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Ultramarathon Comprehensive Injury Prevention

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Abstract

Purpose of Review This paper aims to review injury prevention for ultramarathon runners during training, race day, and recovery.
Recent Findings Injury prevention starts with a training plan that emphasizes a gradual increase in distance interspersed with speed work, long runs, strength training, and active recovery. Pre-race training environment that mirrors race day terrain and climate is preferred. Customized nutrition and hydration strategies are recommended. Further research is needed regarding various carbohydrate/fat nutrition strategies.
Summary There are numerous reviews of ultramarathon running-related injuries, which often include discussion on symptoms, treatment options, and how to improve race day performance. This review rather focuses on recent findings in ultramarathon injury prevention including pre-participation screening, training recommendations, shoe selection, foot strike patterns, blisters, and environmental issues. Pre-race and race day nutrition is highlighted with a discussion on high-carbohydrate low-fat diet vs. low-carbohydrate high-fat diets. Prevention of gastrointestinal distress and exercise-associated hyponatremia are also reviewed.

Keywords Ultramarathon · Injury prevention · Running · Nutrition · Endurance sport

Introduction

An ultramarathon is defined as any race with distance greater than 26.2 miles or 42.2 km [1•]. Recent articles suggest that over seventy thousand runners per year worldwide participate in ultramarathons [2••]. With the increasing popularity of ultramarathon running over the past several decades [1•, 3, 4••], there is an increased need to define, prevent, and treat injuries in ultramarathon runners. This review will focus on both musculoskeletal and medical issues within the ultramarathon population, with a focus on injury prevention. Emphasis will be placed on training strategies, recovery, shoe selection, foot strike patterns, blisters, nutrition, hydration, and environmental issues. In addition, the current nutritional debate regarding the health-related benefits and risks of high-carbohydrate low-fat diet vs. low-carbohydrate high-fat diets will be reviewed.

Ultramarathons are uniquely challenging in their tremendous distance, exposure to the elements, change in altitude, and difficult terrain (see Fig. 1). The most frequent distances include 50-km, 100-km, 50-mile, and 100-mile ultramarathons [3]. The type of running is diverse in terrain, time (24 h vs multi-day), and segments (single stage vs multi-stage event). Unique equipment is often needed such as specialized shoes, gear, and clothing. Sleep deprivation during 24 h and multi-day races may lead to physical and emotional fatigue. Nutrition and hydration strategies are key for such long endurance events. Ultramarathons may be held in remote areas of the world, with limited nutritional resources, and greater importance is placed on highly portable and caloric food. The various challenges make the events about more than just "fast running," as strategy, planning, and acclimatization can all play a role in competitor success.

Pre-participation Screening

While there are no specific inclusion or exclusion standards for medical disqualification based on medical history, medical comorbidities should be considered in relation to the specific ultramarathon and its access to resources [5]. The runner is responsible for filling out pre-participation surveys in regard

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Fig. 1 Difficult sand dune terrain in ultramarathon in the Sahara Desert. *Photo courtesy of Brandee Waite, M.D.*

to health and well-being, obtaining a physical exam (usually coordinated with their primary care provider), as well as signing informed consent. While general pre-participation surveys and screens are recommended, EKGs tend to be controversial [6]. EKG screening may be considered, but due to the overall rarity of cardiovascular events among participants in endurance events, the cost-effectiveness and utility of this screen may be unfavorable.

Ultramarathon-Related Musculoskeletal Injuries

There is a wealth of knowledge on the types of injuries sustained during training and racing an ultramarathon. The most common location for musculoskeletal injuries are the knee, ankle/foot, and hip, respectively (see Table 1) [4••]. On race day, musculoskeletal injuries account for 18% of all medical-treated encounters [7•].

Training related lower extremity injuries can include medial tibial stress syndrome, achilles tendinopathy, plantar fasciitis, patellofemoral syndrome, and stress fractures in the foot [8••]. Training risk factors include a rapid increase in training mileage, inexperience with long distance running, change in footwear, and overall poor running form [8••]. Longer running distance has been

Table 1 Ultramarathon musculoskeletal injuries

Number, distribution, and incidence of various exercise-related injuries in the prior 12 months among 1212 active ultramarathon runners

Injury type and/or location	*n*	Distribution (%)	Incidence (%)
Fractures not involving the extremities	12	0.6	1.0
Upper extremity injuries including fractures	17	0.9	1.4
Back injuries	150	7.9	12.4
Iliotibial band issue	191	10.1	15.8
Hip flexor strain	106	5.6	8.7
Hamstring strain	143	7.5	11.8
Stress fracture involving femur/hip	6	0.3	0.5
Other leg, pelvis or hip issues	45	2.4	3.7
Knee issues	291	153	24.0
Calf strain	159	8.4	13.1
Achilles tendinitis or tear	131	6.9	10.8
Lower leg or ankle tendinitis not involving Achilles	111	5.8	9.2
Stress fracture involving tibia or fibula	23	1.2	1.9
Other lower leg injuries	18	0.9	1.5
Ankle sprain	131	6.9	10.8
Plantar fasciitis	129	6.8	10.6
Stress fracture involving foot	41	2.2	3.4
Morton’s neuroma	38	2.0	3.1
Metatarsalgia	38	2.0	3.1
Great toe metatarsal phalangeal joint pain (bunion)	30	1.6	2.5
Other foot and ankle injuries	54	2.8	4.5
Skin wounds, blisters, and infections	18	0.9	15
Other not previously specified	18	0.9	1.5

Hoffman and Krishnan [4••]. Reference cited with permission from PLOS ONE attributed to increased injury risk when training crosses a threshold of 40 miles per week [9].

Training

Each ultramarathon is unique, just as each runner is unique and prepares for the inherent challenges individually. Cookie cutter training methods would be unwise; however, certain factors in training plans should be considered, such as slowly increasing weekly mileage, incorporating race day running surface for training [10••, 11], cross training, and strengthening programs particularly focusing on hip abductor strength [10••]. A 12-week home-based strength, explosive, and plyometric training program in ultra-marathoners led to a better cost of running at submaximal speeds [12]. Giovanelli et al. recommend 2–3 sessions/week of strength, explosive and plyometric training to improve performance in ultra-endurance athletes [12]. The current literature is sparse regarding strength training for injury prevention in ultramarathon runners. It is reasonable that if strengthening addresses a potential deficit, such as hip abductor weakness being the most significant risk factor for IT Band Friction syndrome, then strengthening hip abductors would be beneficial [2••].

Types of training runs include interval training above anaerobic threshold (90% HRmax) interspersed with jog breaks, intensive endurance runs (80–85% HRmax), endurance runs (75–80% HRmax), long recovery runs (65–70% HRmax), and Fartleks or "speed play" in Swedish (65–90% HRmax) [11]. Although speedwork may seem counterintuitive when endurance is critical, strength and confidence play a role in facing adversity when mental and physical fatigue set in. While it may be tempting to quickly increase mileage (particularly when training volume is the most important factor predicting 100 km ultramarathon performance) [13], progression of training in general should not increase mileage more than 10% per week in order to avoid injury [14•]. There are many training plans that gradually increase mileage and highlight periodization, or strategically varying a training program by regular time intervals to improve performance.

Race day environment should be simulated in training whenever possible (i.e., terrain, weather) so the body can become accustomed to the specific challenges, thus less likely to sustain injury during a race. Additionally, all race day equipment needs to be tried ahead of time so that any problems can be resolved. This includes a nutrition and hydration plan, as well as all gear including shoes, clothing, and any technical devices [15••, 16•].

On race day, one tip is to start relatively slowly to prevent injury. Adrenaline, pre-race jitters, and nearby competitors stimulate runners to use energy quicker than expected. Some runners strive for negative splits (or running the latter half of the race faster than the first half). Starting slower is critical for this performance, especially in multi-stage events. Reserving energy for the latter half may also prevent mental fatigue-related errors and avoid, for example, clumsy footing on rocky terrain.

Recovery

Recovery after an ultramarathon is necessary, particularly for trail ultramarathons with significant downhill running (greater eccentric muscle work, leading to potential for increased muscle damage and soreness). One way to enhance recovery is to increase tolerance of eccentric training [17]. There is an adaptation process during training that helps decrease soreness by helping the muscle more quickly recover from muscle damage due to eccentric exercise. Injury frequently occurs when there is not enough recovery between runs during training. Recovery during training does not necessarily need to be complete rest. Active recovery such as cross training or an easy run can be beneficial.

There are several therapeutic recovery techniques including massage, cold-water immersion, compression, electrical stimulation, and vibration therapy as well as hydration, diet strategies, stretching, and sleep [18]. Twenty minutes of post-race massage or intermittent sequential pneumatic compression provides immediate subjective benefit, but there is no data to support clinically significant functional benefits [18]. In conclusion, there are no specific ultramarathon recovery guidelines; however, overtraining is a known risk factor for injury. A training program that emphasizes active recovery or rest days is recommended, and post-ultramarathon recovery is essential.

Stretching

It is generally accepted that stretching improves muscle and joint flexibility [19]. How this relates to injury prevention is unclear. Methods of stretching include dynamic, static, passive, isometric, ballistic, and proprioceptive neuromuscular facilitation. Flexibility depends on the viscoelasticity of muscle, ligaments, and connective tissue. Injury may be related to too much or too little flexibility, and an imbalance in flexibility may predispose to injury. In general, athletes with hypermobility should limit stretching the joints and instead focus on strengthening the surrounding muscles.

For runners, it is generally recommended to perform dynamic stretching before races and avoid static stretching before races. Current trend is for active warm up and post-run static stretching, though evidence is not conclusive. For exercise in general, there is a lack of evidence and recommendations for or against stretching prior to exercise and after exercise. The importance of a proper warm up is known, and injury prevention is linked to strength training, conditioning, and warming up [20]. Generally when stretching, 15 s or 30 s stretches are more effective than shorter duration stretches to improve flexibility. The level of ideal flexibility that is clinically important for an ultramarathon runner is yet to be determined.

Shoe Selection

The striking pattern itself appears to be more important than the barefoot or shod running conditions [21•]. Shoe selection is a highly controversial topic, and while there is debate regarding heel to toe drop (the vertical distance between the height of the heel and the height of the toes) [22]. Changing the drop distributes forces differently across the foot. While the cushioned heel is meant to protect the transient impact force, shoes with cushioned heels tend to facilitate rear-foot striking patterns [23, 24].

When picking shoes for an ultramarathon, consider how feet will swell during the race and make sure that there is enough room in the toe box. US Elite Ultrarunner Hal Koerner has written how he learned this the hard way during the Western States 100-mile race in 2001 when his toenails repeatedly hit the front of the shoe racing downhill in triple digit temperature [16•]. In an act of necessity, Koerner cutoff the front of his shoes to make running sandals to alleviate the pain but this invited rocks and dirt into the shoes, creating other obstacles [16•]. Consider purchasing a larger size shoe than expected prior to race day, and practice using these shoes well in advance of the race.

Shoe selection is different for trail vs road running. Safety factors to consider with trail shoes include extra grip on the sole to combat challenging terrain, lateral stability to prevent rolling ankles particularly when tired, and reinforced rubber toes to protect against rocks [16•]. Road shoes by comparison will likely be lighter. While shoe selection is such a personal preference, it is recommended to tailor the fit with a shoe specialist in an environment that can test the shoes both in and out of store for personal and observer gait analysis. Shoes should be changed every 300–500 miles due to the gradual breakdown in cushioning and structural support [25••].

Foot Strike Patterns

Given that the average runner strikes the ground six hundred times per kilometer [24], repetitive ground reaction forces can increase risk for stress injuries. Foot strike patterns in runners vary between rear-foot (the heel is the first contact with the ground), mid-foot (simultaneous contact of heel and forefoot), and fore-foot strike patterns [26]. Optimizing biomechanics for race day performance and injury prevention is a widely discussed topic of research; however, there is debate about how to best optimize these parameters to decrease lower extremity injury risk [26]. Kinematic analysis demonstrates smaller collision forces in barefoot runners who forefoot strike compared to runners in shoes who rear-foot strike [24]. In a cohort study of Harvard University Cross Country team fore-foot strikers vs. rear-foot strikers, 74% of runners experienced a moderate/severe lower extremity injury annually; however, the habitual rear-foot strikers had twice the rate of repetitive stress injuries compared to fore-foot strikers [27]. This study suggests that foot strike pattern influences injury rates [27]. While there may be evidence to support certain foot striking patterns (rear-foot vs. fore-foot), cross-over research is warranted to compare runners who have switched their foot strike pattern and determine if the new strike pattern protects against injury [28]. Further research is needed with prospective, epidemiologic studies with large sample sizes [28].

There are many factors associated with individual risk for injury including gait biomechanics and foot loading. In a cross-sectional study of female runners who all rear-foot strike, instantaneous and average vertical loading rate and tibial shock was higher in runners with a history of tibial stress fractures compared to those without a history of tibial stress fractures [29]. Although this is a small retrospective study of 20 runners, it demonstrates that despite similar rear-foot strike patterns there are different loading rates [29]; perhaps the different loading rates contribute to the risk for tibial stress fractures. Napier et al. suggest that the most effective strategy to reduce injury risk is to use real time kinetics/kinematics to adjust running biomechanics and decrease impact loading [30].

Friction and Pressure Blisters

Blisters are caused by either direct pressure or shear forces when skin layers are laterally shifted in relation to each other [31] (see Fig. 2). Podiatrist Rushton outlines five factors in blister formation: skin resilience, bone movement relative to the skin's surface, pressure, friction, and moisture [31, 32•]. Rushton also outlines five major components of blister prevention: fit, socks, patches, lubricants, and powders [31]. A well-fitting synthetic fiber sock wicks away moisture from the skin and provides a low frictional component when worn close to the foot [10••]. Shoes fit better if the lacing is snug but not overly tight [16•]. Gaiters can protect against small debris. Quick removal of small dirt and pebbles from the shoe can reduce debris-associated pressure and friction [10••]. Decreasing weight by reducing the carried load also reduces the magnitude of the forces on the feet [10••]. Blister prevention includes proper training and avoiding changes in footwear prior to races. Paper tape is low-cost, easy to use, and

Fig. 2 **a** Toe blisters from ultramarathon running. *Photo A courtesy of Brandee Waite, MD.* **b** Heel blister and patient-administered forefoot wrap. *Photo B courtesy of Chris Lusher and 4Deserts™*

pre-taping a pre-blister hot spot has been shown to be beneficial [10••]. During a RacingThePlanet™ 155-mile 7-day ultramarathon, pre-race paper taping was applied in several locations on 1 ft of ultrarunners while the other foot served as the control [33]. Although the intervention was well tolerated, this study demonstrated that pre-race paper taping in several locations did not prevent against friction blisters [34].

Nutrition for Ultramarathon Training and Competition

Energy for training and competition comes from proper nutrition and hydration. Having well-tested fueling strategies is an essential component of injury prevention. Ultra-nutritionist Sunny Blende states that "Ultras are just eating and drinking contests, with a little exercise and scenery thrown in" [35]. While humorously underestimating effort, this quote highlights the importance of high caloric intake during ultramarathon training and competition. Prior to race day, it is advisable to develop a nutrition plan by experimenting with different quantities and qualities of food and fluids [36•]. This will help limit the stress of decision-making during competition and prevent flavor fatigue or gastrointestinal issues from commercialized gels, goos, candies, and sports drinks [37]. Depending on race location, determine if certain foods are available in the race country [36•]. To avoid carrying additional weight, assess which nutritional items are provided at the race, then practice consuming these items during training if well tolerated to reduce pack burden [36•].

High-Carbohydrate/Low-Fat Diet

It has been well documented in endurance literature that a High-Carbohydrate/Low-Fat diet (HC/LF) enhances performance, and elite ultrarunners have won races adhering to this nutrition strategy [37]. For multi-day endurance running, carbohydrate intake up to 12 g/kg/day enhances endurance performance [36•]. However, several studies demonstrate suboptimal carbohydrate intake during multi-day ultramarathon; therefore, it is questionable if this rate of intake is tolerated [36•, 38••]. In regard to pre-race fueling, current exercise guidelines from the American College of Sports Medicine and the Academy of Nutrition and Dietetics Dieticians of Canada recommend 1–4 g/kg of carbohydrate 1–4 h before endurance running [39]. An example of the average pre-race breakfast for three veteran elite ultramarathon runners contained on average 70 ± 16 g CHO, 29 ± 20 g protein, and 21 ± 8 g fat [37].

Low-Carbohydrate/High-Fat Diet

Currently, one of the most controversial topics in ultrarunning is the reported increasing popularity of low-carbohydrate/high-fat diets (LC/HF) [40•]. The goal is to improve performance by enhancing fat oxidation thereby decreasing the risk of glycogen depletion and subsequent energy deprivation [40•, 41]. It is known that maximal fat oxidation rate occurs at moderate-intensity exercise at 59–64% VO2max in endurance-trained athletes [41, 42]; however, fat oxidation rate is close to nill above 90% VO2max [42]. To examine the metabolic adaptions in LC/HF diet, a cross-sectional study of 20 elite ultra-marathoners and ironman distance triathletes consumed either a low-carbohydrate diet (< 20% of energy from carbohydrates and > 60% from fat) or a high-carbohydrate diet (> 55% carbohydrates) for an average of 20 months, then ran on a treadmill for 180 min at 64% VO2max. Overall, participants consuming LC/HF diets produced peak fat oxidation rates of approximately 1.5 g/min which is ~ 2.3-fold higher than the peak fat oxidation rate in the high-carbohydrate group [43••]. The runners who consumed a LC/HF diet were accustomed to the diet for at least 6 months prior to measuring peak fat oxidation rates. Gradual accommodation from a HC/LF diet to a LC/HF diet is warranted to reduce the risk of gastrointestinal symptoms caused by abrupt dietary changes. Volek et al. suggest that long-term keto-adaptation contributes to the resultant high rates of fat oxidation [43••]. Chang et al. hypothesize that elevated levels of nonesterified fatty acids and ammonia in the blood during exercise could lead to central fatigue in athletes consuming LC/HF diets [41]. Additional studies are warranted to evaluate the protein intake and its role alongside the HC/LF diet vs. LC/HF diet. In general, recommended protein intake among elite endurance athletes is ~ 1.6–1.8 g/kg/day, which is significantly higher than the recommended daily allowance of 0.8 g/kg/day in healthy non-exercising populations [44••].

While the idea of enhancing fat oxidation to improve performance sounds appealing, how safe is this diet, and what are the risk factors for metabolic disease and coronary artery disease? Defining low-carbohydrate diets as ≤ 45% of energy from carbohydrates vs. low-fat diets as ≤ 30% of energy from fat, Hu et al.'s meta-analysis compares metabolic risk factors between low-carbohydrate diets and low-fat diets [45••]. Overall, both diets reduced weight, blood pressure, total cholesterol, LDL cholesterol, and triglycerides. Surprisingly, participants in low-carbohydrate diets had a greater increase in HDL cholesterol ("good" cholesterol) and decrease in triglycerides compared to participants in low-fat diets. Participants in low-fat diets had a greater reduction in total and LDL cholesterol [45••]. A large prospective study of a LC/HF diet demonstrated less risk for coronary artery disease with a high intake of vegetable protein and unsaturated fats over 19 years of follow-up [46]. Differentiating sources of fat is an important point. In another study, a low-carbohydrate diet with primarily animal-based fat demonstrated higher all-cause mortality and cardiovascular disease mortality rates compared to a vegetable based low-carbohydrate diet [47•]. While there is still much to be determined about the ideal diet for ultrarunners during training and competition, much can be said about individualizing nutrition plans to the ultrarunner's specific needs. Ultimately everyone has their own taste preferences and a nutrition plan is only as successful as it is tolerated. Therefore, while there may be literature to suggest the performance enhancing qualities of one diet over another, the best plan is individualized, taking into consideration gastrointestinal effects based on fueling strategies which may vary from person to person.

Gastrointestinal Distress

Gastrointestinal symptoms are common both during and after endurance events, reported by 85% of ultramarathon runners in multi-stage ultrarunning events and 73% of ultramarathon runners in 24-h continuous events [48]. During 161-km ultramarathons, nausea and/or vomiting was a performance limiting issue and it was the main reason cited for dropping out of the ultramarathon [49•]. Running-Associated Gastrointestinal Symptoms (RAGS) are attributed to decreased blood flow to the blood vessels in the gut and altered gastrointestinal function [50••]. To prevent RAGS, it is important to hydrate, prepare with similar nutrition/hydration prior to race day, reduce heat stress, and avoid NSAIDs prior to race day [50••, 51••].

Recent literature suggested the utility of gut training with a 2-week repetitive gut-challenge [52••]. Twenty-five endurance runners were instructed to describe GI symptoms while participating in gut training by running at 60% VO2 max for 2 h while consuming gel discs containing 30 g carbohydrates (2:1 glucose/fructose ratio). Then participants were randomly assigned to a gut-training group of carbohydrate gel disc, carbohydrate food, or placebo (gel disc without carbohydrate content) for 2 weeks. Upon repeating the second gut-challenge trial of running while consuming gel discs, there was a greater reduction in GI symptoms in the carbohydrate gel disc and carbohydrate food groups compared to placebo [52••]. This research suggests that a structured gut-training protocol may be beneficial and can be customized to individual runner needs and tolerance [52••].

Exercise-Associated Hyponatremia

Exercise-associated hyponatremia (EAH), defined as serum sodium < 135 mmol/L during or up to 24 h after prolonged exercise [10••], is common in ultramarathon runners [53••]. Mild symptoms include bloating, puffiness, nausea, vomiting, and headaches [10••]. Severe cases can lead to seizure and death.

For prevention, current sports literature recommends "drinking to thirst" during ultra-endurance events [38••]. Applying this strategy has been shown to be successful at maintaining the right amount of hydration despite hot ambient conditions [38••]. The American College of Sports Medicine generally recommends drinking during exercise to prevent more than 2% of body weight loss from water deficit [54••]. Hoffman et al. state that in ultra-endurance running, sometimes body mass losses well above 2% are achieved, and these body mass losses are actually needed to avoid exercise-associated hyponatremia [53••]. Body weight change in top finishers of 161-km ultramarathons has varied between ~ 1% gain and ~ 6% loss [55]. Hoffman et al. state that sodium intake alone during exercise will not stop exercise-associated hyponatremia, as there may still be the issue of over-hydration or very concentrated hypertonic sweat [56].

Ultramarathon race logistics are unique compared to marathons in that the spacing of aid stations are further apart, there are frequently more extreme temperature and altitude variations, and greater running times associated with longer distances. Costa et al. report that during a multi-stage ultramarathon, the average total water intake from food and fluids was 7.7 L/day which was enough to maintain normal hydration levels based on ad libitum water intake [38••].

Heat and Cold Illness

Heat-related illness risk factors include an increase in temperature, lack of shade, fatigue, humidity, and lack of acclimatization [10••]. This can further be exacerbated by the intensity and duration of exercise as well as lack of hydration. Heat losses mainly occur through the environment by conduction, convection, radiation, and evaporation. When it is humid, there is less ability for the sweat to evaporate, further increasing the risk for heat-related illness. Cold-related illness risk factors include cold temperature, wet clothing, and wind [10••]. To prevent injury, runners are advised to wear moisture wicking clothing, dress in layers, and recognize changing weather conditions to react accordingly [10••, 16•]. There is further increased risk for cold-related illness if an ultramarathon runner needs to stop or walk. Night-time temperature drops can be issues in overnight events particularly at high altitude [16•].

Altitude

High altitude is challenging for the ultramarathon runner because of the decrease in barometric pressure with increasing elevation and exposure to UV rays [10••]. Prevention of altitude-related illness includes altitude exposure, if not long enough for acclimatization, then for the mental preparedness of knowing how the body feels at high altitude [16•]. To breathe better at altitude, Koerner recommends concentrating on rhythmic breathing, using peppermint candy to open up nasal passages, loosening constricting packs around the chest and abdomen, and using trekking poles to stay upright and keep the rib cage open [16•]. Practicing with training runs at altitude and arriving at a race location at high altitude 7 days in advance of a race can help acclimatize runners and prevent race day altitude-related issues.

Trauma

Technical terrain offers a dynamic running experience including natural obstacles such as rocks, hills, sand, mud, stream crossings, and tree roots. Decreased visibility during night-time racing further increases risk for injury; headlamps are a necessity, and 24 h ultramarathon runners are familiar with both wearing sunglasses to protect from UV rays on the same race as being equipped with a head-lamp. Just as being aware of one's surrounding is important, it is safer for participants to stay in sight of other competitors especially on a long, multi-day race where it is easy to spread out. It is important for novice runners to understand that road running does not smoothly transition to trail running without practice. Each trail is different in its course, elevation, wildlife, and obstacles. A single misstep over a hilly surface can lead to a traumatic injury, and in remote locations without cell phone or GPS coverage, the lack of communication becomes a much larger issue. Ultramarathon event coverage requires intimate knowledge with the surroundings, trail, and awareness of potential dangers in the area that their runners could encounter.

Conclusions

Ultramarathons are gaining in popularity. Injury prevention starts with a thorough training plan which emphasizes a gradual increase in distance interspersed with speed work, long runs, active recovery, and strength training. Ultramarathons are each unique, and preparation for each race is individual in its terrain and environment. Nutrition, hydration, gear, clothes, shoe selection, and awareness of the environmental factors should be customized to the race. When covering ultramarathon events, pre-participation screening also needs to evaluate medical comorbidities and how they can be managed given available resources. Although medical illnesses such as gastrointestinal distress and exercise-associated hyponatremia occur, preparation is key. Further research is indicated to evaluate the risks and benefits of a high-carbohydrate low-fat diet vs. low-carbohydrate high-fat diet in ultramarathon runners.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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