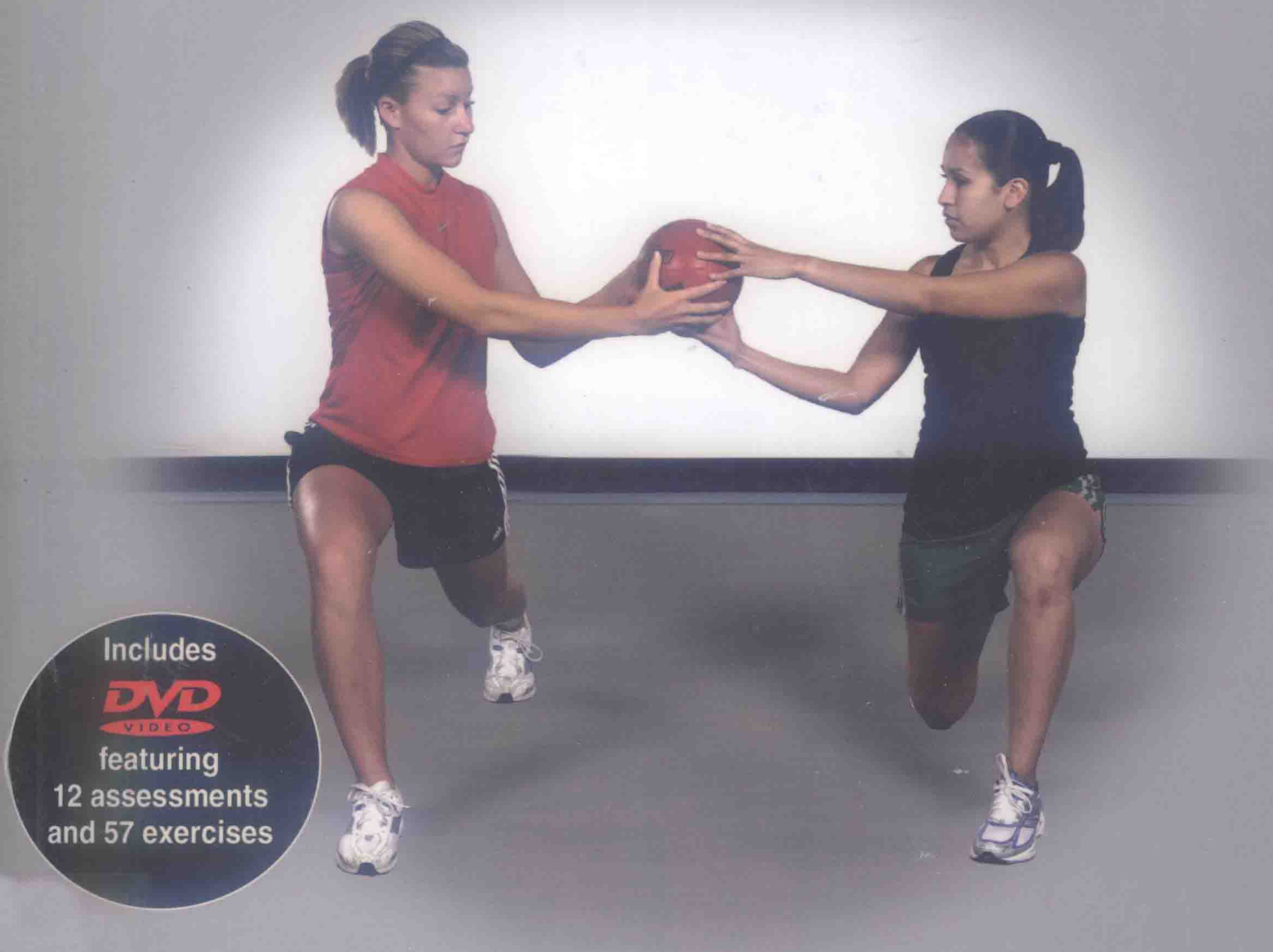
Core Assessment and Training



Human Kinetics

Core Assessment and Training

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Library of Congress Cataloging-in-Publication Data

Core assessment and training / Human Kinetics with Jason Brumitt.
p. ; cm.
Includes bibliographical references and index.
ISBN-13: 978-0-7360-7384-4 (soft cover)
ISBN-10: 0-7360-7384-1 (soft cover)
1. Physical education and training. 2. Abdomen----Muscles. 3. Chest--Muscles. I. Brumitt, Jason. II. Human Kinetics (Organization)
[DNLM: 1. Exercise. 2. Physical Fitness. 3. Athletic Injuries--prevention & control. 4. Athletic Injuries--rehabilitation. 5. Exercise Therapy--methods. 6. Musculoskeletal System--injuries. QT 255 C797 2010]
GV711.5.C662 2010
613.7--dc22

2009036254

ISBN-10: 0-7360-7384-1
ISBN-13: 978-0-7360-7384-4

The Web addresses cited in this text were current as of October, 2009, unless otherwise noted.

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Printed in the United States of America 10 9 8 7 6 5 4 3 2

The paper in this book is certified under a sustainable forestry program.

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E4406

Preface

Core training is one of the hottest trends in fitness and rehabilitation. Our understanding of the role that the core plays in health, injury prevention, sport performance, and rehabilitation has grown dramatically in recent years. Furthermore, biomechanists and sports medicine researchers are continually advancing this understanding—new breakthroughs are occurring all the time. What was true 10 years ago is not true today!

Unfortunately, the terms *core assessment* and *core training* are sometimes thrown around as a catchall phrase describing any exercise or series of exercises purported to train this region of the body. The concepts of core stability training are often misunderstood, resulting in training programs that are poorly designed and sometimes dangerous.

Whether you are a personal trainer, a strength coach, or a rehabilitation professional, you must be able to properly analyze core function and be able to implement safe and effective training programs. This will enable you to help your clients maximize their goals.

To aid your understanding of key core assessments and exercises, the accompanying DVD includes video demonstrations that review proper techniques for many of the exercises and assessments. Throughout the text, assessments and exercises that are demonstrated on the DVD are marked with a DVD icon. A complete list of the assessments and exercises on the DVD appears on page 154.

No two people are the same, and the training programs for two people should not be the same either! *Core Assessment and Training* will help you improve your ability to assess a client's baseline core function. This book will also help you develop the best individualized program for each of your clients.

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1

Introduction to Core Training

Fitness and sports medicine professionals share the common goal of developing and implementing optimal training programs for their clients and athletes. Billions of dollars are spent each year by individuals, schools, universities, and professional teams in order to build better athletes and improve sport and human performance. Likewise, thousands of people employ the services of personal trainers each year in an effort to improve their health and physical fitness. Despite the pursuit of optimal sport performance or improved physical fitness, people who exercise (let alone those who do not exercise) are not immune to injury.

THE CHALLENGE OF DESIGNING OPTIMAL TRAINING PROGRAMS

With all of the technological advances and training innovations designed to enhance sport and human performance, one might assume that the risk of a sport- or work-related overuse injury would be a thing of the past. Unfortunately, this is not the case. Physicians' offices, emergency rooms, physical therapy clinics, and athletic training centers are often filled with competitive athletes, weekend warriors, and laborers seeking care for musculoskeletal injuries. Billions of dollars in health care costs are incurred each year by Americans requiring medical treatment for musculoskeletal injuries.

Injuries to the low back (or low back pain) account for the majority of musculoskeletal injuries. The economic costs associated with low back pain are staggering. In the United States over $25 billion is spent each year treating patients who are suffering from low back pain (Luo et al. 2004). The total economic cost (health care costs, loss of work time, loss of productivity) related to low back pain has been estimated to be nearly $200 billion annually in the United States (Katz 2006).

Millions of patients receive conservative treatments from practitioners such as physical therapists, athletic trainers, chiropractors, and massage therapists. Patients who fail to improve with conservative measures may require more extensive medical evaluations (including imaging studies), the prescription of pain or anti-inflammatory medications, and invasive treatments such as injections or surgery. These medical treatments are not without risk. Radiographs (X rays) expose the body to radiation, prescription medications may cause negative side effects, and surgical interventions sometimes fail to alleviate the person's pain. Despite the resources devoted to the diagnosis and treatment of low back pain, optimal treatment strategies continue to elude health care providers. The best treatment strategy may be to prescribe a comprehensive exercise program that focuses on training the core.

Why Athletes and Fitness Clients Still Sustain Injuries

Why are athletes still sustaining injuries? A likely reason is the inadequate design of the athlete's strength training program, including a failure to address all potential risk factors for injury. When developing and implementing strength training programs, many training professionals rely on their own past experiences or on the advice of an exercise "guru." Using past experiences or suggestions from training experts (who often rely on their own past experiences) may be helpful in guiding the initial development of a program.

However, these routines may fail to account for one or more key components of a comprehensive training program. For training professionals who are seeking assistance with program design, a better option is to access the research literature. Unfortunately, many times there is a **paucity** (or a lack) of good research to help guide the decisions on program design. This book highlights evidence-based training programs (when available). In addition, evidence-supported strategies are presented to help coaches, fitness professionals, and sports medicine practitioners design and implement optimal core training programs. These strategies enable program designers to fill in the gaps in the research literature so they can create effective programs for their clients.

Should a female cross country athlete perform the same strength training program as a male football player? Obviously not. However, some athletes are prescribed a "one-size-fits-all" training program. Although some similar exercises may be performed by different athletic populations, the design of the athlete's training program should be guided by the physiological requirements of the sport as well as the strength and conditioning needs of the individual. In addition, an appreciation for injury risk factors and the proper mechanics of the sport should be factored into the final exercise program.

To highlight the challenges of using the research literature when developing a strength training program, let's look at the female high school athlete in the sport of cross country. Endurance runners risk injury to any lower extremity joint. **Epidemiological** investigations of high school cross country runners have found that female cross country athletes have a greater risk of sustaining a sport-related lower extremity injury when compared with their male counterparts (Rauh et al. 2000; Rauh et al. 2006). Once injured, a majority of the athletes were able to return to running after being sidelined for 1 to 4 days. Although this time lost to injury may seem short, it becomes significant if the injury occurs a day or two before a meet. Also of significance is the finding that, once injured, the cross country athlete has a four- to fivefold increase in her chances of reinjuring the same body part during the season.

Once it has been demonstrated that a particular population—in this case, the female cross country athlete—is at risk (or has a greater risk of injury than another group), potential risk factors should be investigated. Numerous risk factors have been proposed as having a role in the onset of a running-related injury, but very few published reports exist that support (or refute) these claims. An epidemiological investigation was conducted to determine the incidence of **medial tibial stress syndrome (MTSS)** in cross country athletes at the high school level and to identify potential risk factors associated with this injury (Plisky et al. 2007). Some of the risk factors analyzed in this investigation included sex, **body mass index (BMI),** running experience, navicular drop (an objective measurement of foot mechanics), and history of running injury. Female cross country athletes experienced a greater incidence of MTSS and only one risk factor (a higher BMI) demonstrated an association with an increased risk of a MTSS injury.

Findings from this type of epidemiological report should influence strength training coaches who design training programs for cross country athletes at the high school level. However, this athletic population—female high school athletes in the sport of cross country—provides an example of a paucity in the literature regarding each potential factor that may increase the risk of injury (these factors may include hip weakness, poor core endurance capacity, and asymmetrical range of motion in the hip and lumbar area). Because of the lack of epidemiological investigations that assess all potential risk factors, designing and implementing training programs that reduce the risk of injury can be a challenge.

When there is a lack of research (in this case, a lack of epidemiological reports and **evidence-based** training programs), professionals should look for additional studies and reports that use similar populations (e.g., college runners instead of high school runners). These complementary reports may improve one's ability to design a program for the female cross country athlete at the high school level.

In one such study, a **handheld dynamometer** was used to objectively measure the strength of six hip muscle groups in 30 recreational runners (ranging in age from 18 to 55) who were diagnosed with a unilateral running-related overuse injury (Niemuth et al. 2005). The researchers compared these findings with a control group of uninjured runners. They found no significant differences in hip strength between the control group and the uninvolved hip of the injured runners. However, within the experimental group (the injured runners), significant weakness was found for the hip abductors and flexors on the injured side. In addition, the hip adductors were significantly stronger on the injured side. Although a direct cause-and-effect relationship cannot be concluded from this study, the results indicate that hip weakness or muscular imbalance may be associated with running injuries.

In another study, researchers retrospectively identified hip abductor weakness in distance runners with **iliotibial band syndrome (ITBS)** (Fredericson et al. 2000). Runners who had been diagnosed with ITBS demonstrated significant weakness of the hip abductors when compared with uninjured controls. The experimental group was composed of 24 consecutive collegiate or club long-distance runners who attended a "runners' injury clinic" for evaluation and were diagnosed with ITBS. They were compared to a control group consisting of 30 distance runners from Stanford University's cross country or track teams. Those who were diagnosed with ITBS subsequently participated in a 6-week rehab program. The therapy program involved one or two sessions of therapeutic **modalities** along with a progression through a standardized exercise program (consisting of two strengthening exercises for the gluteus medius and two stretching exercises). The injured athletes who participated in the rehab program realized an increase of 35% (females) to 51% (males) in hip abductor torque. Also, 22 of the 24 runners returned to their sport at 6 weeks. This case series is an important study adding to the clinical belief that hip weakness in distance runners may adversely affect biomechanics, thus contributing to overuse-related injuries in the lower extremity.

The findings from these reports suggest that weakness of the core muscles may be a factor in the onset of a running-related injury. Although additional prospective investigations are warranted, the research indicates that a strength training program for this population should address weakness of the core.

Even less research is available to guide exercise prescription for the nonathletic client. A majority of the sports medicine research has focused on the competitive athlete (high school to professional ranks). The literature definitely lacks research related to the recreational athlete or the weekend warrior. In addition, it is difficult to find epidemiological research or evidence-supported training programs for those who work in jobs that involve intensive manual labor. Despite advancements in the field of **ergonomics,** the implementation of corporate injury prevention programs, and employee education on proper lifting mechanics and body awareness, work-related musculoskeletal injuries continue to occur. These injuries contribute to lost productivity, soaring health care costs, and disruption to the lifestyle of the employee.

What Is Missing From Current Programs?

Sometimes athletes and clients fail to follow the training or rehabilitation programs that were designed for them. In some cases, this problem (albeit not a simple one) can be remedied by properly motivating the client (Brown 2004; Middleton 2004; Milne et al. 2005; Muse 2005; Sabin 2005). However, the problem is often the result of the strength training professional (e.g., fitness trainer, strength coach, or sports medicine professional) failing to design and implement a comprehensive training program.

Program design can be extremely challenging. A training professional can feel overwhelmed just trying to figure out where to begin. It would be easy if a universal training program could be prescribed to an individual based on the person's sport or functional goals. The advantage of a "cookbook" program or protocol is that it can offer training suggestions purported to be beneficial by other trainers, coaches, or rehabilitation professionals. Unfortunately, cookbook programs do not account for individual differences in athletes or clients.

The following are clinical cases that represent examples of clients or athletes seen every day in athletic training rooms, rehabilitation clinics, and fitness centers. As you read each scenario, attempt to identify potential functional weaknesses or limitations for each client. Then generate some training ideas to help correct those dysfunctions.

- **Clinical scenario 1:** A 35-year-old female wants to resume a running program. In the past, she ran to maintain physical fitness. She has also participated in weekend 5K and 10K fun runs in the past and wishes to be able to do that again. She had a cesarean section 4 months ago and has not run in over a year and a half. This client will present with abdominal weakness related to the cesarean and more than likely will also present with muscular weakness or imbalance in the remaining core muscles. Failure to address muscular dysfunction and weakness may contribute to the onset of a lower back or lower extremity running-related injury. The addition of a core training program may help to reduce the risk of sustaining an injury.

- **Clinical scenario 2:** A high school discus thrower is frequently straining muscles in his low back. He usually experiences an episode of low back pain when he practices longer than 2 hours in a day. He is currently performing a training program (which his coach adopted from a track and field Web site) that includes squats and lunges. He is able to demonstrate adequate power and strength based on the amount of weight he is able to lift, but something is obviously missing. Evaluating the endurance capacity of his core muscles is crucial. Fatigue of these muscles will affect how forces are generated and transferred through his kinetic chain as he throws.

■ **Clinical scenario 3:** A 23-year-old female has suffered pain in the front of both knees for 3 years. Her previous three attempts at physical therapy have failed to reduce her pain or improve her functional ability. She is employed as a medical transcriptionist and is generally sedentary. She continues to do the exercises previously prescribed by her physical therapist: straight leg raises and short arc quads to strengthen the hip flexors and quadriceps, and hamstring stretches. Is a rehab or postrehab program complete if it emphasizes only the quadriceps and hamstrings? There is research suggesting that the hip musculature plays a crucial role in lower extremity biomechanics. Weakness in the hip may dramatically affect the stresses experienced at the knee.

TRAINING THE CORE IS THE MISSING LINK

In the scenarios described in the previous section, the exercise programs likely failed because they were missing one essential component: core training.

Core training, a popular buzzword in the fitness and rehabilitation worlds, is still poorly understood. In the training programs prescribed by some trainers or therapists, the choice of exercises for training the core (or the lack of core exercises) is often shocking. Core stability training should serve as a foundation for all training and rehabilitation programs. Core training *should not* promote or cause dysfunction in clients! Fitness professionals who follow the advice of a training guru may invite trouble for their clients. These trainers may apply the flavor-of-the-month exercise or implement a generic training program for *all* of their clients irrespective of individual needs and goals.

The strategies outlined in this book will help you design and implement evidence-supported core training programs that reduce the risk of injury and maximize the client's performance (sport or functional performance). To develop optimal training programs, you must be able to assess your clients' functional needs, identify their weaknesses, and prescribe the appropriate exercises. This text guides you through the process of assessment, testing, and prescription of core exercises.

DEFINING CORE TRAINING

Before developing a core training program, you must have an understanding of the core and its unique functional roles. The *core* is the region of the body consisting of the muscles and joints of the abdomen, the low back, the pelvis, and the hips. An overview of human skeletal musculature is shown in figure 1.1. (A basic review of functional anatomy is provided in chapter 2.) The core muscles have dual roles. The first role is protecting (stabilizing) the spine from excessive (and potentially injurious) forces; the second role is in the creation and transfer of forces in a proximal-to-distal sequence (Kibler et al. 2006). **Proximal-to-distal sequencing** refers to how a force may be generated or created and then transferred through the body. An easy way to understand proximal-to-distal sequencing is to think of the pitching motion in baseball. As the pitcher begins his windup, he is generating a force with his rear leg. During the pitching motion, this force is transferred from the lower extremity (proximally) through the body to the throwing arm (distally) in order to maximize the velocity of the pitch.

When the core muscles are functioning optimally, the person will be able to safely perform athletic or functional activities. When dysfunction is present, the person's performance will suffer, and she may also be at an increased risk for injury.

Two terms associated with core training are *core stability* and *core stabilization.* These terms relate to the ability of the core muscles to protect the spine (the terms are also used to describe the exercises that promote core stability). Stability of the core (for athletes) has been defined as "the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic (or kinetic chain) activities" (Kibler et al. 2006, p. 189). Failure to adequately train these muscles will limit the effectiveness of the core in doing its job. *Core training,* then, is the process of using specific exercises to maximize the core's unique functional roles.

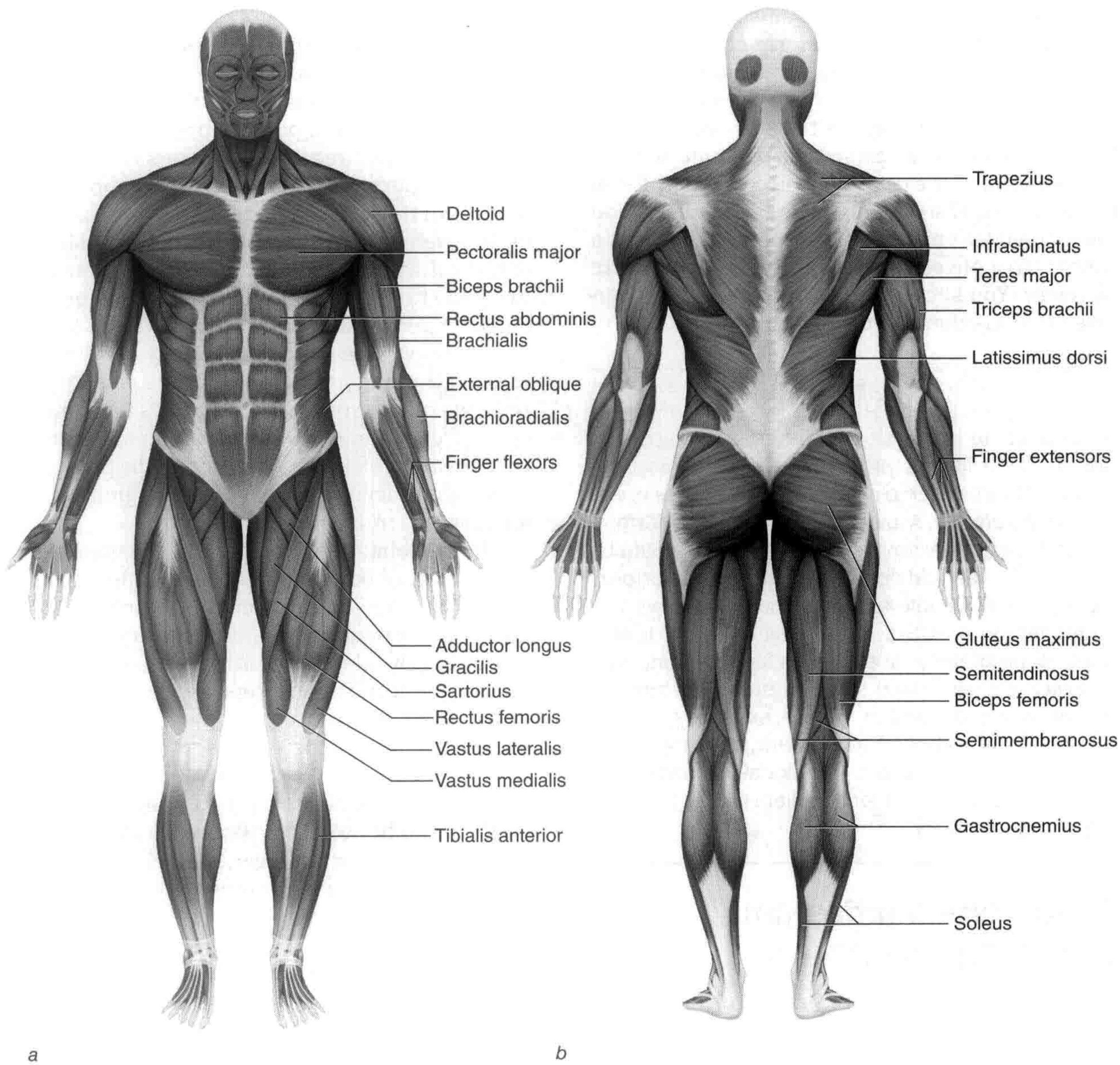

Figure 1.1 Adult male human skeletal musculature, *(a)* front and *(b)* rear views. The core consists of the muscles and joints of the abdomen, low back, pelvis, and hips.

Reprinted, by permission, from NSCA, 2008, Biomechanics of resistance exercise, by E. Harman. In *Essentials of strength training and conditioning*, 3rd ed., edited by T. Baechle and R. Earle (Champaign, IL: Human Kinetics), 68.

How many of your clients are performing basic core exercises? The answer should be all of them. All fitness clients, athletes, rehab patients, and postrehab clients will benefit from the inclusion of core exercises in their individualized training programs.

Improving Physical Fitness

Many clients who seek out services from fitness professionals have only a basic understanding of core training. For many, their previous core training may have been limited by ignorance. Some may believe that core exercises can only be performed by using that "one-of-a-kind" piece of equipment they saw on a late-night infomercial. For others, training the core is equated with performing machine-based exercises such as the seated row and the lat pull-down. Unfortunately, some people purchase expensive gym memberships for the sole purpose of having access to the machines that are purported to isolate key core muscles. In reality, a majority of clients can perform core exercises without the use of any form of machinery!

The services you provide as a personal trainer or strength coach may be the only health- and fitness-related services sought by some of your clients. If this is the case, you must carefully listen to the unique history and goals of the client. You must consider any conditions that may warrant a referral to a physician or appropriate health care provider. You should then choose sensible exercises that maximize the client's potential.

Warning

In an effort to prevent their clients from becoming bored, some fitness professionals prescribe exercises that either serve no functional purpose or are potentially unsafe. Avoid having your clients perform circus tricks! An example of a circus trick would be having a 55-year-old nonathletic individual performing a pull-down cable exercise while balancing on a single leg on a BOSU. As you will see later in this book, many of the best exercises for promoting core stability are performed either in static postures or in one plane of motion. These exercises require minimal or no special equipment. Making subtle changes to these basic functional exercises will increase the challenge for the client without sacrificing personal safety.

Preventing Injuries and Rehabilitating Clients

As previously mentioned, back injuries are one of the most common conditions treated by medical doctors, osteopaths, physical therapists, and chiropractors. Unfortunately, there is a lack of consensus among medical professionals regarding how to best treat patients who are suffering from back pain. To prevent the onset of a back injury, an ounce of prevention may truly be worth a pound of cure.

Low back pain will affect up to 80% of the U.S. population (Rasmussen-Barr et al. 2003). Some sustain low back injuries as a result of a traumatic event such as a motor vehicle accident or a fall from a height. In these situations, it is unlikely that a strength training routine or injury prevention program could have helped the person avoid injury. On the other hand, a majority of patients who suffer from low back pain develop an injury from repetitively overstressing the joints and muscles of the spine. Many of these injuries may be avoided if an evidence-supported strength training program is in place.

Training professionals need to change the way they view people who perform physically demanding jobs. Just like an athlete, laborers require their bodies to perform at high levels for prolonged periods of time. Based on that alone, people who perform labor-intensive jobs should be considered *industrial* or *occupational athletes.* Athletes are expected to perform exercises to avoid injury and enhance performance. Industrial athletes should do the same. Some employees may receive specialized training programs at progressive organizations and corporations, but this is far from the norm. Developing wellness programs (including core training exercises) for people in physically demanding occupations is an emerging market for strength training professionals.

The rehabilitation program for an injured industrial athlete should include core training, regardless of whether the person has a back injury or an extremity injury. Researchers tested isometric hip strength bilaterally in individuals who had undergone a unilateral knee surgery (Jaramillo et al. 1994). Significant weakness was found in the hip flexors, extensors, abductors, and adductors on the surgical extremity. This report was unable to demonstrate a direct cause-and-effect relationship between hip weakness and the need for a knee surgery; however, the results from this study highlight the importance of addressing the core musculature as part of a comprehensive rehabilitation program.

Significant consequences can be associated with some athletic injuries. Sport-related injuries to the spine or hips may result in a loss of practice or training time, missed competitions, countless hours of rehabilitation, or possibly the end of the athlete's career. A growing body of research highlights how core weakness in athletes can contribute to the onset of a sport-related injury.

In one study, researchers performed a prospective investigation in order to assess the effects of core weakness on the incidence of athletic injury (Leetun et al. 2004). The researchers analyzed preseason measures of hip strength and trunk endurance to determine if a particular score was associated with the onset of a sport-related injury during the season. One hundred forty college athletes from six schools were tested within 2 weeks of beginning practice. Using a dynamometer, the researchers collected isometric values for hip abduction and external rotation. Trunk

Case Example: Injured Worker With Poor Core Endurance and Dysfunctional Movement Patterns

A 42-year-old male with a physically demanding job was referred to physical therapy with a diagnosis of low back pain. His job entailed lifting loads ranging from 25 to 100 pounds (11.3 to 45.4 kg) consistently throughout the day. While attempting a "light lift" (his words) of 50 pounds (22.7 kg), he felt a pop in his back, and he fell to his knees. He described it as "initially an intense pain with muscle spasms throughout his back." He scheduled an appointment with his medical doctor, who prescribed pain medication, rest, and physical therapy.

The patient's first physical therapy appointment was 2 weeks after the onset of the injury. He reported that his symptoms had improved and his pain had significantly decreased. During the interview portion of the physical therapy evaluation, he told the therapist the following: "I'm not sure why I'm here. I'm as strong as an ox; I can lift whatever I want." This patient was equating a good (healthy) back with the ability to lift required work loads. The physical therapist evaluated the patient's strength, finding him to be not only grossly weak through his trunk musculature (poor endurance capacity of the torso muscles) but also functionally weak. He was unable to demonstrate proper squatting and lunging techniques. Because this patient was unable to use his core muscles to stabilize and protect his spine, he was instead using dysfunctional movement patterns whenever he attempted to lift an object. He likely used poor body mechanics each time he performed a lift. Improper lifting techniques, especially with heavy objects, will impart **supraphysiologic** loads to his spine. Over time, tissues will fail, leading to injury and dysfunction.

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endurance scores were collected using the endurance tests as described by McGill (see chapter 4) (McGill 2002).

The researchers found that female athletes were significantly weaker in the hip abductors, the hip external rotators, and the lateral core endurance measures (lateral endurance test) than their male counterparts (Leetun et al. 2004). Male athletes also tended to be stronger than the female athletes on the remaining tests. Those who experienced an injury during the season demonstrated significant weakness in both hip abduction and hip external rotation. Preseason weakness of the hip external rotators was determined to be the best predictor for athletes who later sustained a lower extremity injury.

In another study, researchers prospectively tested the hip strength (gluteus maximus and medius) in collegiate athletes to determine if hip strength imbalances increased the likelihood of an athlete requiring treatment for low back pain (LBP) (Nadler et al. 2001). Eight percent of all athletes tested (13 of 163) required LBP treatment during the subsequent year. Not surprisingly, 6 of the 13 athletes had a history of LBP. The percentage difference between a female athlete's left and right hip extensor strength was statistically significant as a predictor for the athlete requiring LBP treatment. All other relationships were determined to be insignificant. The researchers concluded that the findings from this study support the notion of a relationship between hip muscle imbalance and the onset of low back pain in female athletes.

Another group of researchers recorded mean and maximal values for the strength of the hip abductor and extensor muscles in 210 (70 female and 140 male) NCAA collegiate athletes (Nadler et al. 2000). These values were recorded during the athletes' preparticipation screening physical. This investigation was performed to determine if a relationship exists between athletes who demonstrate asymmetrical hip strength and those who have a history of low back or lower extremity injury. Female athletes who reported either a lower extremity injury or low back pain the previous year demonstrated a statistically significant side-to-side difference in maximal hip extension strength. Male athletes who reported a history of low back pain or lower extremity injury did not demonstrate side-to-side differences in hip strength.

In a different study, golfers who had a history of low back pain were found to demonstrate significantly less internal and external rotation of the lead hip when compared to golfers with no history of low back pain (Vad et al. 2004). The golfers with a history of low back pain also demonstrated less flexibility in lumbar extension.

The previous examples show that a dysfunctional core may contribute to an athlete experiencing a sport-related back injury. Core stability training may help to reduce the athlete's risk of injury, aid in rehabilitation after an injury, and enhance athletic performance (Chiu 2007).

Enhancing Athletic Performance

Spine stabilization exercises also serve to enhance athletic performance. The trunk is one component of the functional kinetic link system. For example, athletes who perform overhead throwing will generate power from their lower extremities and transfer those forces through the trunk to the upper extremity. This proximal-to-distal sequencing gives the upper extremity the ability to achieve maximal acceleration at the highest possible speed (Kibler 1998). Dysfunctional activation of the trunk musculature may result in poorer athletic performance. A dysfunctional trunk also places the athlete at risk of injuring a distal segment. The baseball pitcher who has a dysfunctional trunk will still attempt to perform at his optimal level late into a game. The forces generated by the legs will be incompletely transferred to the upper extremity. The pitcher will automatically compensate for this by attempting to generate more torque at the shoulder. Repeating this sequence enough times can lead to excessive loads on the shoulder, resulting in a rotator cuff injury. Establishing adequate endurance capacity and strength of the trunk will not only reduce injury risk but will also improve athletic performance.

SUMMARY

By now you should understand the need for including exercises for the core in the training programs for all clients and athletes. Inadequate program design or a failure to include core exercises may limit the effectiveness of an individual's training program. Failure to address core weakness may put a client or athlete at a greater risk of sustaining a sport- or work-related injury. The growing body of research evidence is pointing to the critical role of core training for injury prevention, rehabilitation, and sport and human performance. Throughout this book, evidence-based training and rehabilitation programs are presented (when available). In addition, evidence-supported strategies are presented to help coaches, fitness professionals, and sports medicine practitioners design and implement optimal core training programs. Research related to core training is in its infancy, and no doubt over time publications from sports medicine researchers will improve our ability to design effective and safe core training programs.

This book is divided into four parts. Part I provides the scientific rationale behind core training; part II covers how to assess a client's core strength and flexibility and how to interpret the findings; part III describes how to develop an evidence-supported core training program based on the client's functional weaknesses; part IV provides a review of common core-related musculoskeletal injuries. Each part builds on the others in order to enhance your ability to design optimal programs for core stability training.

2

Functional Anatomy of the Core

The *core* is the central region of the human body, consisting of musculoskeletal structures from the abdomen, the spine, the pelvis, and the hips (Kibler et al 2006). The core functions to generate movement, create and transfer forces, and provide stability. A dysfunctional core may limit a client's or athlete's performance and may increase the risk of sustaining an injury. Fitness professionals must be able to functionally test the client in order to identify a dysfunctional core. A working knowledge of the functional anatomy of the core will enhance your ability to identify weak or tight muscles and improve your ability to recognize dysfunctional movement patterns. Having this knowledge will improve how you design a core training program and enhance your ability to communicate with other professionals.

This chapter provides a review of the basic functional anatomy of the core, highlighting the functional roles of key core muscles in providing stability and movement. This chapter does *not* provide a comprehensive anatomical or biomechanical study of the core. Refer to a college anatomy text for a more comprehensive review. Two additional reference texts (related to the core and anatomy) that all strength training professionals should own are Stuart McGill's *Low Back Disorders: Evidence-Based Prevention and Rehabilitation, Second Edition* (Human Kinetics 2007) and Robert Behnke's *Kinetic Anatomy, Second Edition* (Human Kinetics 2006).

CORE ANATOMY

Good strength coaches and fitness professionals know how to prescribe a strength training or rehabilitation program and how to progress an individual through that program. Great strength coaches and fitness professionals have a solid understanding of anatomy, an appreciation for joint biomechanics, and the ability to assess functional strengths and weaknesses. These professionals also have the skill to integrate these components when developing a comprehensive individualized training program.

Bony Anatomy

The bony anatomy of the core includes the spine, the pelvis, and the hip joints (figure 2.1). The spinal column (also known as the vertebral column or the backbone) is made up of 33 vertebrae, along with intervertebral discs, numerous ligaments, and associated muscles. From top to bottom, the five vertebral regions are the cervical spine (7 vertebrae), the thoracic spine (12 vertebrae), the lumbar spine (5 vertebrae), the sacrum (5 fused vertebrae), and the coccyx (4 fused vertebrae) (figure 2.2). The spine connects to the pelvis via the sacrum (figure 2.3). The pelvis provides shape to the

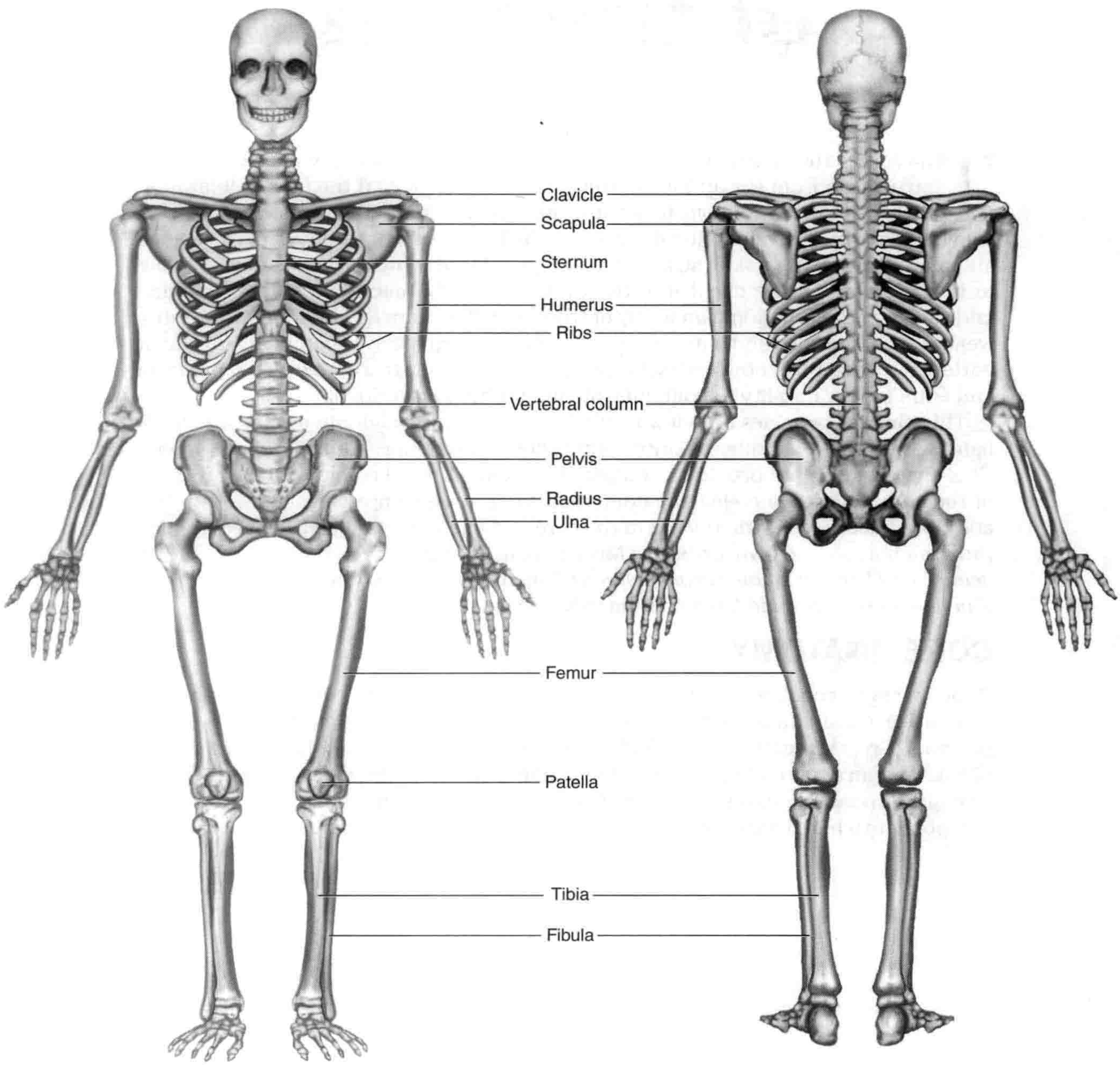

Figure 2.1 The human skeletal system. The bony anatomy of the core includes the spine, pelvis, and hip joints.
Reprinted, by permission, from NSCA, 2000, The biomechanics of resistance exercise, by E. Harman. In *Essentials of strength training and conditioning*, 2nd ed., edited by T. Baechle and R. Earle (Champaign, IL: Human Kinetics), 27.

base of the core and consists of three portions: the ilium, the ischium, and the pubis. The intersection of these three portions helps to form the acetabulum, which is the socket that the head of the thighbone (femur) fits into (figure 2.3). This is called the acetabulofemoral or hip joint.

The lumbar spine (along with the sacrum and coccyx) provides structure to the posterior and inferior parts of the core. Although the significance of the adjacent regions within the core should never be minimized, special attention and consideration should be given to the lumbar spine. As health care professionals can attest, the lumbar spine is at risk for numerous injuries. Over 80% of all people in the United States have had or will experience at least one episode of low back pain (Trainor and Wiesel 2002; Rasmussen-Barr et al. 2003). Billions of dollars are spent each year on operative and nonoperative treatments for the low back (Young et al. 1997; Luo et al. 2004; Katz 2006).

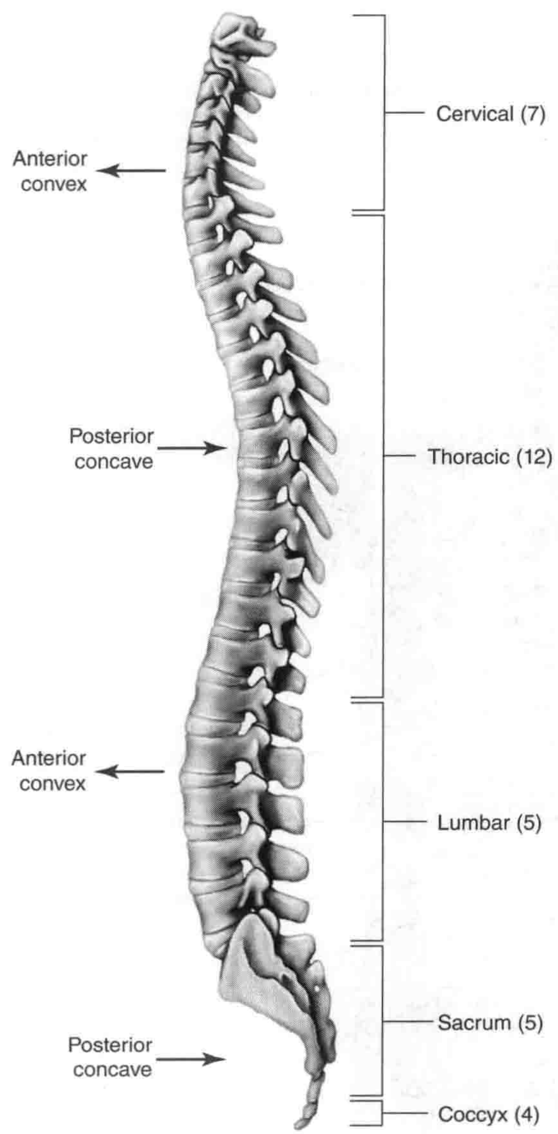

Figure 2.2 The spinal column, showing the five vertebral regions.

Reprinted from R. Behnke, 2005, *Kinetic anatomy*, 2nd ed. (Champaign, IL: Human Kinetics), 120.

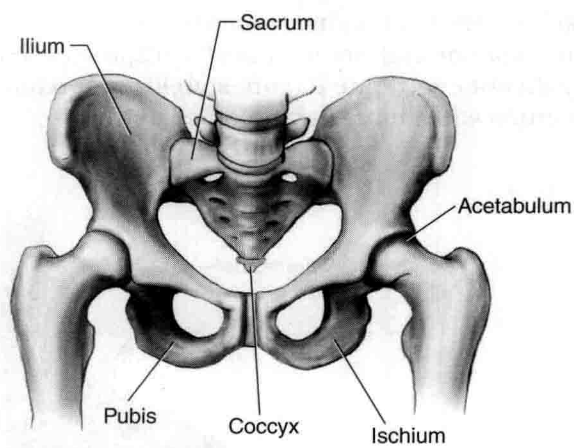

Figure 2.3 The sacrum and pelvis.

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