Endurance Sports Medicine

A Clinical Guide

Timothy L. Miller
Editor

Second Edition

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Editor
Timothy L. Miller
Department of Orthopedic Surgery
The Ohio State University Wexner Medical Center
New Albany, Columbus, OH, USA

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Contributors

Joseph Ascher PhysioPartners, Chicago, IL, USA

Rukayat Balogun Emergency Department, Osan Air Base, Pyeongtaek, Gyeonggi Province, Republic of Korea

Michael R. Baria Department of Physical Medicine and Rehabilitation, The Ohio State University, Columbus, OH, USA

Gloria Beim, MD Department of Orthopaedic Surgery and Sports Medicine, Vail-Summit Orthopaedics and Neurosurgery–Alpine, Elk Avenue, Crested Butte, CO, USA

Holly J. Benjamin Department of Orthopaedic Surgery, Rehabilitation Medicine & Pediatrics, University of Chicago, Chicago, IL, USA

Jenny Berezanskaya Department of Family Medicine, Sports Medicine, Cleveland Clinic Martin Health, Port Saint Lucie, FL, USA

Thomas M. Best Department of Orthopedics, University of Miami, Miami, FL, USA

Mina Botros Department of Orthopeadic Surgery, University of Rochester Medical Center, Rochester, NY, USA

Kyle R. Brena, BS Department of Research and Education, Vail-Summit Orthopaedics and Neurosurgery–Research and Education Foundation, Vail, CO, USA

Jennifer E. Carter Psychiatry and Behavioral Health, Jameson Crane Sports Medicine Institute, Ohio State University Wexner Medical Center, Columbus, OH, USA

Andrea Cyr Department of Orthopedics and Sports Medicine, University of Illinois Hospital and Health Sciences System, Chicago, IL, USA

Curt J. Daniels Division of Cardiology, The Ohio State Wexner Medical Center, Ross Heart Hospital, Columbus, OH, USA

Margie H. Davenport Program for Pregnancy and Postpartum Health, Physical Activity and Diabetes Laboratory, Faculty of Kinesiology, Sport and Recreation, Women and Children's Health Research Institute, Alberta Diabetes Institute, University of Alberta, Edmonton, AB, Canada

Stephanie DeLuca Department of Physical Medicine & Rehabilitation, Spaulding Rehabilitation Hospital, Harvard Medical School, Charlestown, MA, USA

Sarah Depp Wexner Medical Center, Ohio State University Medical Center, Columbus, OH, USA

Joshua F. Feuerbacher Department of Molecular and Cellular Sports Medicine, Institute of Cardiovascular Research and Sports Medicine, German Sport University, Cologne, Germany

Jake Fletcher Department of Family Medicine, Cleveland Clinic, Lakewood, OH, USA

Brian D. Giordano Department of Orthopeadic Surgery, University of Rochester Medical Center, Rochester, NY, USA

Marci Goolsby Primary Care Sports Medicine, Hospital for Special Surgery, New York, NY, USA

Elise Grzeskiewicz Department of Orthopaedic Surgery and Sports Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Joshua D. Harris Department of Orthopedics and Sports Medicine, Houston Methodist Hospital, Houston, TX, USA

Bryan Heiderscheit Departments of Orthopedics and Rehabilitation and Biomedical Engineering, UW Health Runners' Clinic, Badger Athletic Performance Program, University of Wisconsin-Madison, Madison, WI, USA

Jared D. Heinze, MPH Department of Research and Education, Vail-Summit Orthopaedics and Neurosurgery–Research and Education Foundation, Vail, CO, USA

Andrew Hornick Division of Cardiology, The Ohio State Wexner Medical Center, Ross Heart Hospital, Columbus, OH, USA

Shawn Hueglin Sports Performance, United States Olympic and Paralympic Committee, Chula, CA, USA

Mark Hutchinson Department of Orthopaedic Surgery, University of Illinois, Chicago, IL, USA

Carlos Jimenez Health and Performance, Canyon Ranch, Tucson, AZ, USA

Julia Johnson United States Olympic and Paralympic Committee, Colorado Springs, CO, USA

Bridget Holroyd Jones, PT, DPT, OCS Department of Physical Therapy, Avalanche Physical Therapy, Frisco, CO, USA

Kristine A. Karlson Community and Family Medicine, Orthopaedics and Pediatrics, Geisel School of Medicine at Dartmouth, Lebanon, NH, USA

Katie E. Krebs Premier Health, Centerville, OH, USA

Jeniffer Lima Department of Family Medicine, Amita Health Saints Mary and Elizabeth Medical Center, Chicago, IL, USA

Adam Lindsay, MD Department of Orthopaedic Surgery and Sports Medicine, Vail-Summit Orthopaedics and Neurosurgery–Alpine, Crested Butte, CO, USA

Steven Liu Department of Internal Medicine, Providence Portland Medical Center, Portland, OR, USA

Amadeus Mason Departments of Orthopaedics and Family Medicine, Emory School of Medicine, Atlanta, GA, USA

Timothy L. Miller Department of Orthopaedic Surgery and Sports Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

The Jameson Crane Sports Medicine Institute, Columbus, OH, USA

Alexys Monoson Division of Pulmonary, Critical Care, and Sleep, Department of Internal Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Michelle F. Mottola R. Samuel McLaughlin Foundation-Exercise and Pregnancy Laboratory, School of Kinesiology, Faculty of-Health Sciences, Department of Anatomy & Cell Biology, Schulich School of Medicine and Dentistry, Children's Health Research Institute, The University of Western Ontario, London, ON, Canada

Dustin Nabhan Health and Performance, Canyon Ranch, Tucson, AZ, USA

Joshua L. Norman Psychiatry and Behavioral Health, Jameson Crane Sports Medicine Institute, Ohio State University Wexner Medical Center, Columbus, OH, USA

Nathaniel Nye Department of Sports Medicine, Ft. Belvoir Community Hospital, Fort Belvoir, VA, USA

Leonard Tiger Onsen Department of Orthopaedic Surgery, University of Illinois, Chicago, IL, USA

Jonathan Parsons Division of Pulmonary, Critical Care, and Sleep, Department of Internal Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Kevin Pierce United States Olympic and Paralympic Committee, Colorado Springs, CO, USA

Joshua A. Pintar Department of System Health Solutions, Indiana University Health, Indianapolis, IN, USA

Amanda Pipkin Department of Physical Therapy, Nova Southeastern University, Clearwater, FL, USA

Sara Raiser Departments of Orthopaedics and Rehabilitation Medicine, Emory School of Medicine, Atlanta, GA, USA

Elena Randazzo Department of Physical Medicine and Rehabilitation, The Ohio State University, Columbus, OH, USA

Jordan Romick Department of Family Medicine, St. Elizabeth's Hospital, O'Fallon, IL, USA

Jacque Scaramella Sports Dietitian, San Diego, CA, USA

Moritz Schumann Department of Molecular and Cellular Sports Medicine, Institute of Cardiovascular Research and Sports Medicine, German Sport University, Cologne, Germany

William Sterett, MD Department of Research and Education, Vail-Summit Orthopaedics and Neurosurgery–Research and Education Foundation, Vail, CO, USA

Department of Orthopaedic Surgery and Sports Medicine, Vail-Summit Orthopaedics and Neurosurgery, Vail, CO, USA

Genevra L. Stone Harvard Affiliated Emergency Medicine Residency at Beth-Israel Deaconess Medical Center, Boston, MA, USA

Adam S. Tenforde Department of Physical Medicine & Rehabilitation, Spaulding Rehabilitation Hospital, Harvard Medical School, Charlestown, MA, USA

Kathryn Thomas Co-Kinetic, Centor Publishing, London, UK

Jane Thornton Return to Health and Performance Lab, Fowler Kennedy Sport Medicine Clinic, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada

Michael R. Tiso Department of Sports Medicine, Ohio State University Medical Center, Columbus, OH, USA

Kenneth Vitale Department of Orthopedic Surgery, University of California San Diego, La Jolla, CA, USA

Bryant Walrod Department of Family and Community Medicine, The Ohio State University Wexner Medical Center, Columbus, OH, USA

Katherine Wayman Wexner Medical Center, Ohio State University Medical Center, Columbus, OH, USA

Part I

Medical Conditions

1 Taking a Holistic Approach to Treating Endurance Athletes

Gloria Beim, Kyle R. Brena, Bridget Holroyd Jones, Adam Lindsay, William Sterett, and Jared D. Heinze

Abbreviations

BW	Body weight
CWI	Cold-water immersion
DN	Dry needling
Kg	Kilogram
MPS	Myofascial pain syndrome
MTrP	Myofascial trigger point
PHQ	Personal Health Questionnaire

G. Beim · A. Lindsay
Department of Orthopaedic Surgery and Sports Medicine, Vail-Summit Orthopaedics and Neurosurgery–Alpine, Elk Avenue, Crested Butte, CO, USA
e-mail: drbeim@vsortho.com; alindsay@vsortho.com

K. R. Brena · J. D. Heinze (✉)
Department of Research and Education, Vail-Summit Orthopaedics and Neurosurgery–Research and Education Foundation, Vail, CO, USA
e-mail: kbrena@vsortho.com; jheinze@vsortho.com

B. H. Jones
Department of Physical Therapy, Avalanche Physical Therapy, Frisco, CO, USA
e-mail: bjones@vsortho.com

W. Sterett
Department of Research and Education, Vail-Summit Orthopaedics and Neurosurgery–Research and Education Foundation, Vail, CO, USA

Department of Orthopaedic Surgery and Sports Medicine, Vail-Summit Orthopaedics and Neurosurgery, Vail, CO, USA
e-mail: drsterett@vsortho.com

Introduction

Endurance athletes participating in sports such as cycling, running, and swimming strive to maintain peak performance by alternating between periods of intensive training and periods of rest and recovery. Maintaining balance between periods of rest and recovery can be difficult due to the nature of prolonged physical exercise both during training and competition. Because of this, endurance athletes are most at risk for experiencing “overuse” injuries, which are usually a result of an imbalance between overly intensive training and inadequate recovery [1].

Sports medicine providers and orthopedic surgeons who provide care for endurance athletes are technicians and experts in treating injury and diseases related to the musculoskeletal system, with the ability to restore physical function and relieve pain. But for high-level endurance athletes, surgery is often viewed as a “last resort” given it likely means time away from sport, less training, and more emphasis on recovery. Also, despite the overwhelming success of most orthopedic procedures, functional improvements after surgery still vary widely. In fact, suboptimal functional outcomes have been associated with poor emotional health in a variety of orthopedic specialties, including sports-related surgery. It is well documented that emotional health of a patient influences the outcome of many common orthopedic surgeries [2]. This is especially important to consider when providing care for endur-

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ance athletes because emerging evidence suggests that endurance athletes, along with being at increased risk of physical injury, also experience a higher risk of psychological issues and mental health disorders [3].

Given the complexity surrounding the physical and psychological needs of endurance athletes to reach peak performance, it is important to take a holistic approach to providing care. Holistic care is that which takes a multidimensional perspective and aims to target all components of an individual athlete's specific needs. Holistic care is comprehensive, integrative care and can be best understood through a biopsychosocial health model. The biopsychosocial health model was developed by George Engel to complement the traditional biological model of disease that views a disease solely because of biological malfunction. The biopsychosocial model offers a multidimensional perspective by recognizing the impact of psychological and social factors on the development and outcomes of illness and disease [4].

Taking the complex nature of endurance athlete's needs into consideration allows for comprehensive care planning and considerations to be made so that peak performance can be attained while minimizing the risk of injury and need for invasive surgeries. What follows are different components of a holistic program of care that should be included for consideration that encompass the diverse and multidimensional needs of endurance athletes.

Behavioral Health

Elite and recreational endurance athletes are susceptible to a unique variety of stressors which may increase their vulnerability to behavioral health issues and disorders. The psychological impact of injury, overtraining, burnout, and need to manage competitive pressures to perform are important factors which may increase susceptibility to stress. It is widely accepted that overtraining is often required of endurance athletes to achieve peak performance despite growing evidence that extreme overtraining can result in declined performance. Along with the risk of decrement in performance, more research is showing that overtraining may also lead to declines in mood and increased risk of behavioral affective disorders [5, 6]. Although a dose-response relationship between exercise volume and physiologic benefit has been documented in previous studies [7], less is known regarding the relationship between exercise volume and effects on psychological well-being. Some existing studies point to a potential inverse relationship between mental health and training volume. One such study of 400 swimmers at the University of Wisconsin-Madison assessed the mood of athletes at monthly intervals during the entire duration of their training season over a 10-year period [8]. Throughout all 10 years of the study, mood disturbances were reported to be at their highest level during the time of highest volume training blocks.

Currently, there is still a lack of research on prevalence and types of mental health disorders in endurance athletes. This gap in knowledge hinders the ability to generate evidence-based guidelines and standards for clinicians in sports medicine and orthopedics to utilize when treating the complex needs, including psychological needs, of the endurance athlete population. Behavioral screening tools, such as the Personal Health Questionnaire (PHQ) series, exist and should be utilized during clinic visits to identify any psychological issues. Other tools available to endurance athletes which may be beneficial include psychological and mental toughness coaching, resilience training, goal setting, verbal encouragement, and head-to-head competition. These recommended tools can be used to meet a specific athlete's needs and should be evaluated for use on a case-by-case basis.

Nutrition

Nutrition is a key component in the integrated approach for the treatment of endurance athletes. Its effects can promote both physical and mental well-being after an injury, surgery, or hard training session. With a suboptimal diet, endurance athletes can encounter delayed recovery, a decrease in performance, or an increased risk for injury [9–12]. The goal of rehabilitation nutrition is to maintain a recommended body weight and body fat percentage according to an athlete's specific sport to reduce the effects of muscle disuse atrophy [10].

When an athlete is in the inactivity or immobilization phase of recovery, muscle disuse atrophy can cause a 0.5% decrease in muscle mass per day with an overall 50% decline in muscle protein synthesis. Muscle atrophy etiology is a multifactorial process that can be attributed to acute inflammatory cytokines, hormonal changes, bone calcium loss, decreased metabolic rate and insulin sensitivity, and increases in fat deposition [10].

An important factor when attempting to counteract the effects of muscle atrophy is sustaining the amount of available hepatic or muscular glycogen, which can be used for rebuilding damaged tissue after an injury or training session [9–12]. A recent systematic review on rehabilitation nutrition for injured athletes concluded that sufficient intake to maintain glycogen stores requires a caloric intake of approximately 25–30 calories per kilogram (kg) of body weight (BW) with simultaneous intake of carbohydrates and protein [10]. The co-ingestion of protein with carbohydrates increases serum insulin secretion, which leads to better glycogen resynthesis in the presence of carbohydrates. Other research supports these recommendations and has added evidence to the specifics of timing, amount, and other nutrients that may aid to recovery. In summary, it is recommended that recovering or rehabilitating endurance athletes ingest five to six meals throughout the day, including immediately after exercise, with an average of 0.75 g of carbohydrates/kg of BW/meal with 0.25 g of protein/kg of BW/meal [9, 11, 12]. Previous studies have also demonstrated that long-term intake (>8 weeks) of 4 g/day of omega-3 fatty acids may enhance sensitivity to amino acids, as well as provide anti-inflammatory properties, all of which could aid in optimizing recovery [10].

Nutrition does not only provide elements of recovery but also contains preventative properties as well. Stress fractures are a common overuse injury in active populations, occurring in approximately 20% of all athletes [13]. Repeated submaximal loads can cause stress fractures, as endurance athletes may experience from frequently running long distances or from jumping repeatedly. Without proper nutrition (and appropriate time) for recovery, the repeated submaximal loading can eventually cause an accumulation of stress fractures which can be debilitating for an athlete. Studies that have extensively examined active populations have identified correlations between low calcium and/or vitamin D levels and the prevalence of stress fractures [14–19]. Calcium is the main mineral present in the bones which provides strength, as well as helps maintain appropriate blood calcium levels. Vitamin D helps regulate calcium absorption and bone remodeling [20]. Therefore, low levels of either calcium, vitamin D, or both may contribute to the risk of stress fractures and muscular strain in athletes [21]. It is currently recommended that athletes consume 2000 mg of calcium and 800 international units of vitamin D daily to reduce the risk associated with deficiency [13], though 2000–5000 international units per day may be required if an athlete is Vitamin D insufficient or deficient. Foods or supplements that contain probiotics, nitrates, and antioxidants may also have benefits for recovery or injury prevention; however, the body of evidence is currently incomplete and inconclusive [11].

The recommendations provided above on nutrition should be considered for all athletes that are aiming to optimize recovery after a training session or an injury. By consuming the appropriate micro- and macronutrients, athletes can maximize recovery between training sessions and can potentially reduce the time to return to their respective sport after an injury. The nutritional recommendations in this section are consistent across literature; however, it is important to acknowledge that everyone's metabolism varies, and therefore the athlete should consult their physician or nutritionist before following specific protocols. In conclusion, a well-balanced diet plays a fundamental role in the multimodal, holistic approach to the recovery of an endurance athlete and should not be overlooked when aiming to optimize performance or the recovery and rehabilitation process.

Compression Garments

Compression garments are articles of clothing such as knee sleeves, socks, and tights that are frequently worn during endurance training and recovery. The theory behind use of compression garments is that during activity, these garments help to prevent excessive swelling in the muscles, as well as improve circulation and removal of waste products such as lactic acid and muscle metabolites. As a result, manufacturers claim compression wear can improve exercise performance and speed up muscle recovery.

The research behind these garments indicates that there is little to no benefit to using compression clothing during exercise to improve performance [22–27]. However, there is research that supports the use of compression wear for recovery, especially for reducing delayed-onset muscle soreness (DOMS) and improving next-day muscle performance [22, 24, 25, 27]. One systematic review and meta-analysis that aimed to review efficacy of compression garments on measures of DOMS, muscular strength, muscular power, and creatinine kinase concluded that compression garments are effective at enhancing recovery from muscle damage [25]. Another review also concluded that compression garments could be beneficial to enhance next-day endurance performance [26]. In a third systematic review, authors attempted to compare low- vs. high-pressure garments, as well as wear times. The authors found that there was a high level of variation in pressures as well as wear time for garments and were unable to identify a correlation between either measurement. However, the review concluded that in many studies, muscle performance improved, and DOMS was reduced with garment wear during recovery following exercise with a variety of wear times and garment pressures [27]. Overall, more research is needed to determine optimal parameters for compression garments, but many reviews and studies conclude that compression wear is likely to be beneficial for endurance athlete recovery [22, 24–27].

While there is no apparent harm in wearing compression garments during exercise, there is likely limited objective benefit to wearing these to enhance immediate metabolic performance. The benefit of wearing compression garments is mostly identified as the ability to enhance recovery and reduce post-performance inflammation, so while garments can be worn during activity, most of the benefit of compression wear is use after exercise.

Typically, compression garments are purchased by the athlete for personal use, so these are not often used during formal rehab such as in physical therapy. When treating endurance athletes, we recommend wearing compression garments for the affected treatment area after activity to reduce post-activity soreness and inflammation. However, if wearing compression garments provides increased subjective performance during activity, it should not necessarily be discouraged. Compression may provide a sense of increased support, comfort, and the ability to minimize swelling in an injured area during exercise.

Hydrotherapy

The shift in youth and adolescent sports from a school-based, seasonal format to a club or travel team, year-around format has led to an early specialization in one sport, which increases the likelihood of overuse injuries [28, 29]. As a result, parents and athletes are searching for accessible and inexpensive recovery modalities. A particular interest has developed in hydrotherapy, specifically cold-water immersion (CWI) and contrast baths. These treatments may be an effective recovery tool which do not require expensive equipment or a specialist which would be needed for treatments such as dry needling or acupuncture.

Cold-water immersion is one of the most widely implemented and researched recovery modalities for athletes. The exposure to cold water is hypothesized to provide benefits in muscle recovery and subsequent performance from the reduced temperature of the muscles, skin, and core [30, 31]. A systematic review on available literature revealed that CWI can significantly reduce the symptoms of delayed-onset muscle soreness up to 96 h after exercise as well as decrease ratings of perceived exertion 24 h after exercise when compared to passive recovery [32]. The exact physiological mechanisms for reduction in delayed-onset muscle soreness and rating of perceived exertion are not well understood; however, it could be explained by the vasoconstrictive properties of CWI [32, 33]. Vasoconstriction reduces the muscle cell's metabolism, which may reduce the number of metabolites that cause muscle soreness [32]. Vasoconstriction also alters hydrostatic pressure in blood, which may promote muscle metabolite removal, further reducing the number of harmful metabolites in the recovering area [34]. Lowering body temperature reduces the perception of pain by slowing down nerve conductions, which may improve psychological recovery following an intense training session or event [35]. There are numerous protocols for duration and temperature for CWI; however, literature has cited that the optimal time for submersion is between 11 and 15 min at 11–15 °C [36].

Contrast baths are different from CWI in that they utilize repeated immersions of hot then cold water for a specified time, duration, and temperature [37]. The alternating temperature changes from hot to cold cause periodic vasodilation and vasoconstriction that induce a vascular pumping effect. Vascular pumping increases blood flow and oxygenation and thus enhances tissue waste product transportation and removal that can improve recovery [37]. Like studies on CWI, those examining benefits of contrast baths have conflicting evidence on their effectiveness for recovery [38–42]. There is evidence, however, that contrast baths decrease perception of fatigue, but not perceptions of soreness [42]. There is also evidence that contrast baths help athletes maintain performance on subsequent exercise bouts when compared to CWI and passive recovery modalities. The contrast bath strategy utilized in the study included alternating between cold water at 10–12 °C and warm water at 38–40 °C for 60 s in each cycle, through 7 cycles [41].

Contrast baths and CWI are an inexpensive and accessible recovery modality that may be of benefit for endurance athletes. However, the lack of knowledge about the underlying mechanisms of recovery with respect to hydrotherapy limits the ability to conclude whether an athlete will recover more rapidly in comparison with use of other modalities. We recommend that athletes utilize CWI or contrast baths within these guidelines if they believe hydrotherapy provides perception of decreased fatigue and/or muscle soreness. The psychological benefits of perceived recovery may also provide a better frame of mind for the athlete, thus potentially enhancing the athlete's subsequent physical performances [42].

Acupuncture

Acupuncture is a therapeutic intervention in which a clinician inserts small, filiform needles into the skin to stimulate specific points on the body [43–45]. This practice is most frequently associated with a system of medical theory and practice called "traditional Chinese medicine," wherein health is seen as the result of harmony among bodily functions and between body and nature [44, 45]. The main idea behind acupuncture is that stimulation of specific body regions, or "acupoints," can have effects on one's physiology at distant sites [46]. Traditional acupuncture treatment is not based on Western empirical research; however, recent studies have yielded promising results that support the use of acupuncture for reducing the body's inflammatory response and managing certain pain conditions. For the endurance athlete, this may be a useful tool for recovery and more rapid return to sport following injury.

Current research indicates that it is possible to reduce systemic inflammation with acupuncture treatment [43, 46, 47]. In two studies using acupuncture needles stimulated with electric current, termed "electroacupunture," it was shown that researchers could reduce systemic inflammation in mice [43, 46–48]. Two other independent studies that aimed to determine the effect of acupuncture on bone healing produced promising results, indicating that acupuncture can improve outcomes in fractures of the tibia, fibula, and humerus [49, 50]. These studies determined that the addition of acupuncture to usual care protocols can increase positive outcome rates and result in improved function at the injured sites, specifically with improvements in range of motion and reduction in swelling [49, 50]. Studies have also been conducted on human subjects to determine immediate effects of strength and endurance performance. While some of these studies failed to confirm improved ability to produce force with acupuncture [51], several studies indicate that acupuncture may reduce discomfort and delayed-onset muscle soreness and improve muscle activation [44, 51–53]. Evidence to support acupuncture is developing, and more research is needed to narrow down treatment parameters such as needle placement, treatment duration, and treatment intensity to optimize outcomes for the endurance athlete [43, 46, 47].

Currently, parameters for how and when to use acupuncture are widely variable. There is evidence to indicate that acupuncture used immediately prior to performance can reduce pain and rating of perceived exertion during activity, thus improving overall performance times [49–53]. Other studies have aimed at using acupuncture as a recovery tool where treatment is provided following strenuous activity or injury. The theory behind treatment post-activity is to reduce pain and inflammation, which can lead to faster recovery times and earlier improvements in function. If inflammation and pain are controlled early following strenuous activity or injury, we would predict that an athlete should be able to return to training sooner and at a higher intensity that may otherwise be limited.

Dry Needling

Dry needling (DN), also referred to as trigger point dry needling or functional dry needling, is a minimally invasive technique in which a fine, solid filiform needle is inserted through the skin into muscle tissue, often targeting a "knot" or "trigger point" in the muscle. A myofascial trigger point (MTrP) is characterized as a "hypersensitive spot, usually within a taut band of skeletal muscle or in the muscle's fascia, they can have strong focal points of tenderness, a few millimeters in diameter, and can be found at multiple sites in the tissue" [54–57]. Myofascial trigger point can further be classified as active or latent. Active MTrPs are painful and cause a pattern of referred pain at rest and/or while in motion. Latent MTrPs are also areas of hypersensitivity but only refer pain when palpated or pressed on [54, 55, 57–59]. Dry needling is used to influence muscular, neural, and connective tissues such as muscle, tendons, and scar tissue [56]. Dry needling can be used for both active and latent TPs. Typically, DN is performed by a licensed physical therapist, chiropractor, medical doctor, or acupuncturist. Dry needling is frequently confused with acupuncture, but these are separate treatment approaches that differ both in technique and theory behind the practice [56]. Traditional acupuncture is based on Eastern medicine theories related to meridians and balance of yin and yang, and Western medical acupuncture is meant to target ah shi points, which are acupuncture points that are painful with palpation [56, 59]. Dry needling is meant to target MTrPs with the intent of influencing muscle function and reducing pain [54, 57, 59].

Most DN therapy is used to target myofascial pain syndrome (MPS) associated with hyperalgesic zones in MtrPs. Current research generally supports the effectiveness of DN to reduce pain in patients with MPS of the upper quarter. One previous systematic review identified 246 articles on the subject, of which 12 randomized clinical trials were chosen for meta-analysis. The findings of three studies which compared DN to sham or placebo produced evidence that DN can immediately decrease pain in patients with upper-quarter MPS. Two other studies in this meta-analysis suggested that DN, when compared to sham or placebo, decreased pain after 4 weeks in patients with upper-quarter MPS. In addition to reducing pain, there is evidence that DN can increase muscle blood flow and oxygenation by causing vasodilation in small vessels. However, it is unclear whether the increase in blood flow is restricted to the needling site, or if DN increases blood flow to remote areas as well, or how long these effects last [56, 58]. Finally, there is limited evidence that DN has a direct effect on MTrPs by disrupting the "taut band" that forms, resulting in relaxation of the muscle and possible improvements in flexibility and range of motion [56, 58, 60]. Based on the current body of available evidence, recommending DN for management of acute pain should be considered for endurance athletes. Treatment could be combined with other modalities immediately following rigorous activity for management of acute pain as well.

Dry needling is frequently performed by accredited and trained physical therapists and occasionally performed by chiropractors, acupuncturists, and medical doctors to treat individuals before, during, and after endurance activities. Clinicians can perform a variety of treatment techniques using filiform needles with or without electric stimulation to target the affected muscles. Some techniques include needle "pistoning," in which the needle is rapidly moved up and down in the muscle, needling with electric stimulation where the needle is placed in the muscle and the electrical stimulation unit is attached to the needles, and even placing the needle and leaving it for a set period of time (Fig. 1.1). The techniques used will vary based on the clinician's experience level and training. The needles used are sterile and disposable and come in various lengths and gauges, typically between 0.16–0.3 mm thick and 1.5–6 cm long in size. The length and gauge of needle are determined by the depth of the trigger point in the tissue, as well as the technique used for treatment.

As athletes prepare to train for endurance activities, they may consult a medical professional to identify impairments such as decreased range of motion, decreased flexibility, weakness, and poor motor patterns that could contribute to injury. These evaluations are often performed by a physical therapist, and the physical therapist may decide that DN is an appropriate intervention to treat these impairments as the athletes begin their training plan. In some instances, professional athletes may have access to physical therapy during endurance events. For example, if an athlete sustains a minor calf or hamstring strain while competing and a clinician is available to perform DN immediately after injury at the competition site, this could allow the athlete to continue in the competition. Following rigorous training regiments or endurance events, athletes may experience muscle tightness, pain, or even weakness. Clinicians can use needling techniques to release tension in the muscles or place

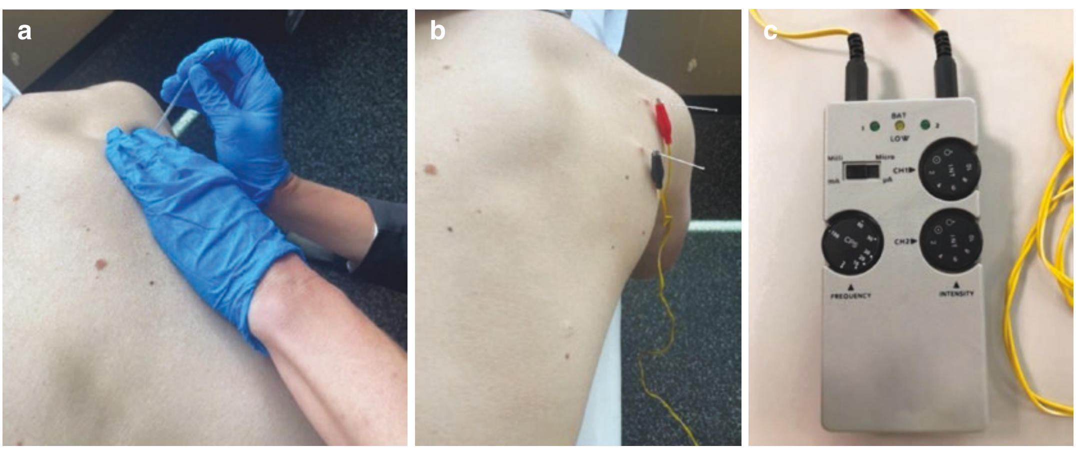

Fig. 1.1 Dry needling. Illustration demonstrating a physical therapist's (**a**) dry needling technique for a supraspinatus myofascial trigger point with (**b**) electrical stimulation. During electric stimulation, the current and frequency were held constant, while the intensity was slowly increased on the (**c**) electrical stimulation machine (E-Stim II) until a slight twitch occurred in the target muscle, which was seen around an intensity of 2 Watts/cm^2 out of 10. The physical therapist allowed for continuous stimulation until a noticeable change was observed in the twitch response

needles into weak muscles and stimulate them with electricity to improve overall muscle fiber recruitment. Often this treatment is followed by corrective exercises to improve movement patterns that may have contributed to the pain or tightness in the first place. Dry needling should be considered as a treatment option for endurance athletes at any stage of training and competition, from preparation to recovery.

Iontophoresis

Steroids administered orally or through injection are often used to treat chronic inflammation in athletes. Although these administration modalities provide short-term relief, they do not come without risk. Injections can disturb the underlying tissue and potentially increase the chance of tendon rupture and cartilage damage [61]. Steroids taken orally allow systemic administration, increasing the chance fluid retention, upset stomach, and high blood pressure [62]. To minimize the risk of steroid administration, iontophoresis was developed as a noninvasive and localized modality for chronic, inflammatory injuries.

Iontophoresis is a transdermal drug delivery technique utilized to reduce inflammation in various musculoskeletal conditions without the use of needle. The principle behind iontophoresis is that the application of a same-charge current can repel a charged drug into the desired area. There are two commonly used methods of iontophoresis. The traditional way in which a current is generated is with lead wires connected to an active and dispersion pad. This method is conducted during the physical therapy session and lasts between 15 and 20 min. The other method is conducted through a battery-charged patch that is loaded with the appropriate medication and administers a current for up to 24 h after application (Fig. 1.2) [63].

Iontophoresis is mainly used for chronic, overuse injuries that endurance athletes may experience over the course of their career. Lateral epicondylitis (tennis elbow), plantar fasciitis, patellar/Achilles tendonitis, and any other superficial soft tissue pathology tend to be the most common injuries that may benefit from iontophoresis. Several randomized studies have evaluated the effectiveness of iontophoresis in the treatment of lateral epicondylitis and have observed that when paired with a strengthening program, iontophoresis results in quicker improvement of strength and decreased pain level [64–66]. One study in particular evaluated the 24-h iontophoresis patch loaded with dexamethasone versus corticosteroid injection in patients undergoing formal physical therapy for lateral epicondylitis. The authors concluded that iontophoresis produced greater short-term strength benefits over injections, possibly due to the lack of deep tissue damage caused by a needle [64].

Iontophoresis may be a useful drug administration technique for athletes battling chronic injuries to superficial soft tissues. For medical professionals and athletes interested in utilizing iontophoresis, there are a few things to consider:

Fig. 1.2 Iontophoresis. Illustration demonstrating the placement of a battery-charged, 80 mA-min iontophoresis patch used for Achilles tendonitis. Prior to application, the negatively charged terminal was loaded with 1.3 mL of dexamethasone and applied with the negatively charged terminal over the injured area

- The type of medication used.
  - In order to be effective, the medication must be water-soluble and have a small molecular size and an ionic charge [63, 64].
- Which application (traditional or patch) is best for the athlete's situation?
  - The traditional method, which is conducted during the physical therapy session, can potentially reduce the time to perform supervised stretches or exercises with the therapist, whereas the patch can be used after the session and administered for a longer period.
- Depth of injury.
  - A study conducted with dexamethasone phosphate determined that a therapeutic concentration could reach depths of only 4 mm below the skin, with a higher concentration at the more superficial depths [67].
- Dose period and current strength.
  - The recommended dose, expressed in milliampere-minutes (mA-min), is 40 mA-min, which can vary depending on the subject's comfort level and type of administration [63].

It is important to note that the athlete should consult with his or her physician prior to using iontophoresis because this technique is introducing a drug.

Ultrasound

An imbalance between training and recovery can lead to overuse injuries that may impact athletic performance. An endurance athlete's training protocol requires a perfect balance between training sessions and rest/recovery periods. It is very important for athletes, coaches, and physical therapists to use various modalities to ensure proper recovery.

Like iontophoresis, ultrasound is a noninvasive, atraumatic recovery modality used by physical therapists to treat painful musculoskeletal conditions, but without the use of a drug. Ultrasound machines emit high-frequency sound waves (above the threshold of human hearing), through a probe which is applied to the skin (Fig. 1.3). The passing of the ultrasound waves through the skin can produce a variety of effects, such as increased tissue temperature, increased

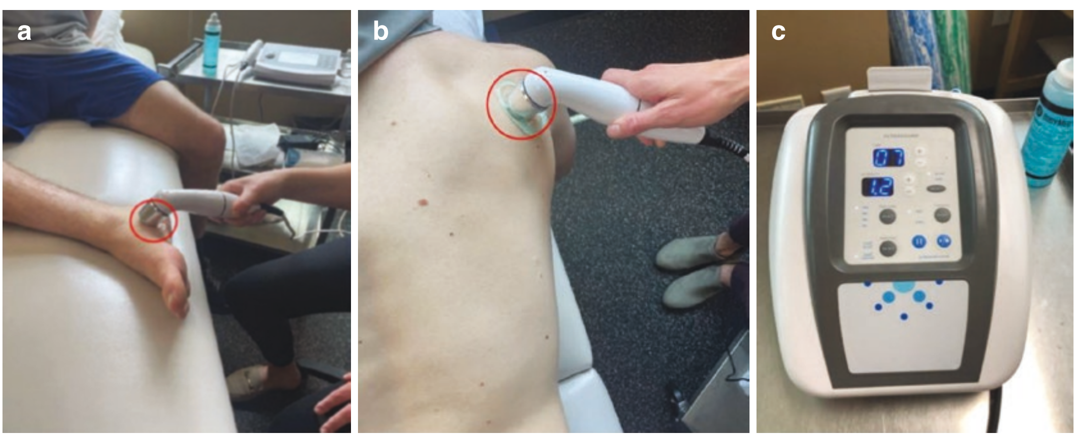

Fig. 1.3 Ultrasound. Illustration demonstrating a physical therapist utilizing ultrasound treatment for (**a**) plantar fasciitis and (**b**) supraspinatus tendinopathy. The treatment area must be approximately twice the size of the probe, as indicated by the red circle. The (**c**) ultrasound machine's parameters were set to an intensity of 1.2 Watts/cm^2 and frequency of 1 MHz; however, these parameters may vary depending on the athlete's tolerance to the treatment and type of injury

tissue metabolism, increased localized blood flow, increased extensibility of collagen fibers, reduced viscosity of fluid elements of the tissue, ultrasonic cavitation, and gas body activation [68, 69], all of which can enhance the recovery process.

Therapeutic ultrasound has been used to treat many types of injuries. Ligament sprains, muscle strains, tendonitis, joint inflammation, plantar fasciitis, facet irritation, bursitis, and scar tissue adhesion are among the typical injuries that can be treated with ultrasound therapy [68, 69]. Literature is inconclusive regarding the effectiveness of ultrasound therapy [70–75]; however, this may be due to differences in the severity of the treated injuries, the specific techniques used by the physical therapist, and/or the evaluations of results (subjective versus objective scores, animal models, etc.). In animal models, where confounding factors are limited, it has been shown that ultrasound therapy can increase cell proliferation during muscle generation, accelerate patellar-bone tendon junction healing, and facilitate tendon healing with increased tensile strength and collagen alignment [76–81].

Ultrasound may be a useful tool for physical therapists to optimize an athlete's recovery when administered concurrently with a strengthening and/or stretching program. The adjustability of the ultrasound machine allows it to treat a variety of injuries/conditions; however, an improper technique may diminish its benefits. Below are a few considerations for medical professionals utilizing ultrasound in their treatment protocol [69].

- Size of the injured area
  - The therapeutic effects of ultrasound derive from its ability to heat localized tissues through continuous mechanical disturbances from sound waves. Only small areas, roughly twice the size of the ultrasound probe, are recommended. Hot packs or baths should be used for any injury that is larger.
- Correct intensity, frequency, and duration
  - The ultrasound's maximum benefit typically occurs when the injured area's temperature is increased by 4 °C. When applied with an intensity of 1.5 Watts/cm^2, heating will take 10–15 min at 1 MHz frequency or 3–5 min at 3 MHz frequency. It is important to note that ultrasound may create a feeling of warmth/burning, which will be tolerated differently by each athlete. Adjusting the intensity of the ultrasound machine can reduce discomfort; however, if the intensity is adjusted, then the duration of treatment should also be adjusted.
- Injured tissue
  - The depths of tissues treated are inversely proportional to the frequency used. A 3 MHz frequency is recommended for superficial tissue injuries less than 3 cm deep, whereas a frequency of 1 MHz is recommended for tissue injuries at 2.5–5 cm deep.
  - The type of tissue may also influence the therapist's decision regarding technique (e.g., tendons typically heat up faster than muscles).
- Appropriate speed of probe movement
  - The recommended speed of the probe is approximately 4 cm/s. This allows for even distribution of the sound waves and helps the therapists stay within a small application area.
- Therapeutic window after application
  - The average time it takes for heated tissues to drop to baseline temperature is approximately 15 min. Therapists should conduct stretching and/or strengthening exercises immediately after application.

Kinesiology Tape

Athletes are always searching for the next best and innovative product or technology to help improve their performance and expedite recovery. In recent years, most of the focus has been on external garments, dietary supplements, hot/cold baths, electro-stimulus, drug therapy, etc.; however, kinesiology tape gained international attention after its notable use in the 2008 Summer Olympics.

Kinesiology tape was developed in the 1970s by a Japanese chiropractor, Dr. Kenzo Kase. The application of the tape was designed to provide support without limiting range of motion (Fig. 1.4) [82]. Today, the innovative blend of nylon, cotton, and medical grade adhesive is believed by some to increase range of motion and strength, stabilize joints, facilitate recovery, and improve blood flow through mechanical stimulation of structures underneath the skin [83]. A magnetic resonance imaging study observed that when kinesiology tape was applied over the tibialis anterior, changes were noted in both the underlying and distant tissues [84]; however, other studies have not been able to consistently demonstrate that kinesiology tape can prevent injury or improve recovery. Additionally, a systematic literature review on kinesiology tape's effect on athletic performance evaluated 11 studies and observed that out of the 193 comparisons, only two reached statistical significance [83]. Another systematic review and meta-analysis of ten studies showed that there is a low quality of evidence to support kinesiology tape in the prevention and treatment of injuries in athletes [85].

While there is limited evidence on the efficacy of kinesiology tape, the placebo affect may be substantial enough to facilitate a positive psychological response. In a single-blinded, placebo-controlled crossover trial evaluating quadriceps force output with kinesiology tape, the authors observed that even when there were no statistical differences in force output, approximately 45% of subjects in the experimental group reported feeling stronger, compared to only 30% of subjects in the placebo group [86]. This indicates that the benefits advertised for kinesiology tape may be strictly due to psychological factors.

Kinesiology tape may be a useful tool for select athletes who find it beneficial. It is

Fig. 1.4 Kinesiology tape. Illustration of kinesiology tape placement for (**a**) shoulder stabilization and (**b**) patellar tendonitis. This particular (**a**) shoulder stabilization technique required three strips of kinesiology tape, originating from the deltoid tuberosity and extending (**a1**) posteriorly, (**a2**) medially, and (**a3**) anteriorly to stabilize the humeral head within the glenohumeral joint. (**b**) The patellar tendonitis technique entailed placing two strips of kinesiology tape along the (**b1**) lateral and (**b2**) medial side of the patella with an additional strip of kinesiology tape placed (**b3**) horizontally across the patella tendon in order to provide support for the tendon when under stress

important to note that the application technique may vary depending on the body part and desired treatment outcome [87]. We recommend athletes consult a medical professional before applying.

Blood Flow Restriction

A significant percentage of athletes will experience an injury over the course of their career. Not all these injuries require surgery; however, some form of physical therapy is frequently prescribed to help the athlete recover. This process is often slow and can be further delayed by the inability to perform high-load resistance exercises (defined as ≥70% of an individual's 1 repetition maximum), which have been shown to promote muscle hypertrophy and strength gains [88, 89]. Various modalities have been investigated to determine whether the physiologic response to a high-load resistance exercise could be mimicked, but without the physical stress. Dr. Yoshiaki Sato developed a training philosophy that we now refer to as blood flow restriction training, which seems to produce a physiologic response similar to that of a high-load resistance exercise [90].

Blood flow restriction training involves applying a pneumatic tourniquet system to the most proximal region of the upper and/or lower limbs while doing a low-load resistance exercise (Fig. 1.5). The pressure from the pneumatic tourniquet or cuff reduces arterial blood flow and inhibits all venous blood flow. It is believed that when resistant exercises are done under this altered state of blood flow, hypoxia is induced in the muscles. Under hypoxic conditions, there is a greater recruitment of motor units, like that of a high-load resistance exercise, and an increase in cellular metabolites that are known meditators of muscle hypertrophy [88, 90, 91].

Current research indicates that low-load blood flow restriction training stimulates muscle hypertrophy through the synergistic effects of muscle activation and hypoxic conditions [88, 91–93]. In an 8-week rehabilitation study conducted in the United Kingdom, 24 patients undergoing anterior

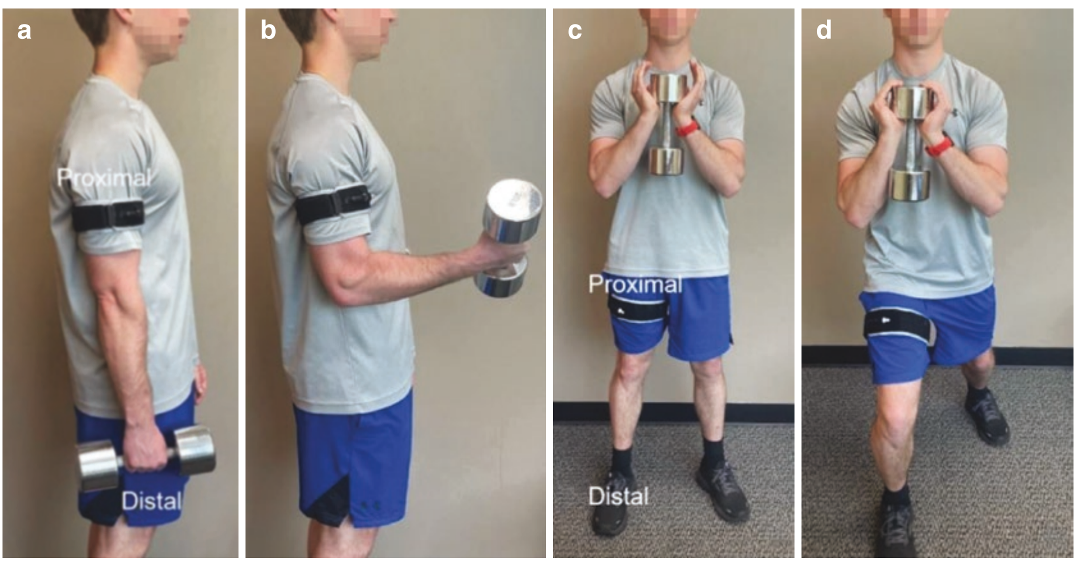

Fig. 1.5 Blood flow restriction. Illustration demonstrating pneumatic cuff placement for (**a**) targeting the upper extremity blood flow restriction prior to and (**b**) during bicep curl exercise movement and (**c**) targeting the lower extremities prior to and (**d**) during lunge exercise movement. Pneumatic cuff must be placed on the most proximal portion of the extremity with an occlusion pressure that restricts arterial flow by approximately 40–80%. Athletes should use a working load of 20–40% of their 1 rep max and aim for four sets of high repetitions (i.e., 30, 15, 15, 15) as tolerated with 30–60 s between sets

cruciate ligament reconstruction were randomized into either a high-load resistance training group (70% of the individual's 1 repetition maximum) or a blood flow restriction resistance training group with loads at 30% of the individual's 1 rep max. The investigators found that blood flow restriction resistance training improved skeletal muscle hypertrophy and strength to a similar extent as the high-load resistance training group, but with a greater reduction in joint pain and effusion [94]. These findings are corroborated by other independent studies, systematic reviews, and meta-analyses [88, 89, 92, 93, 95–98].

Low-load blood flow restriction training does not appear to be superior to high-load resistance training in muscle hypertrophy or strength; however, it could be a useful tool for athletes aiming to regain lost muscle due to an injury or maintain in-season conditioning without risking further injury with a high-resistance load. Literature has cited that the working load should be 20–40% of the individual's 1 repetition maximum. Ideally, athletes should do four sets of high repetitions (i.e., 30, 15, 15, 15) as tolerated with 30–60 s between sets [90, 91, 94]. Caution should be taken when using pneumatic cuffs as they present some risk when not used properly. The amount of pressure applied to the upper and/or lower limb will be athlete dependent. Limb size, resting blood pressure, cuff size/shape, and athlete tolerance to pressure should all be considered during application. The ideal amount of pressure applied should restrict arterial blood flow by 40–80% of its resting pressure, which can be monitored by newer technologically advanced cuffs [90].

Conclusion

Providing comprehensive and holistic care to endurance athletes is often complex and can be challenging when considering the appropriate action. The authors of this chapter have described various preventative and recovery treatments that encompass the diverse and multidimensional needs of endurance athletes. Physicians, physical therapists, and athletic trainers should implement a holistic and individualized approach for treating endurance athletes that considers the athlete's specific injury, mental status, and desired outcome.

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2 Cardiovascular Evaluation and Treatment in the Endurance Athlete

Andrew Hornick and Curt J. Daniels

Introduction

The decade leading up to 2020 saw significantly increased participation in endurance races in the United States. During that time frame, tens of millions of athletes participated in endurance events including road races, multisport competitions, and endurance cross-training events. Though centralized databases do not exist, the majority of reports indicates that the trends in participation continued to increase over this time frame, with some segments of endurance racing seeing up to a 50% increase in participation over the decade [1, 2].

Exercise confers numerous health benefits. Results of recent longitudinal cohort analyses have indicated that the most physically active adults gain up to 7–8 years in life expectancy compared with sedentary peers [3, 4]. Despite this, exercise does not render active persons immune from diseases of the cardiovascular system. Many reports indicate that athletes above the age of 35, so-called masters athletes, have similar cardiovascular risk factors as age-matched peers [5, 6]. Therefore, assessing a patient for cardiovascular health prior to and while engaging in endurance athletics, as well as the resultant effects on the cardiovascular system secondary to endurance athletics, is of increasing importance for clinicians.

Sports cardiology is an emerging subspecialty within the field of cardiology, spurred by tremendous increases in the amount of scientific literature examining the impact of exercise on the cardiovascular system [7, 8]. Perhaps most notably, increasing access to various means of cardiovascular imaging, like transthoracic echocardiography, cardiac computed tomography (CT), and cardiac magnetic resonance imaging (MRI), has allowed for novel insights into differentiating pathologic from physiologic changes in the athlete's heart [7].

The term exercise-induced cardiac remodeling (EICR) has recently become an accepted terminology to describe physiologic adaptations secondary to exercise and to differentiate them from pathologic findings. Becoming familiar with the common forms of adaptive cardiovascular physiology is foundational to providing care and advice for endurance athletes. The aim of this chapter is to provide clinicians with a focused review of training-related cardiovascular adaptations and an approach to endurance athletes with cardiovascular symptoms and preexisting disease.

A. Hornick · C. J. Daniels (✉)
Division of Cardiology, The Ohio State Wexner Medical Center, Ross Heart Hospital, Columbus, OH, USA
e-mail: andrew.hornick@osumc.edu; Curt.Daniels@osumc.edu

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Pre-Participation Cardiovascular Screening

The composition and performance of the pre-participation cardiovascular screen (PPCS) for athletes is an important topic for clinicians seeing athletes in their practice. Numerous health societies have produced guidelines aimed at a systematic approach to screening athletes for occult cardiovascular disease with the aim of reducing the risk of sudden cardiac death during exercise [9–12]. Studies have indicated that while physical activity reduces all-cause and cardiovascular mortality, the risk of sudden cardiac death increases transiently during vigorous exercise [13–16]. It is notable and worth discussing with athletes that while the risk of sudden cardiac arrest or death does increase transiently during exercise, the absolute risk remains very low. Precise data regarding prevalence of sudden cardiac death related to exercise is limited by a lack of a centralized database in athletes. Extrapolated data from databases of runners and marathoners indicate a range of 1 in 15,000 per year to 1 in 50,000 per year. Commonly accepted prevalence in college athletes is 1 in 50,000 per year. Risk is often stated to be higher among athletes engaging in vigorous activity who were previously sedentary [16, 17].

Multiple professional sporting organizations mandate advanced screening, including the International Olympic Committee (IOC), Federation Internationale de Football Association (FIFA), and the majority of North American professional leagues [10, 11, 16, 18, 19]. However, it is worth noting that there is limited data substantiating the value of pre-participation cardiovascular screening, and published recommendations are considered expert opinion. Universal screening for all persons is a matter of some debate, with no clear consensus on indications for screening. Regardless, pre-participation cardiovascular evaluation is a common reason for referral to clinicians seeing athletes in practice, and some considerations are presented below.

History and Physical Examination

Guidelines from the American Heart Association (AHA) and the American College of Cardiology (ACC) have traditionally advocated for a focused medical history and physical examination prior to participation as the core component of PPCS for athletes [20]. The American Heart Association has published a standardized 14-point focused history and physical to promote consistency in screening [10]. This history and physical focuses on traditional cardiovascular risk factors and targets identifying cardiovascular disease that may cause a significant morbidity with exertion.

Most society guidelines and recommendations divide their recommendations by age, with 35 years of age being a common cutoff. Athletes over the age of 35 are commonly referred to as "masters athletes," whereas athletes under the age of 35 are referred to as "young athletes." The rationale for this age cutoff is based upon the prevalence of pathology causing exercise-induced sudden cardiac death in these two age groups.

Masters Athletes

Multiple studies have indicated that the most common cause of sudden cardiac death during exercise for masters athletes is coronary artery disease (CAD) [21, 22]. Specific assessment for patients with either occult or clinical CAD, as well as other forms of diagnosed cardiovascular pathology, will be covered in depth in a later section; the vast majority of these patients should undergo specialty assessment by a cardiologist regarding their fitness for exercise participation [23].

Recent expert recommendations [17] have called into question whether referring all masters athletes for pre-participation cardiovascular screening creates barriers to sedentary persons engaging in physical activity [24]. These barriers may limit sedentary persons from garnering the substantial mortality and cardiovascular benefits of routine exercise. A recent scientific statement