Study of Injury and Illness Rates in Multiday Ultramarathon Runners

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ABSTRACT

KRABAK, B. J., B. WAITE, and M. A. SCHIFF. Study of Injury and Illness Rates in Multiday Ultramarathon Runners. *Med. Sci. Sports Exerc.*, Vol. 43, No. 12, pp. 2314–2320, 2011. **Purpose**: This study aimed to describe injury and illness rates in runners competing in 7-d, 250-km off-road ultramarathon events. **Methods**: Three hundred ninety-six runners competing in the RacingThePlanet© 4 Desert Series ultramarathon races from 2005 to 2006 were prospectively followed. Descriptive analyses were used to evaluate overall injury/illness rates, types of injuries/illnesses, and diagnoses for all medical encounters. Multivariate linear regression was used to estimate the risk of number of injuries/illnesses and 95% confidence intervals associated with age, sex, and race completion time. **Results**: Eight-five percent of runners representing a total of 1173 medical encounters required medical care. The overall injury/illness rates were 3.86 per runner and 65 per 1000-h run. Almost 95% were minor in nature, owing to skin-related disorders (74.3%), musculoskeletal injuries (18.2%), and medical illnesses (7.5%). Medical illnesses were more likely on the first day of the race, whereas musculoskeletal and skin injuries were more likely on day 3 or 4. A 10-yr increase in age was associated with 0.5 fewer injuries/illnesses, and females had 0.16 more medical illnesses compared with males. **Conclusions**: Despite the extreme nature and harsh environments of multiday ultramarathon races, the majority of injuries or illnesses are minor in nature. Future studies are needed to evaluate additional factors contributing to injuries. **Key Words:** INJURY, RUNNER, ULTRAMARATHON, ENDURANCE, AGING, SEX

EPIDEMIOLOGY

Ultramarathon races have grown in popularity during the past few decades (13–15). The majority of these races are point-to-point continuous races (100–150 miles) occurring during a specific period, typically within 1–2 d. More recently, multiday point-to-point ultramarathon races have been developed to further challenge the endurance runner. Competitions, such as the 4 Desert Series by RacingThePlanet©, Trans Swiss Run©, and Marathon des Sables©, challenge the ultraendurance runner to run in extreme terrains for 6–7 d in duration and up to 150 miles. Runners must carry gear through the entire course of the race while traversing mountains, crossing rivers, and traveling through canyons in wide-ranging temperatures. Despite the growth in popularity of these events, very few data exist regarding the injuries and illnesses experienced by these staged-race long-distance runners.

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Only a few small studies exist relating to injuries and injury rates in multiday ultramarathon runners running on paved surfaces. Fallon et al. (8) studied 32 runners competing in a 1005-km multiday road race from Sydney to Melbourne, Australia. The authors noted a total of 64 musculoskeletal (MSK) injuries, with 72% of runners reporting at least one injury during the race. The most common injuries involved the knee (31.3%) and ankle (28.1%). Hutson (17) studied 24 runners competing in a 6-d track race who ran up to 936 km during the study period. The authors noted that >60% of runners experienced some sort of injury, the majority of which were mild in nature and mostly involved the lower extremity, specifically in the regions of the ankle or knee. More recently, Bishop and Fallon (1) studied 17 runners competing in a 6-d track race, noting that 65% of runners experienced at least one MSK injury. Again, the main regions of injury were at the ankle (36%) or the knee (22%).

To our knowledge, no studies have evaluated injuries/illness among the multiday endurance runners competing in off-road races. The purpose of the present study was to analyze and characterize injury/illness rates in runners competing in a multiday off-road ultramarathon event. Specifically, we were interested in documenting the severity, type, and areas of injuries/illnesses during the race. In addition, we identified risk factors that might contribute to injury/illness relating to age, sex, or finishing time. Understanding injury/illness rates and potential risk factors will allow

runners to appreciate the risk of participating in these extreme and remote races. In addition, medical services can be coordinated more efficiently based on these parameters.

METHODS

The RacingThePlanet© 4 Deserts Series is a 7-d, staged, 240-km ultramarathon running race through extreme terrains in several locations throughout the world. Participants competing in these races are primarily experienced runners who have completed marathons or other ultraendurance events as noted in their race application. At each race, participants complete four stages of approximately 40 km each day for 4 d and a fifth stage of approximately 80 km during 1–2 d, all through desert and/or wilderness terrain with little trail or paved road. Participants are required to carry all their personal items throughout the race, including 7 d worth of food, sleeping gear, clothes, and emergency gear at all times during the race. All participants are offered the same amount of water for any given day. Participants are required to start at a specific time each morning and complete the stage within an allotted time. Any participant not starting a specific stage or dropping out of the race during a stage is considered removed from competition. The study race venues included the 2005 and 2006 Gobi Desert, China; the 2005 Sahara Desert, Egypt; and the 2006 Atacama Desert, Chile. Race conditions varied per location for temperature (10°C–48°C) and altitude (−30 to +4300 m).

The study protocol was approved by The Johns Hopkins University, The University of Washington, and The University of California–Davis institutional review boards. All participants competing in one of the RacingThePlanet© 4 Deserts Series ultramarathon running races between 2005 and 2006 were invited to participate in the study. One month before the start of a race, all participants registered for that race received a recruitment flyer via email describing the study and encouraging participation. At the time of race registration, two authors (B.J.K. and B.W.) reviewed the study with the interested participants. All participants enrolled in the study gave their voluntary, written informed consent for their medical and race information to be used for research purposes. A participant was excluded from the study if they were <18 yr, >90 yr, pregnant, or were unable to understand the consent form owing to a language impairment in reading/speaking English. Each study participant was given a unique identifier number, and their demographic information was recorded, including age, height, weight, sex, and race number. Throughout a race, the participant's unique identifier was used to track their race time and any specific injuries experienced during the race as described in the next paragraphs.

During each race, a medical checkpoint staffed by physicians was positioned every 10 km along the course of the day's race and at the finish-line medical tent for each stage. The finish-line medical tent also served as the camp medical tent for that specific stage. There were a total of four to six physicians per race, depending on the total number of runners enrolled in a specific race. An injury/illness was defined as a disability sustained by a study participant during the race, resulting in a medical encounter by the medical staff. All injuries/illnesses were classified by their effect on the racers' ability to continue in the race—major, if the participant could not continue in the race; or minor, if the participant was able to continue in the race. The medical staff documented each medical encounter with a study participant using a standardized form noting diagnosis, site of injury, severity of the injury or illness, checkpoint location, and stage of race. The medical staff collected data on all injuries/illnesses even if the study participants had more than one medical problem during a medical encounter. At the end of the each stage, the primary author (B.J.K.) collected the injury data forms from each medical checkpoint and the medical finish-line tent. At the end of a race, all the information was entered into a computerized data registry for further analysis.

The diagnosis at each medical encounter was classified as a medical illness, an MSK injury, or a skin disorder (Table 1). Exercise-associated collapse (EAC) was defined as a study participant's collapse with resultant hyperthermia, normothermia, or hypothermia, similar to the study definition of medical injury/illnesses in marathon runners of Roberts (26). Altitude sickness was defined as any study participant experiencing complaints of headaches, lightheadedness, dizziness, fatigue, nausea/vomiting, insomnia, shortness of breath/pulmonary edema (high-altitude pulmonary edema), or neurologic changes (high-altitude cerebral edema) within 1–2 d of arriving at an altitude >2500 m. Cardiac arrest, anaphylaxis, asthma, insulin shock, hyponatremia, hematuria, or other easily identifiable medical condition were defined as serious medical illness.

Any study participant not starting a stage or not completing a stage was considered removed from competition.

TABLE 1. Ultramarathon runner medical encounters by diagnosis.

Diagnosis	Major,[a] *n* (%)	Minor,[a] *n* (%)
Medical illnesses		
EAC[b]	35 (56.5)	43 (3.9)
Altitude sickness	0	11 (1.0)
Serious medical diagnosis[c]	1 (1.6)	1 (0.1)
Other medical diagnosis[d]	0	27 (2.4)
Musculoskeletal injuries		
Bursitis	1 (1.6)	11 (1.0)
Sprain	2 (3.2)	25 (2.3)
Strain	1 (1.6)	27 (2.4)
Tendonitis	7 (11.3)	115 (10.3)
Other[e]	3 (4.8)	29 (2.6)
Skin disorders		
Abrasion	0	43 (3.9)
Blister	10 (16.2)	642 (57.8)
Cellulitis	1 (1.6)	8 (0.7)
Hematoma (subungual)	1 (1.6)	106 (9.5)
Other[f]	00	23 (2.1)

[a] Major, unable to continue in race; minor, able to continue in race.
[b] Hyperthermia, normothermia, hypothermia.
[c] Hyponatremia, hematuria, renal stone.
[d] Blurry vision, conjunctivitis, diarrhea, dyspepsia, epistaxis, hematochezia, insect bite, neuropathy, pharyngitis, upper respiratory infections.
[e] Fracture, metatarsalgia, contusion, costochondritis, laceration, splinter.
[f] Callous, nail avulsion, rash, paronchyia, wart.

EPIDEMIOLOGY

Runners, race organizers, and the medical team traveled together throughout the 7-d period (runners traveled by foot, staff traveled by vehicle). Thus, we were able to assess the disposition of every study participant competing in each race. The disposition of every study participant was cross-referenced with official race results. Race stage completion time was recorded for all racers.

We performed descriptive analyses evaluating the age, sex, height, weight, body mass index, race completion time (among finishers), types of injuries/illnesses, and diagnoses of runners. We defined a rate of injury/illness as the number of injuries/illnesses per 1000 runners and per 1000-h run. We calculated an overall injury/illness rate and 95% confidence intervals (CIs), as well as rates for major and minor medical illnesses, MSK injuries, and skin disorders. We evaluated the proportion of each type of injury/illness by race stage. We used general estimating equations to account for runners in more than one race with multivariate linear regression models to estimate the risk of number of injuries/illnesses, medical illnesses, MSK injuries, and skin disorders (β coefficients) and 95% CIs associated with age and sex, adjusting for number of race hours. We also performed a subanalysis among race finishers using a general estimating equation multivariate linear regression to assess the effect of quartiles of race completion time on the risk of number of injuries/illnesses, medical illnesses, MSK injuries, and skin disorders, adjusting for age and sex. All analyses were performed using Stata version 10.0 (College Station, TX).

RESULTS

A total of 407 runners (323 men and 84 women) started the races, with 396 (97%) participated in the study. Eleven participants chose not to participate for personal reasons. The 396 runners in the study represented a total of 303 unique individuals, highlighting the fact that several runners competed in multiple races. Subjects who ran in two or more different races were included in our overall analysis of injury rates. The majority of runners were male (79.2%) compared with female (20.8%). Runner's ages ranged from 18 to 64 yr with a mean age and SD of 40.0 ± 10.6 yr (Table 2). Overall, 85.4% of runners finished the races. The mean race time and SD for completing the 250-km race was 51.06 ± 14.00 h. The mean time for completing a 40-km stage was 7.75 h (range = 2.7–17.0 h) and that of 80-km stage was 18.4 h (range = 6.3–48.0 h).

TABLE 2. Selected characteristics of study participants and race finish times for ultramarathon runners, 2005–2006.

	n = 396
Age, yr (%)	
18–29	18.8
30–39	41.2
40–49	22.4
50–59	14.6
>60	3.0
Sex (%)	
Male	79.2
Female	20.8
Height, mean ± SD (cm)	174.2 ± 9.2
Weight, mean ± SD (kg)	72.9 ± 12.8
Body mass index, mean ± SD ($kg \cdot m^{-2}$)	23.9 ± 3.5
Race times for finishers, mean ± SD (h)	
All races	51.06 ± 14.00
Gobi 2005	52.43 ± 15.73
Sahara 2005	44.10 ± 10.80
Atacama 2006	52.68 ± 12.41
Gobi 2006	50.11 ± 14.60

TABLE 3. Injury/illness rates among ultramarathon runners, 2005–2006.

Type of Illness or Injury	*n*	Rate per 1000 Runners (95% CI)	Rate per 1000 h (95% CI)
All	1173	3871.3 (3652.9–4049.3)	65.0 (61.4–68.7)
Medical (major)	36	118.8 (83.2–164.4)	2.0 (1.4–2.8)
Medical (minor)	82	270.6 (251.2–355.9)	4.5 (3.6–5.6)
MSK (major)	14	46.2 (25.2–77.5)	0.8 (0.4–1.3)
MSK (minor)	203	670.0 (581.0–768.7)	11.2 (9.8–12.9)
Skin (major)	12	39.6 (20.4–69.2)	0.7 (0.3–1.1)
Skin (minor)	826	2726.1 (2543.3–2918.5)	45.8 (42.8–48.9)

During the four 2005 and 2006 races, 257 (84.8%) unique runners were evaluated by the medical staff for an illness or injury, with 46 (15.2%) runners requiring no medical care. A total of 1173 injuries/illnesses (Table 3) were encountered during the study period, with 94.7% (n = 1111) of evaluations being minor in nature. These injuries/illnesses represented an overall injury/illness rate of 3868 per 1000 runners and 65 per 1000-h running. For the minor diagnoses, the majority of encounters were due to skin-related disorders (74.3%), followed by MSK injuries (18.2%) and medical illnesses (7.5%). Only 5.3% (n = 62) of the injuries/illness were classified as major, resulting in a runner discontinuing the race. For these major diagnoses, most encounters were due to a medical illness (58.0%) and less likely to involve an MSK injury (22.6%) or skin disorder (19.4%). Major injuries/illnesses represented a rate of 118.84 per 1000 runners and 2 per 1000 h for medical illnesses, 46.2 per 1000 runners and 0.8 per 1000 h for MSK injuries, and 39.6 per 1000 runners and 0.7 per 1000 h for skin injuries, respectively.

Runners experienced medical illnesses, MSK injuries, and skin disorders during different stages of a race (Table 4). Overall, runners were most likely to experience a medical illness (major or minor) during the first stage of a race. No runner experienced a major medical illness during stage 5. For MSK injuries, major injuries were most likely to occur during stages 3 and 4, whereas minor injuries were most likely to occur during stage 3. No major MSK injuries were experienced during stage 5. For skin disorders, major injuries mostly occurred during stage 3, whereas minor injuries occurred relatively similarly over stages 3–5.

More than 70% of the diagnoses involved skin-related diagnoses, with the majority relating to blisters or hematomas in the feet (Table 1). Approximately 19% of the diagnoses were due to MSK injuries, with tendonitis being the most common injury. Most skin and MSK injuries involved the lower extremity (92.6%) with the majority occurring in the foot (73.7%) followed by the lower leg (8.6%), ankle

TABLE 4. Injury/illness among ultramarathon runners by stage of race, 2005–2006.

	Stage				
	1	2	3	4	5
Type of Illness or Injury	*n* (%)				
Medical (major)	17 (47.2)	03 (8.3)	6 (16.7)	10 (27.8)	00 (0.0)
Medical (minor)	25 (30.5)	18 (22.0)	15 (18.3)	17 (20.7)	7 (8.5)
MSK (major)	00 (0.0)	2 (14.2)	6 (42.9)	6 (42.9)	00 (0.0)
MSK (minor)	17 (8.4)	43 (21.2)	58 (28.6)	47 (23.2)	38 (18.6)
Skin (major)	1 (8.3)	1 (8.3)	5 (41.7)	2 (16.7)	3 (25.0)
Skin (minor)	95 (11.5)	149 (18.0)	200 (24.3)	191 (23.1)	191 (23.1)

(4.9%), and knee (3.5%). Hip and lumbar spine injuries accounted for 3.8% of injuries. The upper limb, thoracic spine, and head/neck regions accounted for 3.6% of injuries (data not shown). Medical diagnoses accounted for only 10% of all diagnoses, with most runners being evaluated for EAC followed by altitude sickness. The most common diagnoses resulting in an athlete not finishing a race (major) were EAC (56.5%), blisters (16.2%), and tendonitis (11.3%). The most common diagnoses in athletes who were able to continue running were blisters (57.8%), tendonitis (10.3%), and subungual hematomas (9.5%). No life-threatening events or fatalities occurred during the study period. No runners required transportation to a hospital during the study period.

Sex and age were analyzed as potential risk factors for number of overall injuries/illnesses, medical illnesses, MSK injuries, and skin disorders (Table 5). A 10-yr increase in age was associated with a 0.5 fewer (95% CI = −0.8 to −0.2) injuries/illnesses, 0.2 fewer (95% CI = −0.3 to −0.1) MSK injuries, and 0.4 fewer (95% CI = −0.6 to −0.1) skin disorders, adjusting for sex and race hours. Females had 0.16 more medical illnesses compared with males, adjusting for age and race hours. Among race finishers, race completion time quartile was not associated with risk of number of injuries/illnesses, MSK injuries, skin disorders, or medical illnesses (data not shown).

DISCUSSION

Despite the increase in ultramarathons, there are very few data regarding the injury and illness rates in ultramarathon runners. To our knowledge, the current study is the first to report injury/illness rates in the multiday off-road ultramarathons runners. Our overall injury/illness rate was 3.8 per runner and 65 per 1000-h run. Almost 95% were minor in nature, mostly due to skin-related disorders involving the foot. Of the 5.3% injuries/illnesses resulting in a runner not finishing the race, most encounters (58%) were due to a medical illness and less likely to involve an MSK injury or skin disorder. The few previous studies of ultramarathon runners have reported MSK injury rates of 1.42–2.7 injuries per runner (1,7,8,17) compared with our finding of 0.71 MSK injuries per runner. These previous studies did not report skin or medical illness rates. Several studies have reported an 8%–50% incidence of hyponatremia (11,16), 2%–4% prevalence of hyponatremia (11,12,24,25,28), and 45%–58% of hypernatremia (11,12) in collapsed ultramarathon runners. Studies of marathon runners have reported an overall injury/illness rate of 18.9–25.5 per 1000 runners, medical illness rates of 10.1–13.7 per 1000 runners, MSK injury rate of 3.35 per 1000 runners, and skin injury rate of 4.1 per 1000 runners (2,9,23,26,29).

The current study's injury/illness rates may be due to a variety of factors relating to the environment, equipment, reporting bias, or definition of athletic exposure. As previously described, multiday off-road ultramarathon runners will experience more extreme terrain and temperatures compared with runners racing on road or track surfaces. The multiday ultramarathon runners will carry packs weighing 7–20 kg with gear and food that must be rationed throughout the course of the 7 d. Water stations are typically every 10–15 km along the daily race course. In contrast, continuous-day ultramarathon or marathon runners may experience similar terrain but typically carry much less gear and food with water stations every 1.5–10 km throughout the racecourse. There may have been a reporting bias in the current study because multiday ultramarathon runners were encouraged to seek medical care earlier in a race. In addition, all runners and medical staff resided in the same area at the end of each stage making it easier for runners to seek medical care. Runners competing in a 1-d ultramarathon or marathon are probably less likely to report minor injuries to the medical staff because there is no concern about repeating the race the next day. Finally, our definition of an athletic exposure represented a marathon or two marathons for a given stage and rate per runner for a race lasting 7 d. In 1-d ultramarathon

TABLE 5. Demographic risk factors for all injuries/illnesses, medical illnesses, MSK injuries, and skins disorders among ultramarathon runners, 2005–2006.

Risk Factor	All Injuries/Illnesses β^a (95% CI)	Medical Illnesses β^a (95% CI)	Musculoskeletal Injuries β^a (95% CI)	Skin Disorders β^a (95% CI)
Age (yr^{-1})	−0.05 (−0.08 to −0.02)	0.002 (−0.004 to 0.007)	−0.02 (−0.03 to −0.01)	−0.04 (−0.06 to −0.01)
Female	0.59 (−0.32 to 1.5)	0.16 (0.01−0.30)	0.16 (−0.17 to 0.50)	0.28 (−0.51 to 1.06)

[a] Adjusted for race hours.

and marathon events, injury rates per runner are typically the same as injuries per athletic exposure, where an athletic exposure would represent a racer completing one race.

In the current study, the majority of MSK and skin injuries were minor in nature, mostly involving skin issues in the foot. The MSK injury rates were lower than prior studies of ultramarathon and marathon runners. The difference may relate to the off-road nature of these multiday races, experience of the ultramarathon runners, and increased chance for cumulative trauma to the foot region due to the terrain. In contrast, previous ultramarathon studies (7,17,22) have reported injuries mostly involving the knee and ankle including Achilles tendinopathy, extensor hallucis tendonitis, and patellar tendinopathy. These studies did not report skin-related issues such as blisters. Studies of marathon runners report injuries mostly involving the knee and leg with common diagnoses of patellofemoral pain, medial tibial stress syndrome, and iliotibial band tendinopathy (9,31). Less common injuries included muscle soreness, foot blisters and abrasions, and chaffing. Future studies with more extensive prerace questionnaires or focused analysis of various specific terrains are needed to identify potential risks factors and preventative strategies for managing MSK and foot injuries in the ultramarathon runner.

As observed in a few previous studies (1,19), we noted a cumulative effect for MSK and skin injuries later in the race, peaking during days 3–4 of the race. This is not unexpected, as one would expect to see a greater incidence of injuries because runners continue to run great distances on sequential days, without standard rest/recovery time (normally days to weeks for marathon runners) between long runs. Interestingly, runners who were able to continue through stage 4 to start on stage 5 (the longest stage of the race) experienced very minimal MSK or skin injuries during the double marathon distance of the stage. One explanation for the findings in the current study could be that the most resilient runners are those who are still left competing at this stage. Another possibility is that by this time in the race, the runners have learned techniques to treat their own skin/blister trauma and are treating themselves rather than seeking an evaluation by the medical staff. It was our observation that many of the runners felt more comfortable managing their blisters toward the end of the race.

In the current study, medical issues were most common during the first stage of the race. These findings are not surprising given the remote nature of these races, time required to travel to the race (often days), and lack of time to acclimate to the environment of the race. In addition, altitude, temperature, and humidity at race sites are often vastly different from the racers' home training environments. Previous studies have shown that these factors, especially warm temperatures, have a negative effect on finish times and reduced odds on finishing a race for both ultramarathons and marathons (5,6,8,16,32). Presumed relative dehydration from air travel, gastrointestinal distress from unfamiliar foods, disruption of circadian rhythm/jet lag, and the aforementioned climate changes may all contribute to the higher incidence of medical illness on stage 1. Athletes should be educated before the start of the race about the likelihood of MSK or medical issues throughout the course of race in anticipation of preventing major injuries or illnesses.

In the current study, female sex did play a role in the injury/illness rates with women being at risk of greater number of medical illness compared with men. There was no association with female sex and MSK injuries or skin disorders. Possible factors could relate to race experience, anatomy, greater relative weight of the pack in women compared to men, or different rates of consumption of fluids. Previous studies provide conflicting data regarding sex and running. Sattherwaite et al. (27) found that female runners in marathon distance races had a greater risk of hip problems, but male runners reported more calf and hamstring problems. The study of Knapik et al. (20) on freshmen cadets in basic training found that sex was not a risk factor for the development of foot blisters during a 21-km road march. Hew (10) noted in a retrospective study of 117 runners competing in the Houston Marathon that female runners were significantly lighter, ran slower, lost the least weight, and dropped serum sodium levels further compared with males consuming the same amount of fluid. The study of Knechtle et al. (21) on female ultrarunners concluded that the incidence of exercise-associated hyponatremia was not truly a sex effect but was due to women being more likely to drink more. Future studies of female ultramarathon runners are needed to identify modifiable risk factors in hopes of preventing injury or illness.

Previous literature has suggested that increasing age has an adverse affect on finish times in marathon distance and ultramarathons, but conflicting data regarding injury rates exist (15,18,30–32). We reported a decrease risk of number of overall injuries/illnesses, MSK injuries, and skin disorders with increasing age. The study of Sattherwaite et al. (27) on marathon runners found a significant decrease in risk of injury in runners ≥40 yr (odds ratio = 0.43; 95% CI = 0.22–0.85) compared with runners <25 yr. However, several studies have reported an increased risk of injury in runners ≥40 yr (risk ratio = 1.92–2.09) (30,33). One explanation is that older runners who are able to continue running greater distances later in life represent the fittest runners. They probably experience fewer injuries that allow them to continue running. Older runners may have a different perspective for running, focusing on participating, instead of winning. Or perhaps they are more likely to slow down during a race to address an injury or illness before it becomes more serious in nature.

We found that overall finishing time was not associated with an increased risk of number of injuries or illnesses. The findings are in contrast to studies of marathon runners, which suggests that longer finishing time (i.e., time >4 h) are associated with an increased risk of hyponatremia (3,4). In our experience, it is reasonable that faster runners would not experience significantly higher injury rates because these

experienced runners spend less time on the course and are better prepared for these grueling races. Anecdotally, we have observed that runners in the second fastest quartile often push themselves beyond their abilities to obtain a better time. However, multivariate analysis found no significant increased risk. It was notable that the slowest runners had a similar injury rate as the faster runners, especially because the slower runners spend much more time on the course exposed to environmental elements. However, the slower runners were more likely to stop or slow down for self-care including monitoring of injuries.

There are several limitations to consider in the current study. Our definition of athletic exposure is different from those used in the marathon literature, making it somewhat difficult to exactly compare rates of injury/illness. It is possible that athletes may have underreported injuries/illness later in the ultramarathon race owing to their ability to self-manage their own concerns. Because we reviewed only injuries/illnesses encountered during the race and not after the race, we could have underestimated the total number or severity of injuries/illness. The differences in rates we report may be due to confounding factors that were not measured in this study. Our study may not be generalizable to other ultramarathons because of the unique conditions that were present for the four races. Finally, we did not analyze the effect of previous injuries or experience on current injuries, which may have played a role in our current findings.

CONCLUSIONS

Despite the extreme nature and harsh environments of multiday ultramarathon races, the current study suggests that the majority of injuries/illnesses experienced by runners are minor in nature. Medical staff and runners should prepare to treat all types of injuries, especially foot injuries relating to blisters throughout the course of a race. Serious injuries/illnesses are relatively rare, but when they do occur, they are often related to dehydration. Possible preventive strategies need to be explored further but could include educating runners regarding the types of injuries throughout the course of a race, importance of acclimation, need for proper hydration, and food intake throughout the race and foot care. Future studies are needed to further evaluate the risk factors contributing to injury or illness, including previous injuries, muscle imbalances, race experience, training program, or equipment use throughout a race.

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