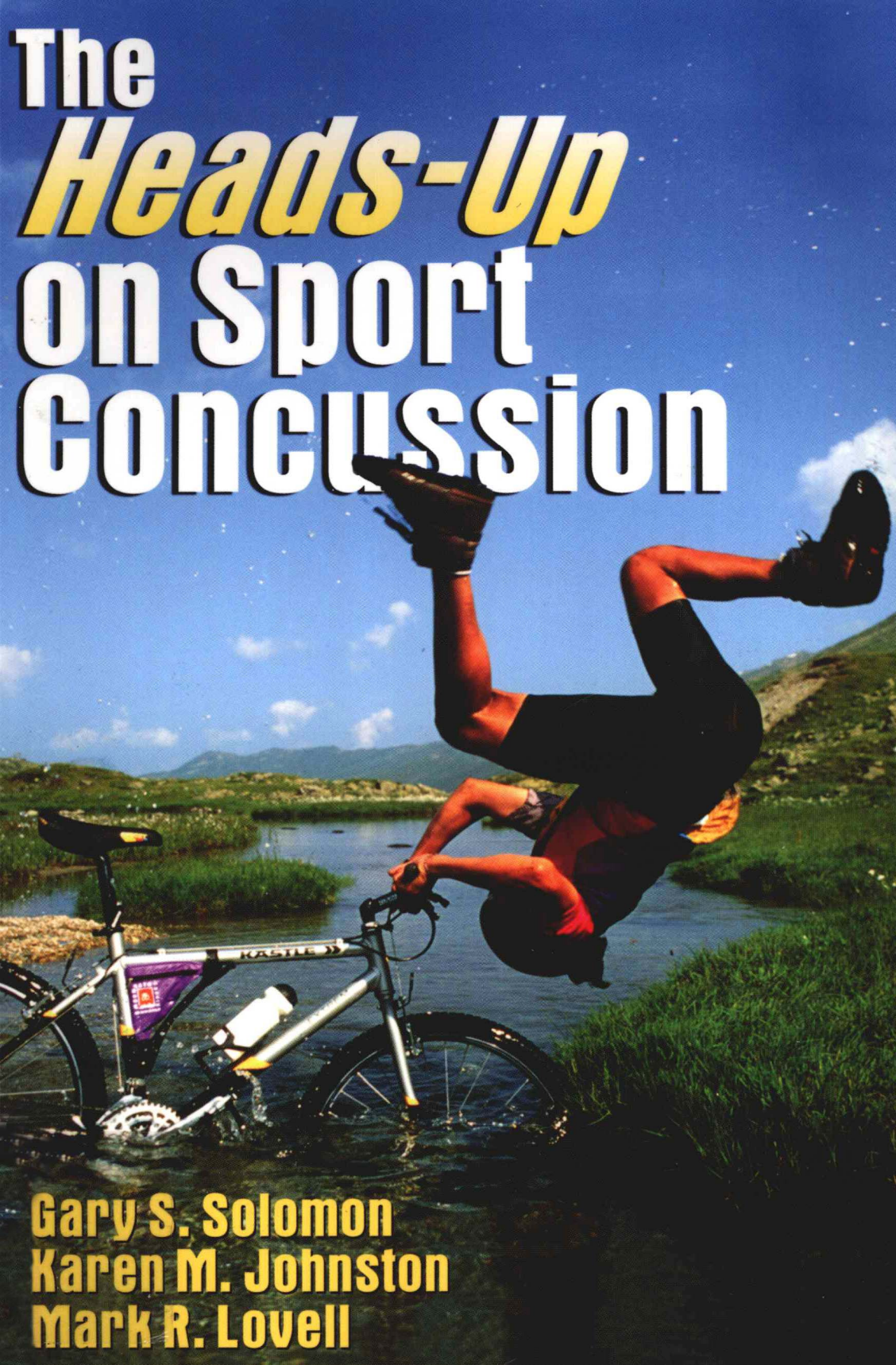


# The *Heads-Up* on Sport Concussion

A full-page photograph of a cyclist performing a handstand on a bicycle in a river. The cyclist is wearing a red shirt, black shorts, and a black cap. The bicycle is silver with a purple frame. The background shows a river, green hills, and a blue sky with scattered clouds.

**Gary S. Solomon**  
**Karen M. Johnston**  
**Mark R. Lovell**

# *The Heads-Up* **on Sport** *Concussion*

**Gary S. Solomon, PhD**

*Psychiatric Consultants, Nashville, Tennessee*

**Karen M. Johnston, MD, PhD**

*McGill University, Montreal, Quebec*

**Mark R. Lovell, PhD**

*University of Pittsburgh Medical Center,  
Pittsburgh, Pennsylvania*



**Human Kinetics**

## Library of Congress Cataloging-in-Publication Data

Solomon, Gary S., 1952-

The heads-up on sport concussion / Gary S. Solomon, Karen M. Johnston, Mark R. Lovell.

p. ; cm.

Includes bibliographical references.

ISBN 0-7360-6008-1 (soft cover)

1. Brain--Concussion. 2. Sports injuries.

[DNLM: 1. Brain Concussion--physiopathology. 2. Athletic Injuries--physiopathology. 3. Athletic Injuries--therapy. 4. Brain Concussion--therapy. WL 354 S689h 2006] I. Johnston, Karen M. II. Lovell, Mark R., 1953- III. Title.

RC394.C7S65 2006

617.4'81044--dc22

2005017701

ISBN: 0-7360-6008-1

Copyright © 2006 by Gary S. Solomon, Karen M. Johnston, and Mark R. Lovell

All rights reserved. Except for use in a review, the reproduction or utilization of this work in any form or by any electronic, mechanical, or other means, now known or hereafter invented, including xerography, photocopying, and recording, and in any information storage and retrieval system, is forbidden without the written permission of the publisher.

The Web addresses cited in this text were current as of July 2005, unless otherwise noted.

**Acquisitions Editor:** Loarn D. Robertson, PhD; **Developmental Editor:** Anne Cole; **Assistant Editor:** Kim Thoren; **Copyeditor:** Amie Bell; **Proofreader:** John Wentworth; **Permission Manager:** Dalene Reeder; **Graphic Designer:** Bob Reuther; **Graphic Artist:** Angela K. Snyder; **Photo Manager:** Sarah Ritz; **Cover Designer:** Keith Blomberg; **Photographer (cover):** MTB©Christian Perret/Jump; **Art Manager:** Kelly Hendren; **Illustrators:** Andrew Tietz and Al Wilborn; **Printer:** United Graphics

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

### Human Kinetics

Web site: [www.HumanKinetics.com](http://www.HumanKinetics.com)

*United States:* Human Kinetics

P.O. Box 5076

Champaign, IL 61825-5076

800-747-4457

e-mail: [humank@hkusa.com](mailto:humank@hkusa.com)

*Canada:* Human Kinetics

475 Devonshire Road Unit 100

Windsor, ON N8Y 2L5

800-465-7301 (in Canada only)

e-mail: [orders@hkcanada.com](mailto:orders@hkcanada.com)

*Europe:* Human Kinetics

107 Bradford Road

Stanningley

Leeds LS28 6AT, United Kingdom

+44 (0) 113 255 5665

e-mail: [hk@hkeurope.com](mailto:hk@hkeurope.com)

*Australia:* Human Kinetics

57A Price Avenue

Lower Mitcham, South Australia 5062

08 8277 1555

e-mail: [liaw@hkaustralia.com](mailto:liaw@hkaustralia.com)

*New Zealand:* Human Kinetics

Division of Sports Distributors NZ Ltd.

P.O. Box 300 226 Albany

North Shore City

Auckland

0064 9 448 1207

e-mail: [info@humankinetics.co.nz](mailto:info@humankinetics.co.nz)



*You'll find  
other outstanding  
sports medicine resources at*

**www.HumanKinetics.com**

*In the U.S. call*

**1-800-747-4457**

- Australia..... 08 8277 1555
- Canada ..... 1-800-465-7301
- Europe..... +44 (0) 113 255 5665
- New Zealand..... 0064 9 448 1207



**HUMAN KINETICS**

*The Information Leader in Physical Activity*  
P.O. Box 5076 • Champaign, IL 61825-5076 USA

"This book is a must-read for all coaches, parents, and yes, contact-sport athletes. Written by respected authorities and comprehensively and clearly covering the white-hot sports medicine topic of concussion, this book merits reading by all involved with sports."

*Robert C. Cantu, MD, MA, FACS, FACSM*  
*Chief of neurosurgery service and director of sports medicine,*  
*Emerson Hospital, Concord, MA*  
*Medical director, National Center for Catastrophic Sports*  
*Injury Research*

"This book provides a unique and much-needed perspective on the increasingly common problem of sport-related concussion. The book covers all aspects of sport-related concussion and will serve as an invaluable resource for physicians, athletic trainers, coaches, parents, and athletes. This book is a must-read for anyone interested in the issue of brain concussion in sports."

*Joseph Maroon, MD*  
*Team neurosurgeon, Pittsburgh Steelers*  
*Heindle Scholar in Neuroscience*  
*Professor, University of Pittsburgh School of Medicine*

"This work by Solomon and colleagues provides for all of us an excellent shelf reference summarizing the current state of clinical practice and applied research related to the assessment and management of sport concussion. The authors have successfully created a valuable resource appropriate for all professionals charged with the care of athletes after a concussion. In contrast to other respected texts intended primarily for a medical readership, this introductory text also provides a wealth of information that athletes, parents, and coaches will find helpful as they attempt to gain a better understanding of concussion, the expected course of recovery, and the basis for a cautionary approach to return-to-play decision making after a head injury. The authors also offer a unique contribution to the literature with their dedicated section on injury treatment and rehabilitation, which is often lacking in the discussion on concussion management. By pointing out those questions yet to be answered regarding young sport participants' early and long-term risks, the authors admirably pave the way for future research that will continue to drive an evidenced-based approach to clinical management of sport concussion."

*Michael McCrea, PhD, ABPP  
Director, Neuroscience Center  
Waukesha Memorial Hospital*

"This book is a unique approach to understanding concussion in sport. The text is current and comprehensive in scope. All aspects of concussion, from anatomy and metabolism of the injury to assessment and treatment of injury, are discussed. As an athletic trainer involved in professional football, I was interested in the information about other professional sports. I found the writing style to be unlike that in a textbook; the information is presented in such a way that it was very readable and easily understood. In addition to being a valuable resource for the athletic trainer, the text will also be of value to parents who have children involved in sports as well as coaches and other health professionals."

*John A. Norwig, ATC  
Head athletic trainer  
Pittsburgh Steelers Football Club*

# Preface

This book began as a five-page "Introduction to Concussion" seminar presented to professional hockey coaches in 2001. We began to expand the information in an attempt to compile an introductory guide to concussion for athletes and their families, professionals, and patients who often have similar questions about concussion, treatments, and long-term outcomes. The material included in this book presents the final product after several years of compiling information on sport concussion.

Some excellent advanced medical textbooks are available on sport concussion (for example, see Lovell, Echemendia, Barth, and Collins, 2004, *Traumatic Brain Injury in Sports: An International Neuropsychological Perspective*). No introductory book on sport concussion, however, is directed specifically toward professionals who work with athletes. *The Heads-Up on Sport Concussion* is directed toward sports medicine and family physicians, athletic trainers, athletes, coaches, psychologists, students, and other professionals interested in sport concussion. Our hope is that the reader of this book will gain a more complete understanding of the various aspects of sport concussion and thus provide better care and education to athletes who sustain sport concussions. Although much of what is presented in this book may be applicable to concussion in general, the focus is on sport-related concussion. This book is not intended to be a substitute for appropriate medical or neuropsychological evaluation and treatment of any type of concussion. An athlete (and any other person) should always see a physician for the initial evaluation of a concussion.

*The Heads-Up on Sport Concussion* is a relatively comprehensive review of the current literature on sport concussion. The book includes information related to concussion and head injury from the fields of biochemistry, neuroimaging, neuropsychology, and epidemiology. We have made a conscious attempt to avoid dealing with detailed scientific critiques of the studies presented. We encourage you to consult the original sources if you would like

more information about scientific methodology, data-analysis techniques, and experimental design. Most chapters include a Research Digest section to provide further scientific details of particular studies. Appendix A presents an overview of the content in chapters 1 through 6, with a special focus on the concerns that interest athletes, parents, and coaches. Clinicians can use this appendix as a communication tool when working with these individuals. Appendix B contains a resource section on sport concussion with a list of helpful Web sites.

Virtually all of the information contained in this book is based on the work of experts in the fields of sports medicine, neurology, neurosurgery, and neuropsychology. We have attempted to synthesize their scientific work into a readable and understandable introductory text. In an effort to make the text accessible for multiple levels of readers, we have included a running glossary that contains terms specific to the field.

We address the definitions of concussion, symptoms of concussion, short- and long-term effects of concussion, the demographic and epidemiological data on sport concussion (by gender and sport, when available), and what is thought to happen in the brain structurally and chemically during and after a concussion. We review grading scales, the use of neuropsychological and neuroimaging tests, and the role of loss of consciousness in sport concussion. We look at what the National Collegiate Athletic Association (NCAA), National Football League (NFL), and National Hockey League (NHL) have done and are doing about concussion. Overviews of concussion in boxing and in soccer are presented with a focus on heading the ball in soccer. Finally, various diagnostic and assessment strategies for concussion are addressed and consensus opinions about rehabilitation are presented. We have attempted to make it clear when we are presenting our personal opinions. We use the terms *concussion*, *closed head injury*, and *mild traumatic brain injury* (mTBI) interchangeably throughout the book, although in scientific parlance and clinical reality they are not necessarily the same.

Various chapters and sections in the book begin by posing a general question about an area of sport concussion. At the end of each section we offer conclusions and our opinions. We are also making a poster available for concussion education. This poster is a free download and can be found at [www.HumanKinetics.com/TheHeadsUpOnSportConcussion](http://www.HumanKinetics.com/TheHeadsUpOnSportConcussion). We hope that trainers, physicians,



coaches, and sports medicine professionals will use this poster to educate athletes and their families about the signs, symptoms, and treatment of concussion.

The evaluation and treatment of sport concussion are rapidly expanding areas of sports medicine. New findings appear in the professional literature almost every month, so it is virtually impossible for the information in this book to be entirely up to date. However, every attempt has been made to keep the information in this book current and timely. With those caveats in mind, let's get to work.

# ***Acknowledgments***

We extend our appreciation to Loarn Robertson, senior acquisitions editor at Human Kinetics, for his willingness to publish our work and to Anne Cole, our editor at Human Kinetics, for making our manuscript readable and presentable.

For permission to use photographs and drawings we heartily thank Dr. David Hovda of UCLA; Dr. Richard Leblanc, Jen-Kai Chen, and Dr. Alain Ptito of the Montreal Neurological Institute; Russ Pace and Andy Solomon of The Citadel; Tom McClellan and Kip Sloan of East Carolina University; Laura Duncan of the Center for Research and Education at Centennial Medical Center; Matt Nelson, Teddie Whitaker, and Mark Cohen of Wofford College; Richard Riley; Brian Stutts; Nancy Solomon-Stutts; Cindy and Lionel Cartwright; Kristy and Katie Solomon; The Alzheimer's Disease Education and Referral Center; the National Institute of Health; and the National Institute on Aging. Appreciation is extended to Dr. Robert Jamieson for computer expertise and to Geoff Kaplan, ATC, of the Tennessee Titans for football terminology specifics.

To our families, friends, business partners, and office staffs who supported us through this endeavor, we offer our apologies and love.

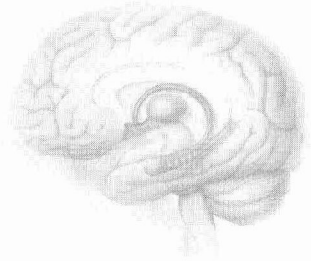
We offer our respect and thanks to the athletes, coaches, athletic therapists, physiotherapists, trainers, physicians, and sports medicine professionals with whom we work in the area of sport concussion.

# Contents

Preface .....	vii
Acknowledgments .....	xi
<b>Chapter 1: Sport Concussion: Just the Facts .....</b>	<b>1</b>
<i>Cast of Characters in Sport Concussion</i> .....	1
<i>The Brain</i> .....	4
<i>What Is a Concussion?</i> .....	7
<i>Are Head Injuries in Sports Really a Problem?</i> .....	12
<i>Second-Impact Syndrome</i> .....	15
<i>Increased Awareness for Sport Concussion</i> .....	17
<i>How Many Athletes Get Concussions?</i> .....	20
<i>Research Digest</i> .....	24
<b>Chapter 2: Brain Processes and Symptoms .....</b>	<b>25</b>
<i>What Happens in the Brain During a Concussion?</i> .....	25
<i>What Are the Typical Symptoms of Concussion?</i> .....	31
<i>What Is the Role of Loss of Consciousness in Sport         Concussion?</i> .....	34
<b>Chapter 3: Assessment and Evaluation .....</b>	<b>37</b>
<i>Clinical History</i> .....	37
<i>Sideline-Assessment Strategies</i> .....	38
<i>Balance Testing</i> .....	42
<i>Neuroimaging Techniques</i> .....	44
<i>Neuropsychological Testing</i> .....	49
<i>Role of Grading Scales in Assessment</i> .....	52
<i>How Long Does It Take to Recover         From a Concussion?</i> .....	56
<i>Research Digest</i> .....	57

<b>Chapter 4: Treatment and Rehabilitation</b> .....	<b>61</b>
<i>Medical Treatments for Concussion</i> .....	61
<i>Nonmedical Management and Rehabilitation</i> .....	63
<i>Research Digest</i> .....	68
<b>Chapter 5: Concussion in Professional Sports</b> .....	<b>69</b>
<i>Concussion in the National Football League</i> .....	69
<i>Concussion in the National Hockey League</i> .....	74
<i>Concussion in Boxing</i> .....	76
<i>Concussion in Soccer</i> .....	82
<i>Research Digest</i> .....	90
<b>Chapter 6: Current Trends, Research, and the Future</b> .....	<b>93</b>
<i>What Are Professional Organizations</i> <i>Doing About Sport Concussion?</i> .....	93
<i>What Are the Long-Term Effects of Concussion?</i> .....	98
<i>Do Helmets Help?</i> .....	106
<i>What Can We Do About Concussion?</i> .....	109
<i>New Research and the Future</i> .....	110
<i>Research Digest</i> .....	112
Appendix A: Essential Information for Athletes, Parents, and Coaches .....	115
<i>Signs and Symptoms</i> .....	117
<i>Assessment, Evaluation, and Treatment</i> .....	118
<i>Sport-Specific Concerns</i> .....	120
<i>Long-Term Effects</i> .....	121
<i>Return to Play</i> .....	122
<i>Educating Athletes About Concussion</i> .....	122
Appendix B: Resources .....	125
References .....	127
About the Authors .....	139

## *chapter 1*



# ***Sport Concussion: Just the Facts***

In this chapter we discuss the people involved in the assessment and treatment of sport concussion; introduce you to some basic facts about the brain; and review some definitions of concussion, which is more difficult to pin down than you might think. We also discuss the demographics of sport concussion and review the available epidemiological data.

## **Cast of Characters in Sport Concussion**

The cast of characters in sport concussion includes athletes, physicians, athletic trainers, sport psychologists, and neuropsychologists (now being called sport neuropsychologists by some authors). Let's get more specific about who these folks are and what they typically do.

The athletes discussed in this book include those involved in various high school, collegiate, and professional sports. We have little data to share regarding athletes younger than the midteens. In general, the information presented relates to athletes in the age range of 15 to 40. The studies reviewed include athletes of both genders, although female athletes have been studied specifically

as a group in sport concussion only recently. Therefore, more data are related to men than women in the available literature. We predict this difference may disappear in the near future (particularly because women appear to incur more concussions than men do in some sports). See the chapter by Brooks (2004) for a discussion on gender issues in brain injury.

The care of athletes who have sustained a sport concussion is generally assigned to a team of sports medicine and health care professionals, which may include athletic trainers, physicians, and neuropsychologists. Responsibilities and duties among these professionals vary across settings and individual levels of training and expertise.

Physicians are major players in the assessment and treatment of sport concussion. Indeed, physicians typically have primary responsibility for medical care and return-to-play decisions. Team physicians at the professional level often include members of the medical specialties of internal medicine, orthopedic surgery, neurology, family practice, neurosurgery, ophthalmology, plastic surgery, and dentistry. Each National Hockey League (NHL) team seems to have a virtual mobile unit of physicians at each game, including an orthopedic surgeon, dentist, internist, plastic surgeon, and ophthalmologist. Most National Football League (NFL) teams have at least an internal medicine physician and an orthopedic surgeon on the sideline at each game. The suggestion has been put forward that a neurological specialist should be in attendance also. A primary care physician (PCP) is also a significant partner in this process, especially in the absence of a full-time team physician.

Although head injury and concussion have typically been viewed as being primarily within the scope of the medical specialties of neurology and neurosurgery in a hospital setting, it seems paradoxical that physicians of varying specialties have become involved in the evaluation and treatment of concussion in sports. It is possible that in many instances the physician's specialty may be less important than his or her knowledge about and experience with concussion.

The team athletic trainer (or ATC, which stands for athletic trainer, certified) is the front-line health care professional in sport concussion. Dr. Michael Ferrara and colleagues (2001) reported that ATCs care for an average of seven concussive injuries per year. It is the ATC to whom most athletes initially report their symptoms and concerns, and it is the ATC in whom athletes often have the

greatest trust. ATCs who work closely with athletes generally know them best and are usually the source of an excellent opinion as to how an athlete is functioning after a concussion.

A neuropsychologist is a doctoral-level psychologist (PhD or PsyD) with specialty training and experience in the assessment and treatment of disordered brain-behavior relationships. A *neuropsychologist* (or sport *neuropsychologist*) is not the same as a sport psychologist. A sport psychologist is a doctoral-level psychologist who has specialty training and experience in the scientific application of psychological factors that are associated with participation and performance in sport and exercise. Kontos and colleagues (2004) have published an introduction to sport concussion for the sport psychology consultant. Neither a sport psychologist nor a neuropsychologist is a medical doctor, and neither can prescribe medication independently or admit a patient to a medical hospital.

Although both types of psychologists can make valuable contributions to athletes, their roles differ considerably. We recommend seeing a neuropsychologist for the evaluation and assessment of sport concussion and a sport psychologist for issues related to athletic performance. New data about the role of sport psychology interventions in concussion rehabilitation are being explored (Bloom et al. 2004). The neuropsychologist typically administers written, oral question-and-answer, or computer-based tests to evaluate the cognitive effects of concussion. In some settings, physicians and ATCs will administer cognitive tests; they should be properly trained and experienced in the administration and interpretation of these tests. Just because someone is licensed as a physician, athletic trainer, or psychologist does not automatically mean that the individual is competent in the administration and interpretation of cognitive tests used for the evaluation of sport concussion.

So this is the cast of characters in sport concussion. Who is the leader of this team of sports medicine professionals? Who makes the decision about returning an athlete to play after a concussion? In a survey of 339 athletic trainers attending the 1999 National Athletic Trainers' Association (NATA) Annual Meeting, Ferrara and colleagues (2001) reported that team physicians (40%) and athletic trainers (34%) were primarily responsible for making return-to-play decisions. Professionals have varying opinions as to who should take the lead and who should make the decision about an athlete's return to play after a concussion. Some maintain that the team physician should decide, whereas others think that the ATC should

**medicolegal**—The interface of medical practice and legal (liability) issues.

make the call. Yet others believe that the neuropsychologist should make the decision. The politics and, more important, the **medicolegal** considerations surrounding this issue are significant.

A simple, straightforward answer to these questions cannot always be found. The circumstances, resources, and professional expertise of the available sports medicine professionals of each team may dictate the answer. With all things being equal and under ideal circumstances, we believe that the final decision should be one of consensus among the professionals, as recommended by the NATA position statement on sport-related concussion (Guskiewicz et al. 2004). Ultimately, however, the final decision in most cases will be left to the team physician.

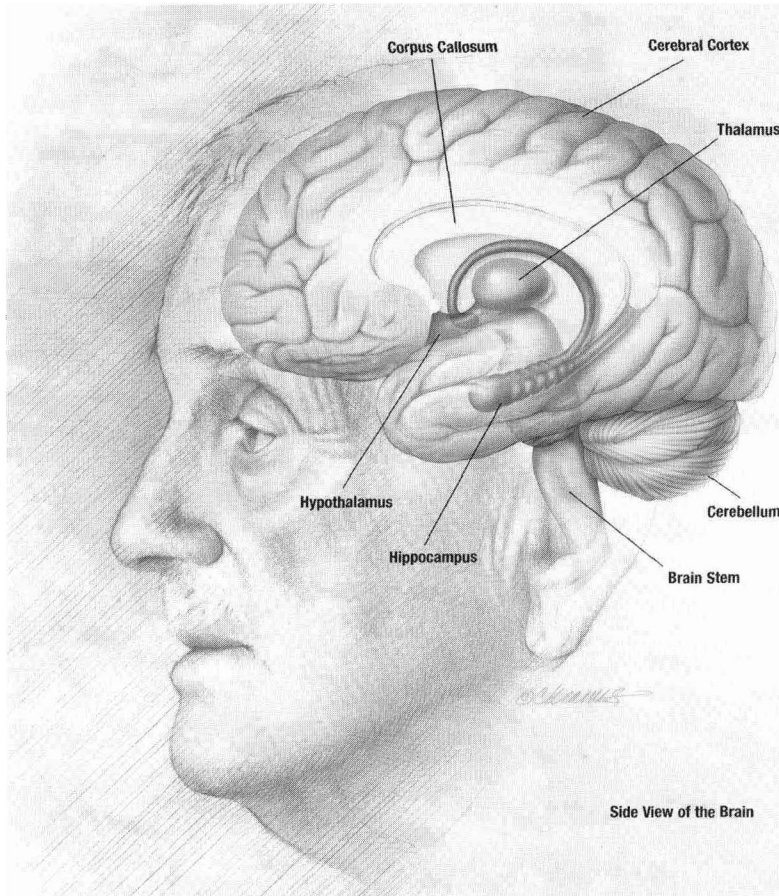
## The Brain

The brain is the head coach, general manager, and chief executive officer of the mind and body. Like the human heart, it is always working. The brain, however, has a much longer life span than the typical career of a sports team head coach, general manager, or corporate CEO. The long life span of the brain is one reason to be concerned about an athlete's brain and to make every effort to protect it. The brain is the only one the athlete will ever have.

Concussion can impair the brain functions of thinking and reaction time (often referred to as speed of information processing), memory, concentration, balance, and eye-hand coordination. These abilities are the cognitive functions of the brain, and they are the most vulnerable in a concussion. A concussion can be as simple as a brief blow to the head, with rapid recovery, or it can be a life-threatening medical emergency. A concussion is an insult to the brain (both literally and figuratively). Figure 1.1 shows a side view of the major parts of the brain.

Athletes tend to show greater worry over an injury to a knee than to the brain. And yet, a knee can be repaired surgically; we cannot do this routinely with an injury to the brain. An athlete with a concussed brain can be a danger on the field, both to herself and to her teammates. Not all concussions are created equally, and all need to be considered individually. Both neurological and psychological factors are relevant and may need to be taken into





**FIGURE 1.1** Knowledge of the structure of the brain and how it functions will aid in understanding concussions.

Courtesy of the Alzheimer's Disease Education and Referral Center, a service of the National Institute on Aging.

account in the assessment of concussion. The clinical evaluation of concussion requires an individualized approach, as recommended and described by the Concussion in Sport Group (2002).

Let's review some basic information about the brain. The consistency of the brain is similar to gelatin and thus is vulnerable to outside trauma. Figure 1.2 shows a lifelike model of an exposed human brain. It is encased within the skull, which offers it some protection. However, the skull does not absorb impact forces to the head, so it functions very poorly as a shock absorber. This lack of ability to absorb impact leaves the brain vulnerable to injury, and