:1805-1811.
25. Link, M.S., Wang, P.J., Pandian, N.G., Udelson, J.E., Man-Young, L., Vechiotti, M.A., Vanderbrink, B.A., Mirra, G., Bharati, S., Maron, B.J., Estes III, N.A.M.: (1998) A Biological Model of Commotio Cordis: Sudden Death From Low Energy Chest Wall Impact. J. Am Coll. Cardiol., 4A. (abstract).
26. Link, M.S., Wang, P.J., Pandian, N.G., Man-Young, L., Vanderbrink, B.A., Avelar, E., Maron, B.J., Estes III, N.A.M.: (1998) Resuscitation in a Biological Model of Commotio Cordis, Sudden Death From Low Energy Chest Wall Impact. J. Am. Coll. Cardiol., 403A (abstract).
27. Link, M.S., Wang, P.J., Pandian, N.G., Man-Young, L., Vanderbrink, B.A., Avelar, E., Maron, B.J., Estes III, N.A.M.: (1998) Safety Baseballs Reduce Ventricular Fibrillation and EKG Changes in a Biological Model of Commotio Cordis, Sudden Death From Low Energy Chest Wall Impact. J. Am. Coll. Cardiol., 133A (abstract).
28. Link, M.S., Maron, B.J., and Estes III, N.A.M.: (1998) Commotio Cordis. In: Sudden Cardiac Dealth in the Athlete (NAM Estes, DN Salem and PJ Wang, eds.) Futura Publishing, Armonk, NY. Chapter 29, pp. 515-528.
29. Link, M.S: (1999) Editorial: Commotio cordis: sudden death due to chest wall impact in sports. Heart, 81:109-110.
30. Link, M.S., Wang, P.J., Vanderbrink, B.A., Maron, B.J., Estes III, N.A.M.: (1999) Reduced risk of death with safety balls in an experimental model of commotio cordis: Sudden death from low-energy chest wall impact. J. Am. Coll. Cardiol., 534A (abstract).

31. Link, M.S., Avelar, E., Wang, P.J., Vanderbrink, B.A., Mirra, G., Maron, B.J., Estes III, N.A.M., and Pandian, N.G: (1999) Global and transient cardiac stunning in an experimental model of sudden death with low-energy chest wall impact-evidence from real time transesophageal echocardiography. J. Am. Coll. Cardiol., 405A (abstract).
32. Link, M.S., Wang, P.J., Vanderbrink, B.A., Avelar, E., Pandian, Maron, B.J., Estes III, N.A.M.: (1999) Upper and lower energy limits of vulnerability to sudden death with chest wall impact (commotio cordis). 71st Scientific Session of Cardiac Medicine, 1-51 (abstract).
33. Maron, B.J., Poliac, L.C., Kyle, S.B.: (1997) Clinical profile of commotio cordis: an under-appreciated cause of sudden cardiac death in the young during sporting activities. Circulation, 96:I-755 (abstract).
34. Maron, B.J., Poliac, J.C., Kyle, S.S.: (1997) Clinical profile of commotio cordis: an underappreciated cause of sudden cardiac death in the young during sports activities. 1997 American Heart Association meeting. Circulation, 96(Suppl. 1):1-775.
35. Maron, B.J.: (1998) Athlete's Heart and Sudden Cardiac Death. In: Comprehensive Cardiovascular Medicine (E.J. Topol, ed.), Lippincott-Raven, Publ., Chapter 37, Philadelphia, PA, pp. 1081-10095.
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