

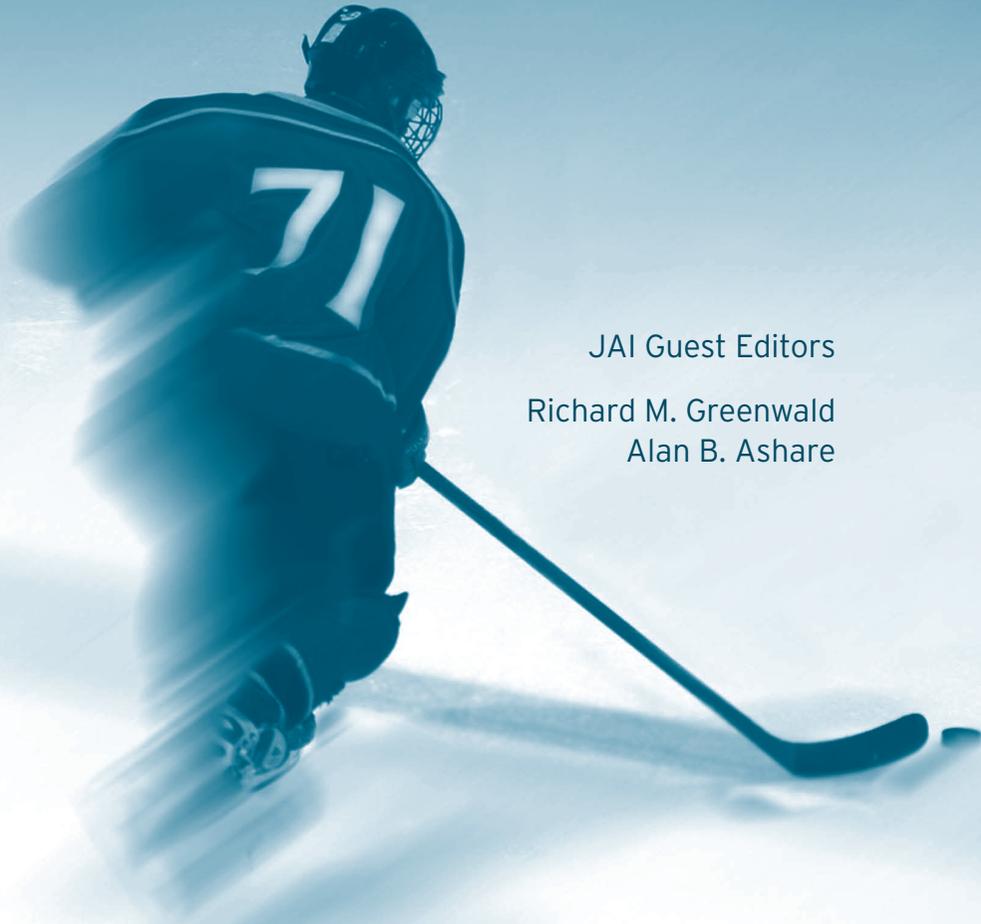
Journal of ASTM International
Selected Technical Papers



STP 1516

Safety in Ice Hockey

5th Volume



JAI Guest Editors

Richard M. Greenwald
Alan B. Ashare

Journal of ASTM International
Selected Technical Papers STP1516
Safety in Ice Hockey: 5th Volume

JAI Guest Editors

Richard M. Greenwald

Alan B. Ashare



ASTM International
100 Barr Harbor Drive
PO Box C700
West Conshohocken, PA 19428-2959

Printed in the U.S.A.

ASTM Stock #: STP1516

Library of Congress Cataloging-in-Publication Data

ISBN: 978-0-8031-7503-7

Copyright © 2009 ASTM INTERNATIONAL, West Conshohocken, PA. All rights reserved. This material may not be reproduced or copied, in whole or in part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of the publisher.

Journal of ASTM International (JAI) Scope

The JAI is a multi-disciplinary forum to serve the international scientific and engineering community through the timely publication of the results of original research and critical review articles in the physical and life sciences and engineering technologies. These peer-reviewed papers cover diverse topics relevant to the science and research that establish the foundation for standards development within ASTM International.

Photocopy Rights

Authorization to photocopy items for internal, personal, or educational classroom use, or the internal, personal, or educational classroom use of specific clients, is granted by ASTM International provided that the appropriate fee is paid to ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9634; online: <http://www.astm.org/copyright>.

The Society is not responsible, as a body, for the statements and opinions expressed in this publication. ASTM International does not endorse any products represented in this publication.

Peer Review Policy

Each paper published in this special issue was evaluated in accordance with the *JAI* review process.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editors, but also the work of the peer reviewers. In keeping with long-standing publication practices, ASTM International maintains the anonymity of the peer reviewers. The ASTM International Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM International.

Citation of Papers

When citing papers from this publication, the appropriate citation includes the paper authors, "paper title", *J. ASTM Intl.*, volume and number, Paper doi, ASTM International, West Conshohocken, PA, Paper, year listed in the footnote to the paper. A citation is provided as a footnote on page one of each paper.

Foreword

THIS COMPILATION OF THE *JOURNAL OF ASTM INTERNATIONAL (JAI)*, STP1516, on *Safety in Ice Hockey: 5th Volume*, contains only the papers published in JAI that were presented at a symposium in Denver, Colorado, May 4–5, 2008 and sponsored by ASTM Committee F08. This symposium was the fifth in a series: the first being held in 1987 in Montreal, the second in 1992 in Pittsburgh, the third in 1997 in St. Louis, and the fourth in 2002 in Pittsburgh. The objective of the symposium and corresponding publication has been to review the current state-of-the-art and science of ice hockey injury prevention.

The JAI Guest Editors are Richard M. Greenwald, Simbex, Lebanon, NH, Thayer School of Engineering, Dartmouth College, Hanover, NH and Alan B. Ashare, St. Elizabeth's Medical Center, Tufts University School of Medicine, Boston, MA.

Contents

Overview	vii
----------------	-----

Invited Commentary

The Acceleration-Axonal Strain Relationship and mTBI: Future Directions for Head Protection	
P. J. Bishop	3

Epidemiology of Ice Hockey Injury

A Synthesis of the World Literature of Ice Hockey Injuries: Epidemiologic Principles and Future Directions	
M. J. Stuart, K. A. Dajani, B. J. Crawford, M. L. Gill, A. A. Link, and A. M. Smith	11
A Prospective Study of Injuries in NCAA Intercollegiate Ice-Hockey Goaltenders	
R. F. LaPrade, C. A. Wijdicks, and S. I. Spiridonov	73
Acute Care in Cervical Spinal Cord Trauma with Long-Term Benefit: A Review	
A. B. Ashare and A. W. Lyckman	84

Ice Hockey Equipment Performance

A Longitudinal Study of Ice Hockey Helmet Shelf Life	
D. J. Pearsall and P. M. Dowler	99
Impact Attenuation Characteristics of Thin Walled Collapsible Air Chambers for Use in Protective Helmets	
T. B. Hoshizaki and A. Post	107
Development of a new methodology capable of characterizing the contribution of a controlled venting system to impact attenuation in chamber structures for head protection	
L. Lamb, A. Post, and T. B. Hoshizaki	117
Analysis of the Impact Performance of Ice Hockey Helmets Using Two Different Test Methodologies	
A. Giacomazzi, T. Smith, and R. Kersey	128
Translational and Rotational Accelerations Generated During Reconstructed Ice Hockey Impacts on a Hybrid III Head Form	
N. R. Coulson, S. G. Foreman, and T. B. Hoshizaki	141
A Comparison of Peak Linear and Angular Headform Accelerations Using Ice Hockey Helmets	
P. Rousseau, A. Post, and T. B. Hoshizaki	152
Preliminary Evaluation of Selected Hockey Equipment Tested according to EN TS15256: Protective Clothing—Hand, Arm, Leg, Genital, and Neck Protectors for Use in Ice Hockey—Protectors for Players Other than Goalkeepers—Requirements and Test Methods	
P. J. Bishop	171
Experimental Characterization of Ice Hockey Pucks and Sticks	
R. L. Bigford and L. V. Smith	186
When Metal Meets Ice: Potential for Performance or Injury	
K. Lockwood and G. Frost	198

Measuring Concussion Risk in Ice Hockey

Concussion in Youth Hockey: Prevalence, Risk Factors, and Management across Observation Strategies	
I. J. S. Williamson and D. Goodman	211
An Analysis of Head Impact Profiles and Safe Hockey Behaviors in Youth Hockey Players	
M. N. McPherson, W. J. Montelpare, M. Keightley, N. Reed, M. Sutherland, T. Taha, J. McAuliffe, J. R. Baker, J. Cubos, and B. Faught	234
In situ Measures of Head Impact Acceleration in NCAA Division I Men’s Ice Hockey: Implications for ASTM F1045 and Other Ice Hockey Helmet Standards	
J. T. Gwin, J. J. Chu, T. A. McAllister, and R. M. Greenwald	244
Relationships among Risk Factors for Concussion in Minor Ice Hockey	
J. Cubos, J. Baker, B. Faught, J. McAuliffe, M. L. Keightley, M. McPherson, A. Macpherson, N. Reed, C. Duggan, T. Taha, and W. J. Montelpare	260
Measuring Athlete Exposure and Body Contact Using Time-on-Task Technology in Ice Hockey	
B. E. Faught, J. Baker, J. Cairney, P. N. Corey, W. J. Montelpare, and M. Nystrom	277

Education, Warnings and Safety

Hockey Education Program (HEP): A Statewide Measure of Fair Play, Skill Development, and Coaching Excellence	
A. M. Smith, M. Jorgenson, M. C. Sorenson, D. Margenau, A. A. Link, M. MacMillan, and M. J. Stuart	291
Warnings and Instructions: One of Three Legs on Ice Hockey’s Safety Stool	
M. S. Granger and R. W. Miosek	311
Ice Hockey Facility Safety: Litigated Case Studies Involving Ice Hockey Injuries	
L. K. Lucenko	318
Author Index	335

Overview

This is the fifth in a series of presentations addressing issues of safety, injury prevention, and decreasing the risk of catastrophic injury—the first being published from the symposium held in 1987 at Montreal. These Symposia have been held every five to six years, which we feel is an adequate time for new ideas to be formulated. The idea is to present the latest ideas and promote discussion among researchers of expertise and experience in injury prevention and decreasing the risk for catastrophic injury. These presentations bring together researchers in a diverse group of fields, including sports medicine, bioengineering, mechanical engineering, neuropsychology, sports litigation, and sports epidemiology.

In some ways the game of ice hockey has changed, become faster, players have become bigger, and, to some extent, the game has become more dangerous. However, to the vast majority, the players are still “normal” size, are not very much faster than they were twenty years ago, but the players are still sustaining injuries, sometimes catastrophic, which incidence really should decrease with improvements in safety.

There are two objectives of these symposia: the first is injury prevention, and the second is decreasing the risk of catastrophic injuries. There are basically four approaches to achieving these objectives:

- changes or improvements in protective equipment,
- new coaching techniques,
- changes in the playing rules, and
- awareness of possible injuries by the players and coaches.

Head and neck injuries have again taken center stage with eleven of twenty two presentations. The analysis, prevention, and treatment of concussions (mild traumatic brain injuries) have been prominent for the past decade in ice hockey and other contact sports (football, soccer, lacrosse). We have learned to identify the problem, and we have taken steps to treat the injury, but, more importantly, we are looking to make strides in prevention.

There are continued improvements in protective equipment, the playing rules are continually evaluated to address reducing specific injuries, and coaches are using training techniques designed to help players avoid injuries, especially catastrophic injuries. But players still sustain injuries.

Acknowledgments

We would like to acknowledge the support and efforts of various individuals at ASTM. Martyn Shorten was Chairman of F08 when this symposium was being planned, and was extremely supportive and helpful. Harvey Voris was Chair of F08.90, Subcommittee on Symposia, and strongly supported this project. Christi Sierk, Staff Manager of F08, provided both on-site logis-

tical support and expertise in planning. Dorothy Fitzpatrick was essential in the coordination and execution of the symposium, as she has been for the last two (or is it three) symposia.

Linda Boniello worked tirelessly through the editorial process, and Suze Reilly was invaluable in the final process of completing and publishing this STP.

We acknowledge the financial support of HECC (Hockey Equipment Certification Council), USA Hockey, and USA Hockey Foundation. We want to thank the leadership of USA Hockey and the USA Hockey Foundation, Ron DeGregorio, President, Dave Ogreaan, Executive Director, and Bill Hall, Secretary, for their support and encouragement for this project. We want to thank Dr. Michael Nanne, President of HECC, for his support. We also thank our colleagues, the researchers, the rink managers, the manufacturers, the general safety enthusiasts, the players, and their families for their great interest in the prevention of injuries and promotion of safety for all hockey players.

Richard M. Greenwald, PhD
Simbex, Lebanon, New Hampshire
Thayer School of Engineering, Dartmouth College,
Hanover, New Hampshire

Alan B. Ashare, M.D.
St. Elizabeth's Medical Center
Tufts University School of Medicine
Boston, Massachusetts



www.astm.org

ISBN 978-0-8031-7503-7

Stock #: STP1516