Basic Athletic Training

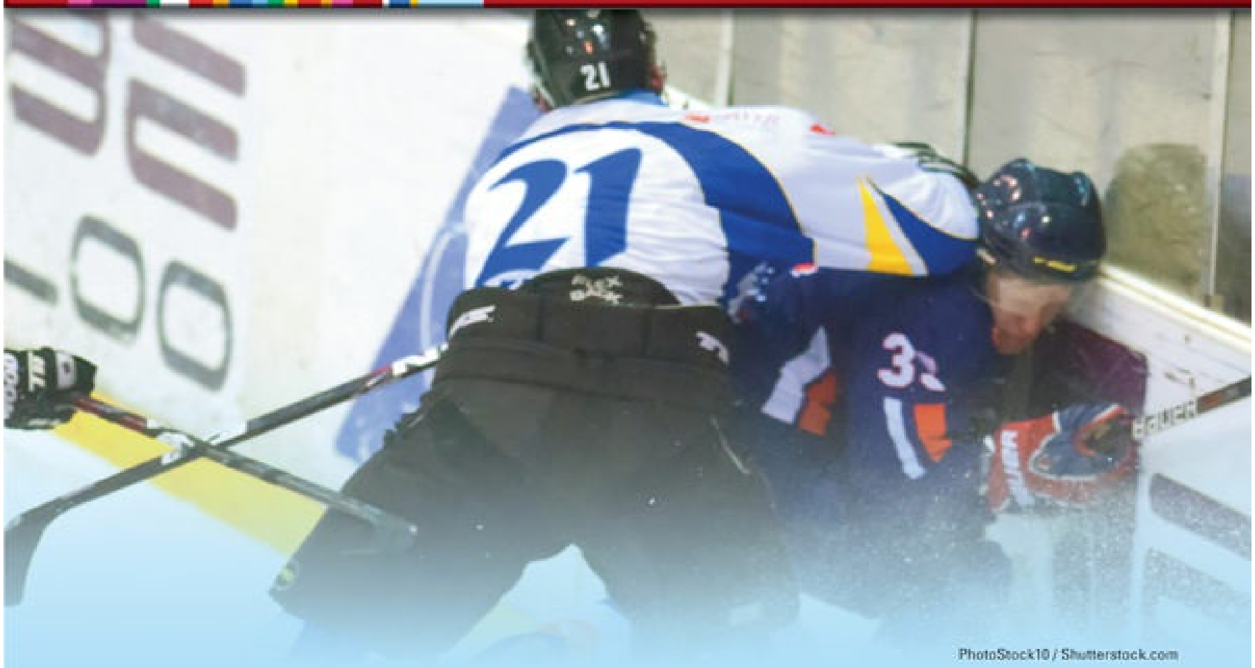
Course Pack A

For use in PES 385, Basic Athletic Training, SUNY Brockport.

CHAPTER

3

Protective Equipment



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STUDENT OUTCOMES

1. Describe the forces that produce focal and diffuse injuries.
2. State the principles used to design protective equipment.
3. Identify the different types of soft and hard materials used to make protective pads.
4. Explain the athletic trainer's legal duty of care in selecting and fitting protective equipment.
5. List the agencies responsible for establishing material standards for protective devices.
6. Identify the information that should be documented to support an organization's legal duty to provide safe

equipment.

7. Demonstrate proper selection and fitting of selected equipment (e.g., football helmets, mouth guards, and shoulder pads).
8. Identify and describe common protective equipment for the head and face, the torso, and the upper and lower body.

INTRODUCTION

Specialized equipment, when properly used, can protect a participant from accidental or routine injuries associated with a particular sport or physical activity, but limitations exist regarding the effectiveness of protective equipment. A natural outcome of wearing protective equipment is to feel more secure. Unfortunately, this often leads to more aggressive play, which can result in injury to the participant or an opponent. In many cases, it is the shared or sole responsibility of the athletic trainer to ensure that protective equipment meets minimum standards of protection, is in good condition, is clean and properly fitted, used routinely, and used as intended. This is one of the most critical responsibilities that an athletic trainer does to minimize the risk of injury to sport participants.

In this chapter, principles of protective equipment and materials used in the development of padding are discussed. This is followed by a review of protective equipment for the head and face and then of equipment used to protect the upper and lower body. When appropriate, guidelines for fitting specific equipment are listed. Although several commercial braces and support devices are illustrated, these are intended only to demonstrate the variety of products available to protect a body region.

PRINCIPLES OF PROTECTIVE EQUIPMENT

? What are the advantages of using high-density material in the protection of injuries?

In events involving impact and collisions, the participant must be protected from high-velocity, low-mass forces and from low-velocity, high-mass forces. High-velocity, low-mass forces occur, for example, when an individual is struck by a ball, puck, bat, or hockey stick. The high speed and low velocity of such an impact leads to forces being concentrated in a smaller area, causing **focal injuries** (i.e., injuries concentrated in a small area, such as a contusion). In contrast, an example of low-velocity, high-mass forces is an individual falling on the ground or ice or being checked into the sideboards of an ice hockey rink, thereby absorbing the forces over a larger area. Low-velocity, high-mass forces lead to **diffuse injuries** (i.e., injuries spread over a larger area, such as a concussion).

Sport-related and physical activity injuries can result from a variety of factors, including the following:

- Illegal play
- Poor technique
- Inadequate conditioning
- Poorly matched player levels
- A previously injured area that is vulnerable to reinjury
- Low tolerance of an individual to injury
- Inability to adequately protect an area without restricting motion
- Poor quality, maintenance, or cleanliness of protective equipment

Potential means by which equipment can protect an area from accidental or routine injuries associated with a particular activity are listed in **Box 3.1**. Equipment design extends beyond the physical protective properties to include size, comfort, style, tradition, and both initial and long-term maintenance costs. Individuals responsible for the selection and purchase of equipment should be less concerned about appearance, style, and cost, and be most concerned about the ability of the equipment to prevent injury.

BOX 3.1 Equipment Design Factors That Can Reduce Potential Injury

- Increase the impact area
- Transfer or disperse the impact area to another body part
- Limit the relative motion of a body part
- Add mass to the body part to limit deformation and displacement
- Reduce friction between contacting surfaces
- Absorb energy
- Resist the absorption of bacteria, fungi, and viruses

Materials Used

The design and selection of protective equipment is based on the optimal level of impact intensity afforded by the given thickness, density, and temperature of the energy-absorbing material. Soft, **low-density material** is light and comfortable to wear, but such material is effective only at low levels of impact intensity. Examples of low-density material include gauze padding, foam, neoprene, Sorbothane, felt, and moleskin. Low-density materials are useful in reducing friction and preventing blisters and abrasions. In contrast, firmer, **high-density material** of the same thickness tends to be less comfortable, offers less cushioning of low-level impact, but can absorb more energy by deformation. As such, it transfers less stress to an area at higher levels of impact intensity. Examples of high-density material include thermomoldable plastics, such as orthoplast and thermoplast, and casting materials, such as fiberglass and plaster. High-density materials are useful in protecting the patient from direct blows and focal injuries.

Another factor to consider in energy-absorbing material is **resilience** to impact forces. Highly resilient materials regain their shape after impact and are used over areas that are subject to repeated impacts. Nonresilient (or slow-recovery resilient) material offers the best protection and is used over areas subjected to one-time or occasional impacts. It is important to select equipment that will absorb an impact and disperse it before injury occurs to the underlying body part.

Soft Materials

Soft materials are light because of the incorporation of air into the material. Examples include gauze padding, neoprene, Sorbothane, felt, moleskin, and foam. Gauze padding comes in a variety of widths and thicknesses and is used as an absorbent or protective pad. Neoprene sleeves provide uniform compression, therapeutic warmth, and support for a chronic injury, such as a recurrent quadriceps or hamstring strain. The nylon-coated rubber material is comfortable and allows full mobility, better absorption of sweat, and less skin breakdown; it also provides the individual with proprioceptive feedback in the affected area. Sorbothane often is used for shoe insoles to absorb and dissipate impact forces during walking and running. Felt is made from matted wool fibers and pressed into several thicknesses, ranging from 0.25 to 1 in. Felt can absorb perspiration but, in doing so, has less of a tendency to move under stress. Typically, it is necessary to replace felt daily. Moleskin is a thin felt product with an adhesive bonding on one side that prevents any movement once applied to the skin. This product is used over friction spots to reduce skin irritation or blisters.

Foam, like felt, comes in a variety of thicknesses, ranging from 0.125 to 1 in, and ranges in density from a very soft, open-cell foam to a denser, closed-cell foam. **Open-cell foam** has cells that are connected to allow the passage of air from cell to cell. Similar to a sponge, this material can absorb fluids and is used to pad bony prominences or to protect the skin under hard edges of protective equipment or custom-fabricated pads. Open-cell foams deform quickly under stress; therefore, they do not have good shock-absorbing qualities. **Closed-cell foam** is used primarily for protection because air cannot pass from one cell to another. The material rebounds and returns to its original shape quickly, but it offers less cushioning at low levels of impact and is not as comfortable next to the skin.1

To use the differing properties of foam effectively, many equipment designers layer materials of varying density. Air management pads combine open- and closed-cell foams encased in polyurethane or nylon to provide maximal shock absorption. Soft, lower density material is placed next to the skin and is covered by increasingly denser, closed-cell material away from the skin to absorb and disperse higher intensity blows. The pad is airtight, which prevents quick deformation of the foam so energy can be dissipated over the entire surface of the pad. Air management pads often are used in football shoulder pads, but they are more expensive and require extensive maintenance if the nylon covering is torn. If the covering tears, air can pass into the pads, reducing their effectiveness. The liners must then be patched or replaced. Nylon prevents the absorption of perspiration or water, which can help to avoid additional weight, and is easily cleaned with a weak bleach solution.

Some dense foams are thermomoldable; that is, when heated, they can be molded and shaped to fit any body part. When cooled, they retain their shape. These pads can be used repeatedly to immobilize a body structure, deflect an impact, and absorb shock. The pad is secured to the body part with elastic or nonelastic tape.

Hard Materials

Hard materials include thermomoldable plastics, such as orthoplast and thermoplast, and casting materials, such as fiberglass and plaster, which can be used to splint or protect an area. Thermoplastics are divided into two categories: plastic and rubber. The plastic group uses a polycaprolactone base with varying amounts of inorganic filler, resins, and elastomers to affect the memory, stiffness, and durability of the material. The plastic category tends to conform better than the rubber category and is more appropriate for small splints, such as on the hand. Plastics include materials such as Aquaplast Bluestripe (WFR/Aquaplast), Multiform I and II (Alimed), Orfit (North Coast Medical), and Orthoplast II (Johnson & Johnson). Rubberlike materials use a polyisoprene base and include Aquaplast Greenstrip (WFR/Aquaplast), Orthoplast (Johnson & Johnson), Synergy (Rolyan), and Ultraform Traditions (Sammons).

Most of these materials are heated while lying flat for about 1 minute at temperatures between 150° and 180°F. The material is then shaped for 3 to 4 minutes before returning to a hardened form. Minor changes can be made with a heat gun, but changes should never be performed while the splint is on the patient.

Casting materials, such as fiberglass and plaster, are used to splint a body part, but conditions such as macerations, ulcerations, infections, burns, blisters, rashes, and allergic contact dermatitis can result from extended use. Individuals often report that such casts itch, smell, and are difficult to keep dry. Fiberglass casts with a stockinette or cast padding can limit moisture, but they must be dried (usually with a hair dryer) to prevent maceration, odor, and itching. A new Gore-Tex liner developed for use under fiberglass repels water; permits evaporation; and allows bathing, swimming, sweating, and hydrotherapy without any special drying of the cast or skin. The liner comes in 2-in, 3-in, and 4-in widths and is applied directly to the skin. Fiberglass casting material is then applied over the liner. Although slightly more expensive than traditional casts, those incorporating this type of liner do not have to be changed as often because they stay more comfortable throughout the immobilization period.

Construction of Custom Pads and Protective Devices

In some settings, the athletic trainer has access to the soft and hard materials mentioned earlier in this chapter. These materials can be used in constructing a variety of custom pads or protective devices. Custom pads can be advantageous for several reasons, such as cost, design, and availability. In addition, custom pads can be designed to meet the needs of the individual. The athletic trainer should ensure that custom-made devices are constructed and fit properly. The athletic trainer assumes legal responsibility for use of any custom-made devices.

Rules Regarding Protective Pads

The National Federation of State High School Associations (NFSHSA) and the National Collegiate Athletic Association (NCAA) have specific rules regarding the use of soft and hard materials to protect a body area. The on-site referee must determine that specific fabricated pads are made of soft materials or meet the standards for hard materials established by the NFSHSA or NCAA. Hard, abrasive, or unyielding substances may be used on the hand, wrist, forearm, or elbow if the substance is covered on all exterior surfaces with no less than a 0.5-in thick, high-density, closed-cell polyurethane or a material of the same minimum thickness and similar physical properties. In addition, a written authorization form must be signed by a licensed medical physician that indicates the cast or splint is necessary to protect the body part. This form must be available to the referee before the start of competition. The referee must verify that the hard material is properly padded according to the guidelines and has the right to eject the player for using the cast or splint as a weapon.[1]

> High-density materials, such as thermomoldable plastics and casting materials, can absorb more energy by deformation and, in doing so, transfer less stress to an injured area.

LIABILITY AND EQUIPMENT STANDARDS

> During football practice, an athletic trainer notices that the quarterback is wearing a helmet with a two-point chin strap. What action or actions should be taken by the athletic trainer, and why?

Legal issues concerning protective equipment are a major concern for every athletic trainer and organized sport program. An organization's duty to ensure the proper use of protective equipment usually is a shared responsibility among the members of the athletics staff. For example, the head coach may be responsible for recommending specific equipment for that particular sport. The athletics director may be responsible for purchasing this recommended equipment. The equipment manager or athletic trainer may then be responsible for properly fitting the equipment based on the manufacturer's guidelines, instructing and warning the individual about proper use of the equipment, regularly inspecting the protective equipment, and keeping accurate records of any repair or reconditioning of the equipment.

Negligence and standard of care for the athletic trainer are discussed in broad terms in Chapter 1. When focusing on protective equipment, the athletic trainer has a duty to:

- Select the most appropriate equipment
- Properly fit the equipment to the individual
- Instruct the individual in proper care of the equipment
- Warn the individual of any danger in using the equipment inappropriately
- Supervise and monitor the proper use of all protective equipment

It is the duty of the manufacturer to design, manufacture, and package safe equipment that will not cause injury to an individual when the equipment is used as it was intended. To protect the sport participant from ineffective and poorly constructed athletic equipment, several agencies have developed standards of quality to ensure that equipment does not fail under normal athletic circumstances or contribute to injury. The National Operating Committee on Standards for Athletic Equipment (NOCSAE) sets the standards for football helmets to tolerate certain forces when applied to different areas of the helmet. Currently, baseball, softball, lacrosse helmets and face masks, and soccer shin guards also must be NOCSAE-certified. Other testing agencies for protective equipment include the American Society for Testing and Materials (ASTM) and the Hockey Equipment Certification Council (HECC) of the Canadian Standards Association (CSA). These agencies have established material standards for equipment such as protective eyewear (ASTM) and ice hockey helmets and face masks (HECC).

In addition to agencies that establish standards for the manufacture of equipment, athletic governing bodies establish rules for the mandatory use of specific protective equipment as well as rules governing special protective equipment. These governing bodies include the NFSHSA, the National Association of Intercollegiate Athletics (NAIA), the NCAA, and the U.S. Olympic Committee. For example, the NCAA requires football players to use a face mask and helmet with a secured, four-point chin strap. In addition, all players must wear helmets that carry a warning label regarding the risk of injury and a manufacturer's or reconditioner's certification indicating that the equipment meets the NOCSAE test standards.[1]

After equipment has been purchased, the manufacturer's informational materials, such as brochures and warranties used in the selection process, should be cataloged for reference in the event an injury occurs. This information can document the selection process and particular attributes of the chosen equipment. When an individual provides one's own protective equipment, the responsibilities of the athletic trainer do not change. The athletic trainer must ensure that the equipment meets safety standards and is fitted correctly, properly maintained and cleaned, and used appropriately. Athletic trainers and coaches should know the dangers involved in using sport equipment and have a duty to properly supervise its fitting and intended use. Athletes should not be allowed to wear or alter any equipment that may endanger the individual or other team members.

> The athletic trainer should remove from practice any athlete whose helmet does not have a four-point chin strap. Interscholastic and collegiate athletic governing bodies require that helmets be secured with a four-point chin strap. As such, the two-point strap does not meet minimum protection standards and should not be allowed on the helmet. If the individual were to sustain an injury while wearing an improper helmet, the athletic trainer could be considered negligent.

PROTECTIVE EQUIPMENT FOR THE HEAD

AND FACE

> ? A high school athletic trainer is concerned about a variety of oral injuries that have occurred on the school's basketball teams. What rationale can be used to convince the administration to purchase mouth guards for the teams?

Many head and facial injuries can be prevented with regular use of properly fitted helmets and facial protective devices, such as face guards, eyewear, ear wear, mouth guards, and throat protectors. Helmets in particular are required in football, ice hockey, men's lacrosse, baseball, softball, white-water sports (kayaking), amateur boxing, and bicycling and must be fitted properly to disperse impact forces.

Football Helmets

Football helmets have been found to be useful in preventing injury to the face, scalp, and skull, but there is little conclusive evidence to support that football helmets prevent concussions.[2,3] Football helmet designs typically use a single or double air bladder, closed-cell padding, or a combination of the two. Air bladders are excellent at absorbing shock, but they must be inspected daily by the players to ensure that adequate inflation is maintained for a proper fit.

Helmet shells can be constructed of plastic or a polycarbonate alloy. Polycarbonate is a plastic used in making jet canopies and police riot gear; it is lightweight and both scratch- and impact-resistant. Helmets vary in life expectancy. Typically, the polycarbonate alloy shell has a 5-year warranty; the ABS plastic shell has a 2-year warranty. Manufacturer's guidelines should be followed with regard to the appropriate time for retiring a helmet.

Heat, as an environmental factor, can alter the effectiveness of shock absorption in the liner and some shell materials. As a result, materials compress more easily and absorb less shock at higher compared with lower temperatures. As part of the testing process, the NOCSAE exposes new helmets to temperatures of 100°F (±3°F) for no less than 4 hours and no longer than 24 hours. A standard drop test is also conducted, and shock measurements are taken to determine if the helmet meets an established high severity index and thereby meets the NOCSAE football helmet standard test.[4]

The NOCSAE mark on a helmet indicates that it meets the minimum impact standards and can tolerate forces applied to several different areas. In addition, the NOCSAE includes a warning label regarding the risk of injury on each helmet that states the following[4]:

> NO HELMET CAN PREVENT ALL HEAD OR ANY NECK INJURIES A PLAYER MIGHT RECEIVE WHILE PARTICIPATING IN FOOTBALL.
>
> DO NOT USE THIS HELMET TO BUTT, RAM OR SPEAR AN OPPOSING PLAYER. THIS IS IN VIOLATION OF THE FOOTBALL RULES AND SUCH USE CAN RESULT IN SEVERE HEAD OR NECK INJURIES, PARALYSIS OR DEATH TO YOU AND POSSIBLE INJURY TO YOUR OPPONENT.

This warning label must be clearly visible on the exterior shell of all new and reconditioned helmets. In addition, the athletic trainer should continually warn athletes of the risks involved in football and ensure that the helmet is properly used within the guidelines and rules of the game.

Manufacturer's guidelines should always be followed when fitting a football helmet. Before fitting, the individual should have a haircut in the style that will be worn during the athletics season and wet the head to simulate game conditions. Application Strategy 3.1 lists the general steps in fitting a football helmet.

APPLICATION STRATEGY 3.1

Proper Fitting of a Football Helmet

1. The player should have a haircut in the style that will be worn during the competitive season and should wet the hair to simulate game conditions. Measure the circumference of the head above the ears using the tape measure supplied by the manufacturer. The suggested helmet size is listed on the reverse side of the tape.

2. Select the proper-sized shell and adjust the front and back sizers and jaw pads for a proper fit.
3. Inflate the air bladder by holding the bulb with an arch in the hose; to deflate, the hose is in a straight position.
4. Ensure that the helmet fits snugly around the player's head and covers the base of the skull but does not impinge the cervical spine when the neck is extended. The ear holes should match up with the external auditory ear canal.
5. Check that the four-point chin strap is of equal tension and length on both sides, placing the chin pad an equal distance from each side of the helmet (Fig. A).

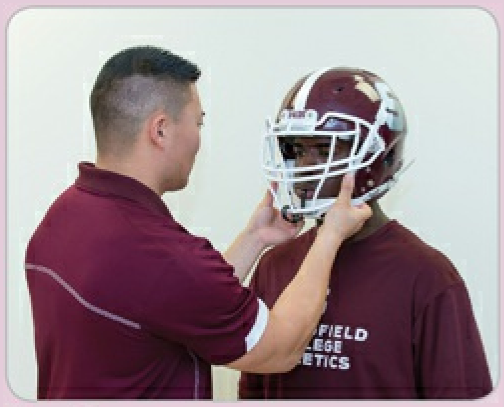

Figure A

6. Check that the face mask allows for a complete field of vision and the helmet is one to two finger widths above the eyebrows and extends two finger widths away from the forehead and nose (Fig. B).

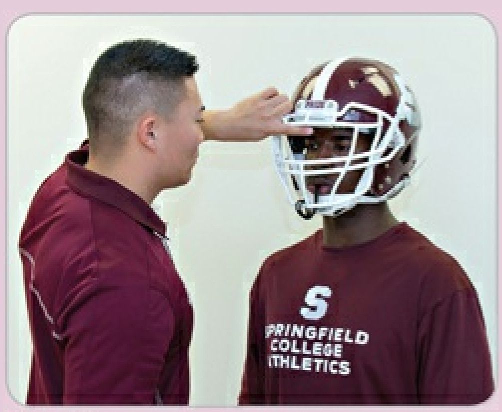

Figure B

7. Check that the helmet does not move when the athlete presses forward on the rear of the helmet and presses straight down on top of the helmet (**Fig. C**).

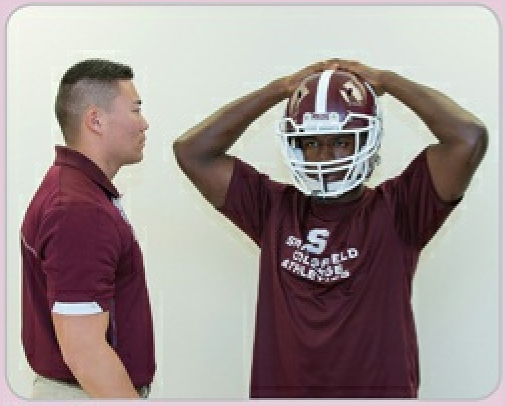

Figure C

8. Check that the helmet does not slip when the athlete is asked to "bull" the neck while you grasp the face mask pulling left, then right (**Fig. D**).

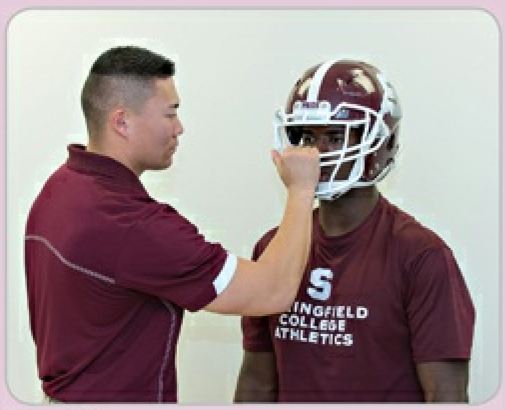

Figure D

Once fitted, the helmet should be checked daily for proper fit, which can be altered by hair length, deterioration of internal padding, loss of air from cells, and spread of the face mask. This check is performed by inserting a tongue depressor between the pads and the face. When moved back and forth, a firm resistance should be felt. A snug-fitting helmet should not move in one direction when the head moves in another. In addition, the helmet should be checked weekly by the athletic trainer to ensure proper fit and compliance with safety standards (**Box 3.2**).

BOX 3.2 Weekly Helmet Inspection Checklist

- Check proper fit according to manufacturer's guidelines.
- Examine the shell for cracks, particularly around the holes. Replace the shell if any cracks are detected.
- Examine all mounting rivets, screws, Velcro, and snaps for breakage, sharp edges, and/or looseness. Repair or replace as necessary.
- Replace the face guard if bare metal is visible, has a broken weld, or is grossly misshapen.
- Examine and replace any parts that are damaged, such as jaw pads, sweatbands, nose snubbers, and chin straps.
- Examine the chin strap for proper shape and fit; inspect the hardware to see if it needs replacement.
- Inspect shell according to NOCSAE and the manufacturer's standards; only approved paints, waxes, decals, or cleaning agents are to be used on any helmet. Severe or delayed reaction to the substances may permanently damage the shell and affect its safety performance.
- If air- and fluid-filled helmets are used, and the team travels to a different altitude, recheck the fit prior to use.

Each helmet should have the purchase date and tracking number engraved on the inside. Detailed records should be kept that identify the purchase date, use, reconditioning history, and certification seals. Each individual also should be instructed regarding the proper use, fit, and care of the helmet. In addition, each individual should sign a statement that confirms having read the NOCSAE seal and been informed of the risks of injury through improper use of the helmet or face mask when striking an opponent. This statement should be signed, dated, and kept as part of the individual's medical files.

Ice Hockey Helmets

Ice hockey helmets must absorb and disperse high-velocity, low-mass forces (e.g., being struck by a stick or puck) and low-velocity, high-mass forces (e.g., being checked into the sideboard or falling on the ice) (Fig. 3.1). As with football helmets, ice hockey helmets reduce head injuries; however, they do not prevent neck injuries caused by axial loading. The use of head protection with a face mask seems to have given many players a sense of invulnerability to injury. Studies have shown that the risk of spinal cord injury and, in particular, quadriplegia may be threefold greater in hockey than in American football.[5] The major mechanism of injury is head-first contact with the boards secondary to a push or a check from behind.

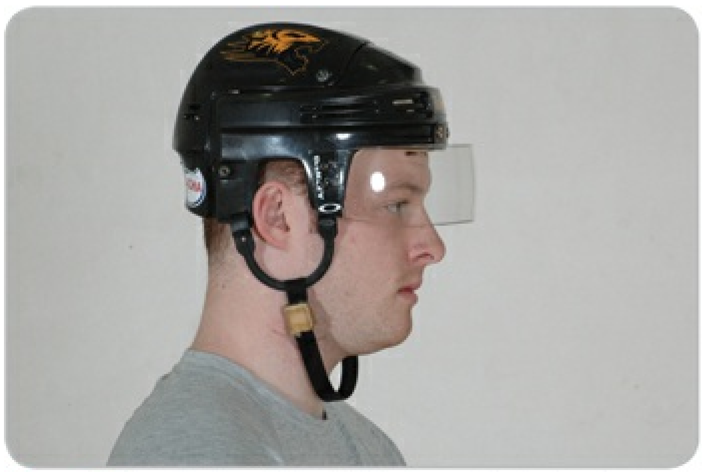

Figure 3.1. Ice hockey helmet. Helmets used in ice hockey must absorb and disperse high-velocity, low-mass forces (e.g., being hit by a high stick or a puck) and low-velocity, high-mass forces (e.g., being checked into the boards). Full face guards may be clear or wire mesh.

Ice hockey helmet standards are monitored by the ASTM and the HECC, and ice hockey helmets are required to carry the stamp of approval from the CSA. When properly fitted, the helmet should sit level on the head one to two finger widths above the eyebrows. There should be a maximum of two finger widths between the neck and chin strap. The face mask should fit properly in the J-clips, and the chin should rest in the chin cup.[6] Proper fit is achieved when a snug-fitting helmet does not move, slide, or rotate when the head is turned.

Batting Helmets

Batting helmets are now compulsory in baseball and softball and require the

NOCSAE mark.[1] Most batting helmets are open-faced with a double ear-flap design and can protect the majority of the superolateral cranium but not the jaw or facial area. Although some studies claim that batting helmets fitted with face shields may prevent or reduce the severity of facial injuries to children, no rigorous data currently support such a claim.[7]

It is best to have a thick layer of foam between the primary energy absorber and the head to allow the shell to move slightly and deform. This maximizes its ability to absorb missile kinetic energy from a ball or a bat and prevents excessive pressure on the cranium. The helmet should be snug enough that it does not move or fall off during batting and running bases.

Other Helmets

Lacrosse helmets are mandatory in the men's game and optional in the women's game. These helmets also are worn by field hockey goalies. The helmet is made of a highly resistant plastic or fiberglass shell and must meet NOCSAE standards. The helmet, wire face guard, and chin pad are secured with a four-point chin strap (Fig. 3.2). The helmet should not move in one direction when the head moves in another.

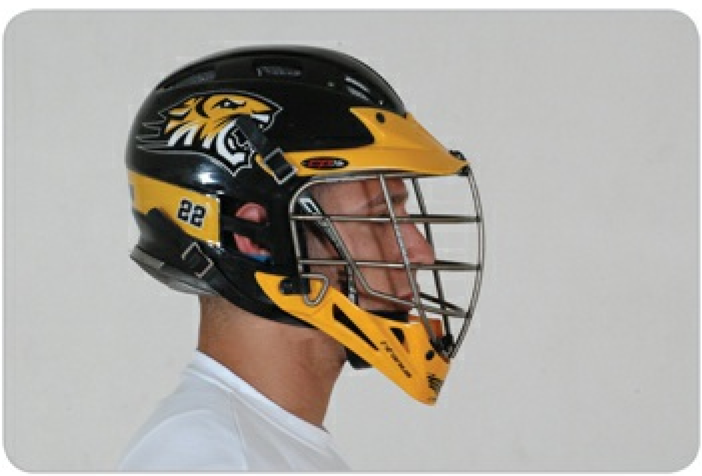

Figure 3.2. Lacrosse helmet. Lacrosse helmets provide full face and neck protection.

An effective bicycle helmet has a plastic or fiberglass, rigid shell with a chin strap, and an energy-absorbing foam liner. Regardless of the type, the helmet can provide substantial protection against injuries to the head and the upper and midface region. A stiffer shell results in better diffusion and resilience to impact. A firmer, dense foam liner is more effective at higher velocities, whereas less stiff foam provides more protection at lower velocities. Increasing the thickness of the liner may lead to a more effective level of protection, but the increased mass and weight of the helmet may make it more uncomfortable. Improved designs have produced helmets that are lightweight and aerodynamic, with an increase in the number of ventilation ports. Wearing a cycling helmet does not increase thermal discomfort to the head or body and has no additional impact on core temperature, head skin temperature, thermal sensation, heart rate, sweat rate, and overall perceived exertion.[8]

Although the rate of bicycle helmet usage has increased in the United States, at least one study has found that the overwhelming majority of children, adolescents, and their parents cannot properly fit a bicycle helmet. This increases the potential for exposure of the head's frontal region, which is the most common site of impact in bicycle head injuries.[9] Common fitting errors include having the helmet rest too high on the forehead, improper strap position (failure of strap to make a "V" around the ear), and excessive front-to-back movement of the helmet.[9,10]

Bicycle helmet fitting should first begin with a properly conditioned helmet (i.e., certified by the Consumer Product Safety Commission, ASTM, American National Standards Institute, or CSA). The helmet should be less than 10 years old, and the plastic cover should be intact, with no visible cracks. When resting on the head, the following guidelines should be used to properly fit the helmet[9]:

- There should be space of less than two fingerbreadths in front of, and in the side of, the helmet.
- The helmet should rest two fingerbreadths above the eyebrows.
- The chin strap should form a "V" around the ear and clip below the ear.
- The helmet front should pull down over the forehead when the mouth is opened.

- Side-to-side, front-to-front, and rotational movement should be 1 in or less.

Face Guards

Face guards, which vary in size and style, protect and shield the facial region from flying projectiles. The NOCSAE has set standards for strength and deflection for football face guards worn at the high school and college levels. Football face guards are made of heavy-gauge, plastic-coated steel rod designed to withstand impacts from blunt surfaces, such as the turf or another player's knee or elbow. The effectiveness of a football face guard depends on the strength of the guard itself, the helmet attachments, and the four-point (or six-point) chin strap on the helmet. When properly fitted, the face mask should extend two finger widths away from the forehead and allow complete field of vision. No face protection should be less than two bars. If needed, eye shields made of Plexiglas or polycarbonate can be attached to the face mask.

Ice hockey face guards are made of clear plastic (polycarbonate), steel wire, or a combination of the two and must meet HECC and ASTM standards (see **Fig. 3.1**). Hockey face guards primarily prevent penetration of the hockey stick, but they also are effective against flying pucks and collisions with helmets, elbows, side boards, and the ice. The use of full-coverage face masks in amateur ice hockey has greatly reduced facial trauma. The use of a single chin strap, however, still allows the helmet to ride back on the head when a force is directed to the frontal region, thus exposing the chin to lacerations. The guard stands away from the nose approximately 1 to 1.5 in. If a wire mesh is used, the holes should be small enough to prevent penetration by a hockey stick.

Lacrosse face guards must meet NOCSAE standards. The wire mesh guard stands away from the face, but the four-point chin strap has a padded chin region in case the guard is driven back during a collision with another player (see **Fig. 3.2**). Face masks used by catchers and the home-plate umpire in baseball and softball should fit snugly to the cheeks and forehead but should not impair vision. These devices can be used by players in the field and must meet ASTM standards. Men's and women's fencing masks have an adjustable spring to prevent the mask from moving during competition.

Eyewear

Eye injuries are relatively common and almost always preventable if proper protective wear is used. There are three types of protective eyewear: goggles, face shields, and spectacles.

Goggles have several designs. One is the eyecup design seen in swimming, whereby the eye socket is completely covered. Goggles are made of hard, impact-resistant plastic that is watertight. Because of the streamlined shape and design, contact lenses may be worn during competition when wearing these goggles. Vision may be slightly distorted; however, enhanced vision with the goggles could be a great advantage during flip turns. Another style of goggles can be worn over spectacles, such as ski goggles. These usually are well ventilated to allow air currents to minimize fogging. A third style of goggles is a sport goggle with a mask design. This type of goggle is relatively lightweight, may or may not include a shield, and is designed to withstand the forces generated by a ball traveling at significant speeds. After the introduction of mandatory protective eyewear in women's lacrosse, a 16% reduction in eye injuries occurred in the year immediately following the mandate.[11] Goggles worn for women's lacrosse must be ASTM-approved.[1]

Face shields are secondary protective devices that can be attached to specific helmets. Individuals who wear contact lenses often prefer the shield because there is less chance that a finger or hand can hit the eye. The shield can be tinted to reduce glare from the sun; however, the plastic can become scratched and may fog up in cold weather.

Spectacles (eyeglasses) contain the lenses, frame, and side shields commonly seen in industrial eye protective wear. The lenses should be 3-mm thick and be made from CR 39 plastic or polycarbonate, both of which can be incorporated with prescription lenses. CR 39 plastic lenses are less expensive, but they scratch more easily, often are thicker and heavier than polycarbonate, and are not impact resistant. In contrast, polycarbonate is lightweight, is scratch resistant, and can have an antifog and ultraviolet inhibitor incorporated into the lens. Of the clear materials developed for protective equipment, polycarbonate has the greatest impact resistance. A disadvantage of the polycarbonate is that static charges cause dust to cling to the lenses more readily than to glass lenses.

The frame should be constructed of a resilient plastic, with reinforced temples, hinges, and nosepiece. Adequate cushioning should protect the eyebrow and nasal bridge from sharp edges. Only polycarbonate eye protectors and eye frames that meet ASTM and parallel CSA standards offer enough protection for a sport participant. Approved eye guards protect the eye when impacted with a racquet ball traveling at 90 mph (40 m per second) or a racquet going 50 mph (22.2 m per second). Written acknowledgment that an eye guard meets standards can be found on the product package.

Regardless of the type of protection used, the lenses should be cleaned with warm, soapy water and rinsed with clean water, or a commercially available eyeglass cleaner should be used. A soft cloth is used to blot dry the lenses. A dry lens should never be wiped or rubbed because of the possibility of scratching the lens by moving foreign particles across the surface. The frames and elastic straps also may be cleaned with soap and water and air-dried. Lenses should be replaced when scratches affect vision or cracks appear at the edges. Protective eyewear always should be stored in a hard case to protect the polycarbonate lenses from being scratched.

Any individual with monocular vision should consult an ophthalmologist before participation in any sport or physical activity because of the resultant reduction of visual fields and depth perception. If a decision is made to participate, the individual should wear maximum eye protection during all practices and competitions. A sweatband should be worn to keep sweat out of the eye guard.

Although participants in physical activity often wear contact lenses because they improve peripheral vision and astigmatism and do not normally cloud during temperature changes, contact lenses do not protect against eye injury. Contact lenses come in two types: a hard or corneal type, which covers only the iris of the eye, and a soft or scleral type, which covers the entire front of the eye. Hard contact lenses often become dislodged and are more frequently associated with irritation from foreign bodies (e.g., corneal abrasions). Dust and other foreign matter may get underneath the lens and damage the cornea, or the cornea may be scratched while inserting or removing the lens.

Soft contact lenses can protect the eye from irritation by chlorine in pools. Although research has shown that pool water causes soft lenses to adhere to the cornea, reducing the risk of loss, wearing soft lenses while swimming is not recommended. Microorganisms found in pool water, especially *Acanthamoeba* sp., are responsible for a rare but serious corneal infection, *Acanthamoeba* keratitis. It is recommended that with or without contact lenses, goggles should always be worn in water to protect against foreign organisms and irritation from chlorine. Swimmers should wait 20 to 30 minutes after leaving the water before removing contact lenses or use saline drops if the lenses must be removed earlier. This allows time for the lenses to stop sticking to the cornea. Lenses should then be immediately disinfected. Removing the lenses too soon may cause corneal abrasions, leaving the cornea susceptible to infection.

Ear Wear

With the exception of boxing, wrestling, and water polo, few sports have specialized ear protection. Repeated friction and trauma to the ear can lead to a permanent deformity, called **hematoma auris** or cauliflower ear (see Chapter 20). For this reason, ear protection should be worn regularly in these sports. Proper fit is achieved when the chin strap is snug and the head gear does not move during contact with another player (**Fig. 3.3**). The protective ear cup should be deep enough so as not to compress the external ear. Ear protection should also be worn by those competing in the biathlon and other rifle competitions not to protect the outer ear but to protect hearing function.[1]

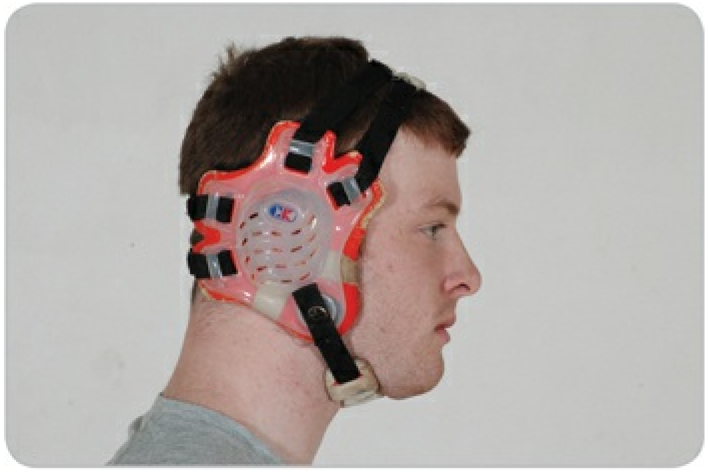

Figure 3.3. **Ear protectors.** Protective ear wear can prevent friction and trauma to the ear that may lead to permanent deformity.

Mouth Guards

An intraoral, readily visible mouth guard is required in all interscholastic and intercollegiate football, ice hockey, field hockey, and men's and women's lacrosse. The American Dental Association has recommended requiring a mouth guard in acrobatics, basketball, bicycling, boxing, equestrian events, extreme sports, field events, field hockey, football, gymnastics, handball, ice hockey, in-line skating, lacrosse, martial arts, racquetball, rugby, shot putting, skateboarding, skiing, skydiving, soccer, softball, squash, surfing, volleyball, water polo, weight lifting, and wrestling.[12] The American Academy of Pediatric Dentistry recommends a properly fitted mouth guard for all children and adolescents participating in any contact or collision sport to lower the risk of orofacial injury.[13] The Academy of Sports Dentistry, although recommending the use of a properly fitted mouth guard in any contact or collision sport, highly recommends the use of a custom-fabricated mouth guard made over a dental cast and delivered under the supervision of a dentist.[14]

Properly fitted across the upper teeth, a mouth guard can absorb energy, disperse impact, cushion contact between the upper and lower teeth, and keep the upper lip away from the incisal edges of the teeth. This action significantly reduces dental and oral soft-tissue injuries and, to a lesser extent, jaw fractures, cerebral concussions, and temporomandibular joint injuries.[15,16] The practice of cutting down mouth guards to cover only the front four teeth invalidates the manufacturer's warranty, cannot prevent many dental injuries, and can lead to airway obstruction should the mouth guard become dislodged. Although some individuals may complain that use of a mouth guard adversely affects speech and breathing, a properly fitted mouth guard should not interfere with either function. The benefits of preventing oral injuries through the use of mouth guards far outweigh any disadvantages.

Three types of mouth guards are commonly available: type I (custom), type II ("boil and bite"), and type III (stock).[15] Stock or type III mouth guards are the least expensive and least protective. Stock mouth guards are designed for use without modification and in general are not recommended.[15] The most frequently used mouth guard is the type II guard. This "boil and bite" guard is thermally set and mouth-formed, with a firm outer shell fitted with a softer inner material. The guard is immersed in very warm water and then placed into the patient's mouth and molded in placed by the patient.[15] When properly fitted, the mouth-formed guard can virtually match the efficacy and comfort of the custom-made guard. This type of guard is readily available, is inexpensive, and has a loop strap for attachment to a face mask. The loop strap has two advantages: It prevents individuals from choking on the mouth guard, and it prevents the individual from losing the mouth guard when it is ejected from the mouth. These mouth guards often lack full extension into the labial and buccal vestibules. Therefore, they do not provide adequate protection against oral soft-tissue injuries. Furthermore, the thermoplastic inner material loses its elasticity at mouth temperature and may cause the protector to loosen.

The most effective type of mouth protector is the type I custom-fabricated protective mouth guard, which may be a pressure-formed, laminated type, or a vacuum-formed type. This protector is expensive and requires special training to obtain the best results. Individuals using this style of protection report that the mouth guard is more comfortable, does not interfere with breathing or speaking, permits more complete jaw closure, does not cause soft-tissue irritation, and causes less excess salivation.[17] Cost of the basic materials is higher than the thermally set mouth guards. The laminated mouth guard uses high heat and pressure to form the material, leading to less deformation of the material when worn for a long period of time. In addition, the mouth guard can be thickened in selected areas as needed and may have inserts added for additional wearer protection.[17] Vacuum-formed mouth guards, on the other hand, are less expensive and easier to design. A triple-layered, ethyl vinyl acetate material (thickness, 5 mm) makes for a sturdier and more protective mouth guard.[17] The fit of vacuum-formed mouth guards, however, can be compromised by an elastic memory because of the low heat used in their construction. After a few minutes of wearing the mouth guard, the warmth from the mouth can trigger the elastic memory, leading to adaptations in the design that make speaking and unrestricted breathing more difficult.

The recommended care of mouth guards is to thoroughly rinse the guard with water after each use and place it in a plastic mouth guard retainer box to air-dry. Periodically, the mouth guard should be soaked overnight in a weak bleach solution (i.e., 1 quart of water to 1 tablespoon of bleach).

Throat and Neck Protectors

Blows to the anterior throat can cause serious airway compromise as a result of a crushed larynx and/or upper trachea, edema of the glottic structures, vocal cord disarticulation, hemorrhage, or laryngospasm. The NCAA requires that catchers in baseball and softball wear a built-in or attachable throat guard on their mask.[1] Fencing masks and helmets used in field hockey, lacrosse, and ice hockey also provide anterior neck protectors to guard this vulnerable area.

Cervical neck rolls and collars are designed to limit excessive motion of the cervical spine and can be effective in reducing cervical hyperextension when compared to helmet and shoulder pads alone.[18] There is little evidence to support that neck rolls and collars decrease lateral cervical flexion, a common mechanism of brachial plexus traction injuries.[18] Several commercial collars can be added to the shoulder pads, including the Cowboy collar (McDavid), Longhorn neck roll, LaPorta collar, and numerous others of similar design.

The Cowboy collar is closed-cell, polyethylene foam that fits underneath the shoulder pads. This collar can be further reinforced by adding a plastic back plate along the posterior aspect of the support. The Longhorn neck roll is larger in diameter than conventional foam collars and can further restrict motion by attaching auxiliary pads over the collar at specific sites. The LaPorta collar is a more rigid, plastic shell secured directly to the shoulder pad arch. The helmet wedges into the collar, further restricting cervical motion. Cervical collars do not decrease axial loading on the cervical spine when the neck is flexed during a tackle.

A properly fitted mouth guard will absorb energy, disperse impact, cushion the contact between the upper and lower teeth, and keep the upper lip away from the incisal edges of teeth. As such, a mouth guard will significantly reduce dental and oral soft-tissue injuries and, to a lesser extent, jaw fractures, cerebral concussion, and temporomandibular joint injuries.

PROTECTIVE EQUIPMENT FOR THE UPPER BODY

How does use of a cantilevered system provide protection in football shoulder pads? Is this superior to flat shoulder pads?

In the upper body, special pads and braces often are used to protect the shoulder region, ribs, thorax, breasts, arms, elbows, wrists, and hands. Depending on the activity, special design modifications are needed to allow maximum protection while providing maximal performance.

Shoulder Protection

Shoulder pads should protect the soft- and bony-tissue structures in the shoulder, upper back, and chest. The external shell generally is made of a lightweight yet hard plastic. The inner lining may be composed of closed- or open-cell padding to absorb and disperse the shock; however, use of open-cell padding reduces peak impact forces compared with use of closed-cell pads.

Football shoulder pads are available in two general types: cantilevered and flat. A channel system, incorporated into both types, uses a series of long, thinner pads attached by Velcro in the shoulder pads. The pads can be individually fitted so that an air space exists at the acromioclavicular (AC) joint. The impact forces are placed entirely on the anterior and posterior aspect of the shoulder.

Cantilevered pads have a hard plastic bridge over the superior aspect of the shoulder to protect the AC joint. These bridges are lightweight, allow maximal range of motion at the shoulder, and can distribute the impact forces throughout the entire shoulder girdle. The cantilevers come in three types: inside, outside, and double. The inside cantilever fits under the arch of the pads and rests against the shoulder. It is more commonly used because it is less bulky than the outside cantilever, which sits on top of the pad outside of the arch. The outside cantilever is preferred by linemen, because it provides a larger blocking surface and more protection to the shoulder region. The double cantilever is a combination of the inside and outside cantilevers. It provides the greatest amount of protection but is not feasible for all players because of its bulk.

Flat shoulder pads are lightweight and provide less protection to the shoulder region but allow more glenohumeral joint motion. These pads often are used by quarterbacks and receivers, who must raise their arms above the head to throw or catch a pass. The flat pads often use a belt-buckle strapping to prevent pad displacement because the elastic webbing straps typically seen in most shoulder pads are inadequate to maintain proper positioning of the flat pads.

In addition to cantilevers, football shoulder pads consist of an arch, two sets of epaulets (shoulder flaps), shoulder cups, and anterior and posterior pads. The arch is shaped to fit the contour of the upper body. The epaulets extend from the edge of the arch and cover the shoulder cups to protect the top of the entire shoulder region. The shoulder cups attach to the arch, run under the epaulets, and should cover the entire deltoid. The anterior pads cover the pectoral muscles and protect the sternum and clavicles. The posterior pads cover the trapezius and protect the scapula and spine.

Football shoulder pads should be selected based on the player's position, body type, and medical history. Linemen need more protection against constant contact and require larger cantilevers. Quarterbacks, offensive backs, and receivers require smaller shoulder cups and flaps to allow greater range of motion in passing and catching. Application Strategy 3.2 lists the general steps used in fitting football shoulder pads.

APPLICATION STRATEGY 3.2

Fitting Football Shoulder Pads

1. Determine the chest girth measurement at the nipple line or measure the distance between shoulder tips. Select pads based on player position. Place the pads on the shoulders and tighten all straps and laces. The laces should be pulled together until touching. The straps should have equal tension and be as tight as functionally tolerable to ensure proper force distribution over the pads. Tension on the straps should prevent no more than two fingers from being inserted under the strap. The entire clavicle should be covered and protected by the pads. If the clavicles can be palpated without moving the pads, refit with a smaller pad (Fig. A).

Figure A

2. Anterior view: The laces should be centered over the sternum with no gap between the two halves. There should be full coverage of the AC joint, clavicles, and pectoral muscles. Caps should cover the upper portion of the arch and entire deltoid muscle (Fig. B).

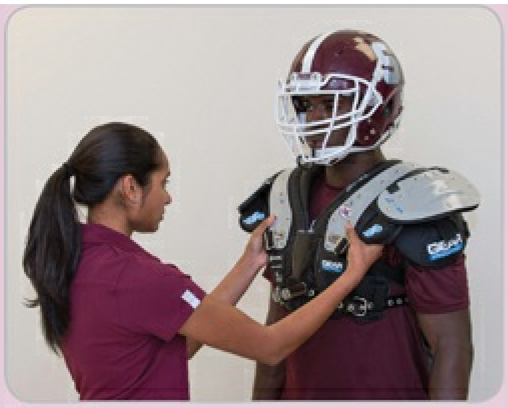

Figure B

3. Posterior view: The entire scapula and trapezius should be covered with the lower pad arch extending below the inferior angle of the scapula to adequately protect the latissimus dorsi. The laces should be pulled tight and centered over the spine (Fig. C).

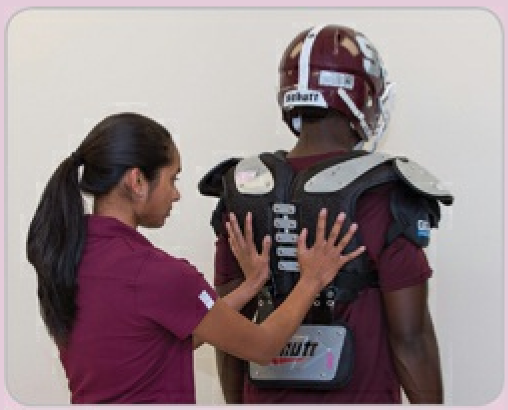

Figure C

4. With the arms abducted, the neck opening should not be uncomfortable or pinch the neck. Finally, inspection should include the shoulder pads with the helmet and jersey in place to ensure that no impingement of the cervical region is present (Fig. D).

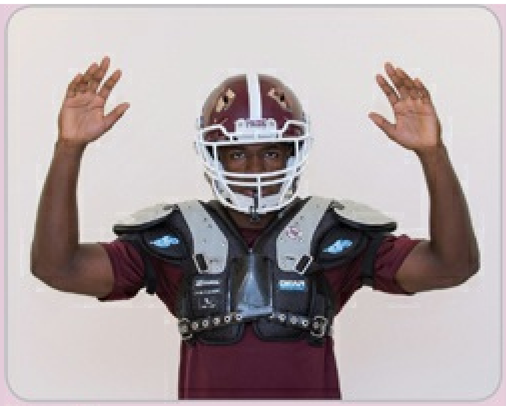

Figure D

Elbow, Forearm, Wrist, and Hand Protection

The entire arm is subjected to compressive and shearing forces in a variety of sports, such as when blocking and tackling an opponent, deflecting projectiles, pushing opponents away to prevent collisions, or breaking a fall. Goalies and field players in many sports are required to have arm, elbow, wrist, and hand protection. In high school and collegiate play, however, no rigid material can be worn at the elbow or below unless covered on all sides by closed-cell foam padding.[1]

The use of a counterforce forearm brace may provide some relief for individuals with lateral and medial epicondylitis. These braces are designed to reduce tensile forces in the wrist flexors and extensors, particularly the extensor carpi radialis brevis. Although these braces may relieve pain on return to activity, debate continues about the effectiveness of counterforce forearm braces.[19] These braces should not be used for other causes of elbow pain, such as growth plate problems in children and adolescents or medial elbow instability in adults.

The forearm, wrist, and hand are especially vulnerable to external forces and often are neglected when considering protective equipment. In collision and contact sports, this area should be protected with specialized gloves and pads.

Thorax, Rib, and Abdominal Protection

Many collision and contact sports require special protection of the thorax, rib, and abdominal areas. Commotio cordis, the second leading cause of sudden cardiac death in young athletes, is triggered by a blow from a small spherical fast moving object, such as a baseball or lacrosse ball, that strikes the athlete over the heart.[20] Although there are many commercially made wall protectors for use by youth lacrosse and baseball athletes, no chest wall protectors have been found to be effective in preventing commotio cordis.[20] Catchers in baseball and softball wear full thoracic and abdominal protectors to prevent high-speed blows from a bat or a ball. Individuals in fencing, and goalies in many sports, also wear full thoracic protectors (Fig. 3.4A). Quarterbacks and wide receivers in football may wear rib protectors composed of air-inflated, interconnected cylinders to absorb impact forces caused during tackling (Fig. 3.4B). These protectors should be fitted according to the manufacturer's instructions.

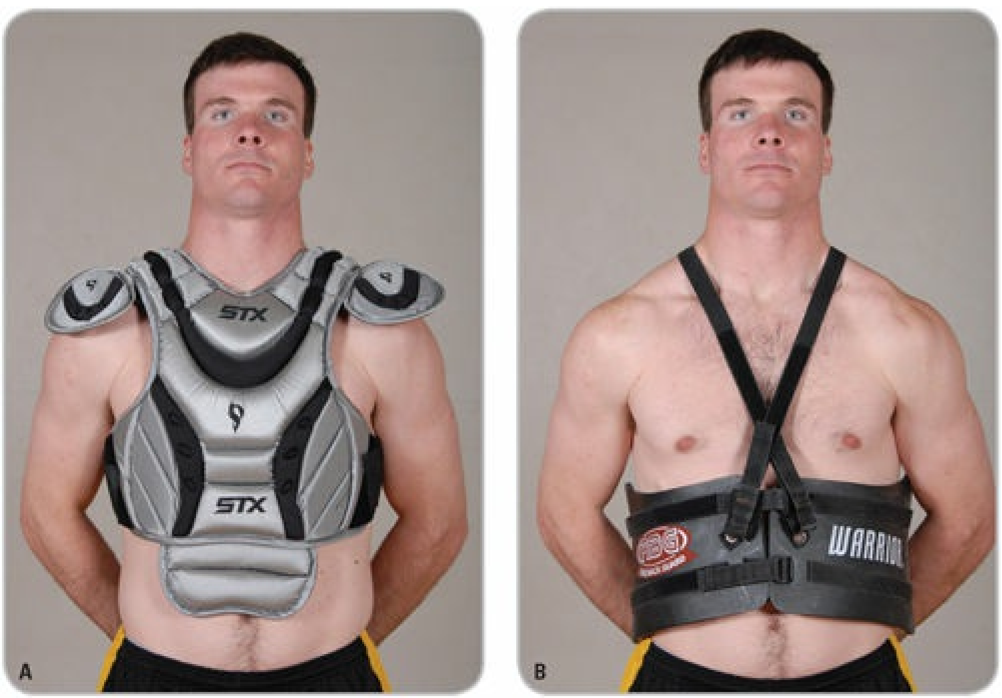

Figure 3.4. Chest and rib protection. A, Several sports require extensive chest protection (e.g., ice hockey). **B,** Rib protectors absorb impact forces caused during tackling.

Sport Bras

Sport bras provide added support to prevent excessive vertical and horizontal breast motion during exercise. Although sport bras are designed to limit motion, few of those currently on the market actually do so, and as a result, many women continue to experience sore or tender breasts after exercise. Sport bras fall into two categories:

1. Bras made from nonelastic material with wide shoulder straps and wide bands under the breasts to provide upward support. Waist-length designs can prevent cutting in below the breasts.
2. Compressive bras that bind the breasts to the chest wall. Women with medium-sized breasts typically prefer this type.

Girls and women with small breasts may not need a special bra. Women with a size C cup or larger need a firm, supportive bra. The bra should have nonslip straps and no irritating seams or fasteners next to the skin, and it should be firm and durable. Choice of fabric depends on the intensity of activity, support needs, sensitivity to fiber, and climatic and seasonal conditions. A cotton/polyester/Lycra fabric is a popular blend seen in sport bras. In hot weather, an additional outer layer of textured nylon mesh can promote natural cooling of the skin. In sports requiring significant overhead motion, bra straps should stretch to prevent the bra from riding up over the breasts. When overhead motion is not a significant part of the activity, nonstretch straps connected directly to a nonelastic cup are preferable.

Lumbar/Sacral Protection

Lumbar/sacral protection includes weight-training belts used during heavy weight lifting, abdominal binders, and other similar supportive devices (**Fig. 3.5**). Each should support the abdominal contents, stabilize the trunk, and prevent spinal deformity or injury during heavy lifting. Use of belts or binders may be beneficial in reducing spinal compression, stabilizing the spine, increasing motor unit recruitment in prime movers, and increasing exercise velocity.[21] The use of back belts to prevent occupational low back pain or to reduce lost work time because of occupational low back pain is not supported by the Canadian Centre for Occupational Health and Safety or by the U.S.

National Institute for Occupational Safety and Health.[22,23] In contrast, the U.S. Occupational Safety and Health Administration's recent ergonomics regulation classified lumbar supports as personal protective equipment and suggested that they may prevent back injuries in certain industrial settings.[23]

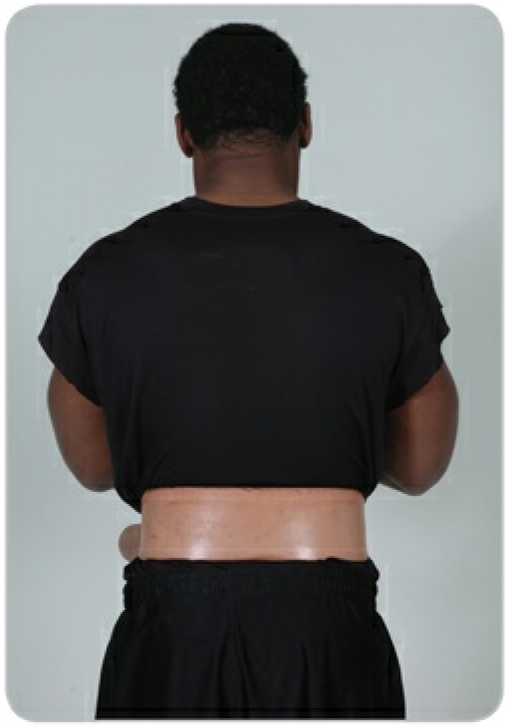

Figure 3.5. Lumbar/sacral protection. Abdominal binders support the abdominal contents, stabilize the trunk, and prevent spinal deformity or injury.

Cantilevered pads have a hard plastic bridge over the superior aspect of the shoulder to protect the AC joint. These lightweight bridges allow maximal range of motion at the shoulder and can distribute the impact forces throughout the entire shoulder girdle. As such, they provide the greatest amount of protection to the shoulder region but are not feasible for all players because of their bulk.

PROTECTIVE EQUIPMENT FOR THE LOWER BODY

? A pitcher sustains a thigh contusion after being struck by a hard-driven baseball. What type of padding should be used to protect the thigh from another significant blow?

In the lower body, commercial braces commonly are used to protect the knee and ankle. In addition, special pads are used to protect bony- and soft-tissue structures in the hip and thigh region. Depending on the sport/activity, special design modifications are needed to allow maximum protection while providing maximal performance.

Hip and Buttock Protection

In collision and contact sports, the hip and buttock region require special pads, typically composed of hard polyethylene covered with layers of Ensolite to protect the iliac crest, sacrum, coccyx, and genital region. A girdle with special pockets can effectively hold the pads in place (**Fig. 3.6**). The male genital region is best protected by a protective cup placed in an athletic supporter.

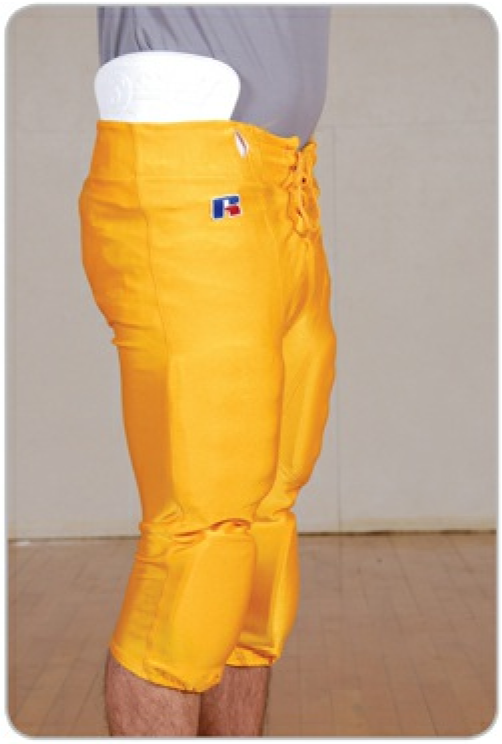

Figure 3.6. Hip protection. Girdle pads protect the gluteal and sacral area from high-velocity forces. Thigh pads can also be inserted to protect the quadriceps area.

Thigh Protection

Thigh and upper leg pads, such as those illustrated in Figure 3.6, slip into ready-made pockets in the girdle to prevent injury to the quadriceps area. Thigh pads should be placed over the quadriceps muscle group, approximately 6 to 7 in proximal to the patella. When using asymmetrical thigh pads, the larger flare should be placed on the lateral aspect of the thigh to avoid injury to the genitalia. In addition to thigh pads, neoprene sleeves can provide uniform compression, therapeutic warmth, and support for a quadriceps or hamstring strain.

Knee and Patella Protection

The knee is second only to the ankle and foot in incidence of injury. Knee pads can protect the area from impact during a collision or fall and, in wrestling, can protect the prepatellar and infrapatellar bursa from friction injuries. In football, knee pads reduce contusion and abrasions when falling on artificial turf.

Knee braces fall into three broad functional categories: prophylactic, functional, and rehabilitative. Prophylactic knee braces (PKBs) are designed to protect the medial collateral ligament by redirecting a lateral valgus force away from the joint itself to points more distal on the tibia and femur. Functional knee braces are widely used to provide proprioceptive feedback and to protect unstable anterior cruciate ligament (ACL) injuries or in postsurgical ACL repair or reconstruction (Fig. 3.7A). Rehabilitative braces provide immobilization at a selected angle after injury or surgery, permit controlled range of motion through predetermined arcs, and prevent accidental loading in non–weight-bearing patients (Fig. 3.7B).

Figure 3.7. Knee braces. A, Functional knee braces control tibial translation and rotational stress relative to the femur and can provide extension limitations to protect the ACL. **B,** Rehabilitative braces provide absolute or relative immobilization following surgery.

Decisions to use any of the three major categories of knee braces should rest with the supervising physician or surgeon. Selection should be based on the projected objectives, needs of the participant relative to activity demands, cost-effectiveness, durability, fit, and comfort.

Prophylactic Knee Braces

Two general types of PKBs are the lateral and bilateral bar designs. The lateral bar PKBs are constructed with single, dual, or polycentric hinge designs. Each model has a knee hyperextension stop and is applied using a combination of neoprene wraps, Velcro straps, and/or adhesive tape. The bilateral bar PKB has a medial and lateral upright bar with biaxial hinges.

In a review of past studies between 1970 and 2006, results were inconclusive to advocate or discourage the use of PKBs in preventing knee ligament injuries in collegiate football players.[24] There is some evidence that the use of PKBs may be a contributing factor to injury.[24] As future innovations and design modifications are made in PKBs, benefits in injury prevention may become more cost-effective. Until then, clinicians should base decisions regarding PKB use on the individual needs of the athlete.

Functional Knee Braces

Functional knee braces, commonly called derotation or ACL braces, are designed to control tibial translation and rotational stress relative to the femur with a rigid, snug fit and extension limitations. There are two basic styles of ACL braces: hinge-post-strap and hinge-post-shell. Performance of either brace depends on the magnitude of anterior shear load and the internal torque applied across the tibiofemoral joint, and it may be affected by several factors, including the following:

- Technique of attachment
- Design of the brace, including hinge design; materials of fabrication; geometry of attachment interface; and mechanism of attachment
- Variables in attachment interface, including how the interface molds around the soft-tissue contours of the limb and how much displacement occurs between the rigid brace and the compliant soft tissues surrounding the distal femur and proximal tibia while loads are applied across the knee.

Derotation braces may be prescribed by a physician for individuals with a mild to moderate degree of instability who participate in activities with low or moderate load potential. Functional knee braces do not guarantee increased stability in those sports requiring cutting, pivoting, or other quick changes in direction. The braces also are used after surgical ACL reconstruction. No consensus exists in the literature relative to whether functional braces have any beneficial muscle activation or proprioceptive effects on the ACL-deficient or reconstructed limb.[25] It is suggested that patient satisfaction (e.g., symptom reduction or subjective improvement in function) may be positively related to proper fit and hinge alignment along with the maintenance of optimal muscle tone.[26,27]

Rehabilitative Braces

Rehabilitative braces come in two distinct designs: a straight immobilizer made of foam with two metal rods running down the side that is secured with Velcro to prevent all motion and a hinged brace that allows range of motion to be set by tightening a screw control. Early motion prevents joint adhesions from forming, enhances proprioception, and increases synovial nutrient flow to promote healing of cartilage and collagen tissue. The braces are lighter in weight, are adjustable for optimal fit, and can be easily removed and reapplied for wound inspection and rehabilitation. As the individual progresses through the rehabilitation program, the allowable range of motion can be adjusted periodically by the clinician. Rehabilitative braces are more effective in protecting against excessive flexion–extension than against anterior/posterior displacement.[27]

Patellofemoral Protection

Patella braces are designed to dissipate force, maintain patellar alignment, and improve patellar tracking. A horseshoe-type silicone or felt pad is sewn into an elastic or neoprene sleeve to relieve tension in recurring patellofemoral subluxation or dislocations. These braces relieve anterior knee pain syndrome.[28] An alternate brace for treating patellar pain is a strap worn over the infrapatellar tendon (**Fig. 3.8**).

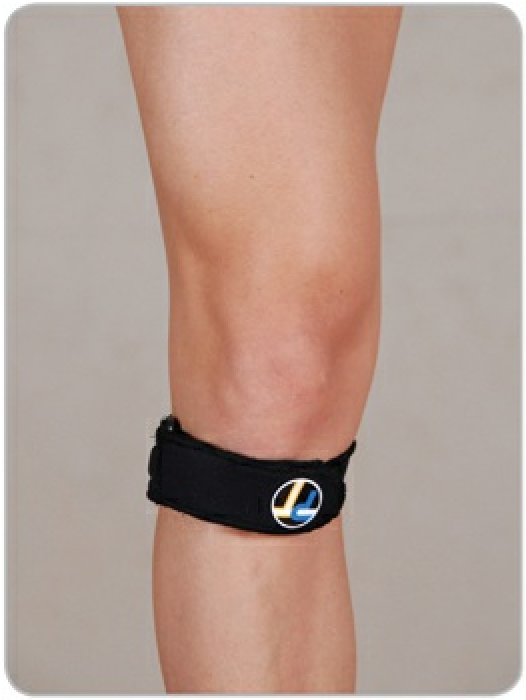

Figure 3.8. **Patellofemoral brace.** A strap worn over the infrapatellar ligament may relieve patellar pain.

Lower Leg Protection

Pads for the anterior tibial area should consist of a hard, deflective outer layer and an inner layer of thin foam. Velcro straps and stirrups help to stabilize the pad inside the sock. Many styles also incorporate padding or plastic shells over the ankle malleoli, which often are subject to repeated contusions. Several commercial designs are available.

Ankle and Foot Protection

Commercial ankle braces can be used to prevent or support a postinjury ankle sprain and come in three categories: lace-up brace, semirigid orthosis, or air-bladder brace (Fig. 3.9). A lace-up brace can limit all ankle motions, whereas a semirigid orthosis and air-bladder brace limit only inversion and eversion. Ankle braces have been compared with ankle taping. It is fairly well accepted that maximal loss in taping restriction for both inversion and eversion occurs after 20 minutes or more of exercise. Ankle braces are more effective in reducing ankle injuries, are easier for the wearer to apply independently, do not produce some of the skin irritation associated with adhesive tape, provide better comfort and fit, are more cost-effective, are comfortable to wear, and do not disrupt lower extremity dynamic balance.[29–32]

Figure 3.9. Ankle protectors. Commercial designs include the lace-up brace **(A)**, semirigid orthosis **(B)**, and air-bladder brace **(C)**.

Selection and fit of shoes also may affect injuries to the lower extremity. Shoes should adequately cushion impact forces and support and guide the foot during the stance and final push-off phase of running. In activities requiring repeated heel impact, additional heel cushioning should be present. Length should be sufficient to allow all toes to be fully extended. Individuals with toe abnormalities or bunions also may require a wider toe box. Application Strategy 3.3 identifies factors when selecting and fitting athletic shoes.

APPLICATION STRATEGY 3.3

Factors in the Selection and Fit of Athletic Shoes

- Fit shoes toward late afternoon or evening, preferably after a workout, and wear socks typically worn during sport participation.
- Fit shoes to the longest toe of the largest foot, providing one thumb's width to the end of the toe box.
- The widest part of the shoe should coincide with the widest part of the foot. Eyelets should be at least 1 in apart with normal lacing. Women with big or wider feet should consider purchasing boy's or men's shoes.

- The sole of the shoe should provide moderate support but should not be too rigid. Sole tread typically comes in a horizontal bar (commonly used on asphalt or concrete) or waffle design (used on off-road terrain).
- The midsole may be composed of ethylene vinyl acetate (EVA), polyurethane, or preferably, a combination of the two. EVA provides good cushioning but will break down over time. Polyurethane has minimal compressibility and provides good durability and stability.
- A thermoplastic heel counter maintains its shape and firmness even in adverse weather conditions.
- Running shoes should position the heel at least 0.5 in above the outsole to minimize stretch on the Achilles tendon.
- While wearing the shoes, approximate athletic skills (walking, running, jumping, and changing directions).
- Individuals with specific conditions need special shoes, such as the following:
  - Runners with normal feet—more forefoot and toe flexibility
  - Overpronation—greater control on the medial side
  - Achilles tendonitis—a heel wedge of at least 15 mm
  - Court sports—added side-to-side stability
  - High, rigid arches—soft midsoles, curved lasts, and low or moderate hindfoot stability
  - Normal arches—firm midsole, semicurved lasts, and moderate hindfoot stability
  - Flexible low arch—very firm midsole, straight lasts, and strong hindfoot stability
- Walk in the newly purchased shoes for 2–3 days to allow them to adapt to the feet. Next, begin running or practicing in the shoes for about 25%–30% of the workout. To prevent blisters, gradually extend the length of time the shoes are worn.
- Avid runners should replace shoes every 3 months, recreational runners every 6 months.

In field sports, shoes may have a flat-sole, long-cleat, short-cleat, or multicleated design. The cleats should be properly positioned under the major weight-bearing joints of the foot and should not be felt through the sole of the shoe. Shoes with the longer, irregular cleats placed at the peripheral margin of the sole, with a number of smaller pointed cleats positioned in the middle of the sole, produce significantly higher torsional resistance and are associated with a significantly higher rate of ACL injury compared with shoes having flat cleats, screw-in cleats, or pivot disks.[33] When increased temperature is a factor, such as when playing on turf, only the flat-soled, basketball-style turf shoes are reported to have low-release coefficients at varying elevated temperatures.[34] This may lead to a lesser incidence of lower leg injuries. In individuals with arch problems, the shoe should include adequate forefoot, arch, and heel support. In all cases, individuals should select shoes based on the demands of the activity.

Specific foot conditions, such as fallen arches, pronated feet, or medial tibial stress syndrome, can be padded and supported with inner soles, semirigid orthotics, and rigid orthotics. Cushioning is a critical function of sport shoes with the midsole playing the most important role in attenuating impact shock.[35] Research has found that a 6.5-mm thick polymeric foam rubber material is more effective in absorbing heel-strike impact than a viscoelastic polymeric shoe insert.[36] Antishock heel lifts use a dense silicone mixture to cushion heel impact to relieve strain on the Achilles tendon, and heel cups reduce tissue shearing and shock in the calcaneal region. Other commercially available pads may be used to protect the forefoot region, bunions, and toes, or adhesive felt (moleskin), felt, and foam can be cut to construct similar pads.

Foot Orthotics

Orthotics are devices used in the treatment and prevention of foot and gait abnormalities and related conditions, such as plantar fasciitis, heel pain, shin splints, patellofemoral pain, and low back pain. By changing the angle at which the foot strikes the surface, orthotics can make standing, walking, and running more comfortable and efficient. Orthotics are available in several forms and are constructed of a variety of materials. Foot orthotics fall into three broad categories: orthotics to change foot function, protective orthotics, and those that combine functional control and protection.

Foot orthotics can be rigid, soft, or semirigid. Rigid orthotics are designed to control motion. These orthotics are made from a firm material, such as plastic or carbon fiber, to increase their longevity and decrease the likelihood for changes in their shape. Most often, rigid orthotics are worn in dress or walking shoes. Soft orthotics assist in absorbing shock, improving balance, and relieving painful pressure sites. The use of soft, compressible materials in the construction of soft orthotics readily enables adjustment to changing weight-bearing forces. Eventually, however, the material breaks down; therefore, soft orthotics must be replaced regularly. Semirigid orthotics are used to provide for dynamic balance of the foot while walking or participating in sport and physical activity. This type of orthotic is constructed of layers of soft material that are reinforced with hard, rigid materials.

In addition to the proper selection of the appropriate type of orthotic, accurate fit is an essential component in the use of orthotics. As such, orthotics should be measured and fitted by a qualified medical professional.

The pitcher's thigh should be protected with nonresilient padding made of high-density material, such as orthoplast or thermoplast. The padding should be layered with a soft material that has shock-absorbing qualities, such as closed-cell foam.

SUMMARY

1. Protective equipment is effective only when it is properly fitted and maintained, periodically cleaned and disinfected, and used as intended.
2. The sport participant must be protected from high-velocity, low-mass forces to prevent focal injuries and from low-velocity, high-mass forces to prevent diffuse injuries.

3. Design and selection of protective equipment is based on the following energy-absorbing material factors: thickness, density, resilience, and temperature.
4. The NOCSAE establishes standards for football, baseball, softball, and lacrosse helmets and face masks.
5. The HECC of the CSA establishes standards for ice hockey helmets and face masks.
6. The ASTM establishes standards for protective eyewear, ice hockey helmets and face masks, and other protective equipment.
7. The athletic trainer is ultimately responsible for knowing the rules and standards governing the selection and fitting of protective equipment for each sport.

APPLICATION QUESTIONS

1. A high school football coach has 50 sets of uniforms. The last student selected for the team is also the last student to receive a uniform. The available pants and shoulder pads are slightly large for the student. In addition, the helmet does not fit snugly. The coach does not anticipate that the student will see much playing time; he kept him on the team roster because the student is enthusiastic and a hard worker. As the school's athletic trainer, how would you respond to this situation? Is it acceptable for the student to practice in the uniform and safety equipment that was provided to him? Explain your response.
2. A high school basketball coach is concerned about the various oral injuries that have occurred on the school's basketball teams. The coach asks for your input in providing a rationale to convince the administration to contract with a local dentist to provide customized mouth guards for the teams. How would you respond? What recommendations might you consider in developing the rationale?

3. An athletic trainer for a college football team fits the place kicker with a football helmet that has a double bar face guard. However, the athletic trainer notices that the kicker has come to the practice field with a single bar face guard. The kicker insists that the double bar guard interferes with his vision during field-goal attempts. Should the athletic trainer permit the kicker to use the single bar face guard during practice? Why or why not?
4. A high school football player has been cleared to practice following rehabilitation for a cervical sprain. The school's athletic trainer makes alterations to the helmet and shoulder pads of the player as a prophylactic measure to reduce the potential for another future cervical sprain. The team physician is in support of the actions taken by the athletic trainer. Is the athletic trainer potentially liable if the athlete sustains an injury while wearing the altered equipment?

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