WILDERNESS & ENVIRONMENTAL MEDICINE, ▮, ▮▮▮–▮▮▮ (2014)

BRIEF REPORT

An Investigation of Ultramarathon-Associated Visual Impairment

Tracy B. Høeg, MD, PhD; Genevieve K. Corrigan, OD; Martin D. Hoffman, MD

From the Department of Clinical Ophthalmology, Næstved University Hospital; and the Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark (Dr Høeg); the El Dorado Hills Optometric Center, El Dorado Hills, CA (Dr Corrigan); and the Department of Physical Medicine and Rehabilitation, Department of Veterans Affairs, Northern California Health Care System; and University of California Davis Medical Center, Sacramento, CA (Dr Hoffman).

Objective.—The purpose of this study was to investigate the characteristics under which ultramarathon-associated visual impairment occurs and to seek to identify its physiological basis and risk factors.

Methods.—Through an online questionnaire, distributed worldwide, we obtained information from 173 self-identified ultramarathon runners who had experienced visual impairment during an ultramarathon. We attempted to characterize this vision impairment—its symptoms, duration, and the conditions under which it occurs. Select characteristics were compared with a reference group of 412 registrants of the 161-km Western States Endurance Run.

Results.—Ultramarathon-associated visual impairment was typically characterized as painless clouding of vision that resolved either during (13.5%) or after racing within a median of 3.5 hours (range 0 to 48 hours) upon cessation of running. The mean (±SD) distance at which vision impairment occurred was 73 ± 40 km, and the 161-km distance was the most frequent race distance (46.8%) in which visual impairment occurred. Visual impairment was often recurrent, with respondents reporting having it develop during a median of 2 races. Respondents with a history of refractive surgery had more episodes than those without such history (median 3.5 vs 2 episodes, $P = .010$). Compared with the reference group, runners with visual impairment were nearly twice as likely (23.7% vs 12.1%, $P < .001$) to have had refractive surgery.

Conclusions.—Ultramarathon-associated visual impairment typically presents as a painless clouding of vision that is self-limited but tends to recur in certain runners. Risk appears higher among those with a history of refractive surgery, which is relevant for ultramarathon runners who are considering, or who have a history of, refractive surgery.

Key words: visual impairment, corneal edema, refractive surgery, running, physical endurance

Introduction

Ultramarathons are races that are longer than the standard marathon distance of 42.2 km. Participation in these events has steadily increased to nearly 70,000 ultramarathon finishes in North America in 2013, representing a more than doubling in participation over the last 5 years.[1] With increasing participation, even relatively rare problems may affect a large number of athletes.

During the course of a single race, an ultramarathon runner could experience a combination of temperature extremes, snow, rain, wind, dust, and high altitude. Given the length of these events, runners could be exposed to such environmental conditions for many hours. There are physiological changes, such as dehydration, loss of electrolytes, sleep deprivation, and a high level of exertion that may impact vision to varying degrees. One recent questionnaire-based study[2] showed that vision problems developed in 2.1% of finishers and in 3.6% of nonfinishers of 161-km ultramarathons. However, most reports of visual impairment during ultramarathons have been anecdotal.

Preliminary results of this study were presented at the American College of Sports Medicine annual meeting, May 28, 2014, Orlando, FL.

The contents reported here do not represent the views of the Department of Veterans Affairs or the United States Government.

Corresponding author: Martin D. Hoffman, MD, 10535 Hospital Way, 117, Mather, CA 95655-1200. (e-mail: mdhoffman@ucdavis.edu).

Corneal edema is a condition in which fluid accumulates within the cornea, and it has a multitude of causes, including trauma, chemical irritation, inflammation, hypoxia, and increased intraocular pressure.[3] Corneal edema has also been associated with cold temperatures[4,5] and drying of the eyes.[6] Specifically, cold temperatures and windy conditions have been identified and demonstrated as triggers for corneal edema and vision impairment in an endurance cyclist.[7] We hypothesize that a similar process is occurring among ultramarathon runners who have vision impairment.

In the present study, we invited ultramarathon runners who had vision impairment during an ultramarathon to complete a questionnaire directed at identifying the risk factors and triggers for vision impairment, as well as the nature of this condition in terms of duration, recurrence, and examination findings reported in medical records. These data were then further compared with those of a reference group of ultramarathoners. Our objectives were to investigate the characteristics under which ultramarathon-associated visual impairment occurs, identify associated factors, and gain insight into its physiological basis.

Methods

Study approval was attained from the Institutional Review Board of the Veterans Administration Northern California Health Care System, and the study was conducted in accordance with the Declaration of Helsinki. Survey participants were consent electronically.

QUESTIONNAIRE ON VISION IMPAIRMENT

A link to an Internet-based survey was posted on ultramarathon running listserves based in the United States and Europe, announced on widely read ultramarathon running websites, and distributed to several ultramarathon running groups using social media. The survey was available in English only. Anyone who confirmed having experienced "significant visual difficulties" during an ultramarathon, not including hallucinations, was directed to fill out the questionnaire. The survey sought basic demographic and background information, number of ultramarathons completed, and number of episodes of vision impairment during an ultramarathon. Participants also answered questions about their medical and ophthalmological history and provided specific details about each episode of vision impairment.

REFERENCE GROUP

A reference group of 412 ultramarathon runners was obtained at the 2013 Western States Endurance Run (WSER). The WSER is a 161-km run, mostly on single-track mountain trails, from Squaw Valley to Auburn, California. A more detailed description of the race is provided elsewhere.[8] All WSER participants were asked at race registration if they had a history of refractive surgery or wore contact lenses. This group was used as a representative sample of 161-km ultramarathon runners for comparison with survey respondents.

STATISTICAL ANALYSIS AND DATA HANDLING

Normal distribution was determined using Shapiro-Wilk tests, skewness and kurtosis tests, and histograms. We report mean values for normally distributed data and median values for skewed data. Group comparisons were made with $\chi 2$ and unpaired t tests.

Results

PARTICIPANT CHARACTERISTICS

The survey was completed by 173 ultramarathon runners. Characteristics of the subjects are displayed in Table 1. Most survey participants (90.1%) were from the United States, and most (61.3%) were men. Participants tended to be experienced ultramarathon runners with a low prevalence of diabetes mellitus, high blood pressure, and heart disease. The prevalence of common eye diseases in the study group is also displayed in Table 1.

Characteristics of survey participants and the reference group are compared in Table 2. The survey participants included a higher percentage ($P < .001$) of women than the reference group, and refractive surgery was more prevalent ($P < .001$) among survey participants than the reference group (23.7% vs 12.1%). Use of contact lenses did not differ between groups.

NUMBER OF EPISODES

The 173 survey respondents reported a total of 779 lifetime episodes (median 2) of ultramarathon-associated visual impairment, and provided detailed descriptions on 218 episodes. Respondents with a history of refractive surgery experienced a median of 3.5 episodes (range 1 to 38), which was greater ($P = .010$) than for respondents without a history of refractive surgery, who experienced a median of 2 episodes (range 1 to 30). Survey respondents who reported contact lens usage (not necessarily at the time of the race) had a median of 2 episodes (range 1 to 30), which was similar ($P = .21$) to respondents who did not report using contact lenses (median of 3 episodes; range 1 to 38).

RACE AND ENVIRONMENTAL CHARACTERISTICS

The mean (±SD) distance at which visual impairment began was 72.7 ± 40.1 km (interquartile range 24 to 65

Table 1. Selected characteristics of survey respondents with history of vision impairment during an ultramarathon

Characteristic	*Mean[a] or percent*	*Median[a]*	*Interquartile range*
Age at survey completion, years	46.2		39.2–53.9
Women, %	38.7		
Episodes of vision impairment		2	1–5
Ultramarathons completed			
50 km		10	4–20
80 km		5	2–12
100 km		2	0–5
161 km		2	1–7
>161 km		0	0–0
Multiple day race		0	0–0
Medical history, %			
Cardiac arrhythmias	4.1		
High blood pressure	3.5		
Ischemic heart disease[b]	1.2		
Diabetes mellitus	0.6		
Ophthalmological history, %			
Contact wear[c]	24.9		
Refractive surgery	23.7		
Contacts wear[c] or refractive surgery	46.2		
Dry eye	8.1		
Cataract	4.6		
Amblyopia	3.5		
Glaucoma	2.3		
Retinal disorder	1.2		

[a] Mean given for normally distributed data and median given for nonnormally distributed data.
[b] Responded affirmatively to "coronary artery disease or prior heart attack."
[c] Responded affirmatively to wearing contacts, not necessarily during the race.

km). The 161-km distance was the most common race distance in which survey participants reported vision impairment, accounting for 46.8% of episodes. An additional 46.3% of incidents occurred in races of distances longer than 42.2 km but shorter than 161 km. The remaining incidents occurred in timed events (2.8%), distances greater than 161 km (2.3%), and distances of 42.2 km or less (1.8%).

In 32.4% of the episodes, symptoms began after the subject had been at an altitude of 2000 m or higher. Participants selected "significant wind" as being present before the onset of their symptoms in 22.7% of episodes. The mean temperature before vision impairment was reported to be 12.9°C (range −21ºC to 49°C). The distribution of reported temperatures did not suggest vision impairment was associated with high or low temperatures.

SYMPTOMS

From a multiple option menu, survey participants reported that the most common symptoms associated

Table 2. Comparison of characteristics between survey respondents with vision impairment during an ultramarathon and the reference group

Characteristic	*Respondents with vision impairment*	*Reference group*	*P or t value*
Race age, years	42.0	41.9	.84
Women, %	38.7	20.1	<.001
Contact lens wear, %[a]	24.9	25.4	.88
Refractive surgery, %	23.7	12.1	<.001

[a] Not necessarily at time of event.

with the visual impairment included cloudy or foggy vision (69.1%), blurry vision (61.3%), eye dryness (23.5%), halos (21.2%), eye pain (6.0%), and tunnel vision (1.8%). When asked "how long after the race" vision was regained, normal vision reportedly returned by the end of the race in 13.5% of episodes. Of the 86.5% with persistent visual impairment after the race, resolution of symptoms was reported within a median of 3.5 hours (interquartile range 1.5 to 12 hours). After removing 1 outlier (who reported symptoms lasting 6 to 8 months and who did not seek medical care), all had resolution of symptoms within 48 hours, and 95.5% within 24 hours.

In response to the question "what did you do to relieve your symptoms," in 29.5% of the 218 detailed episodes, survey participants indicated that nothing helped. At least partial improvement was reported with hydrating eye drops or washing eyes with water (16.8%), oral hydration (9.2%), resting or stopping (8.1%), use of protective eyewear (2.3%), and the morning sun or warmer temperatures (2.3%).

DIAGNOSES

Of the 173 survey participants, 10 reported being examined by a medical professional while their visual impairment persisted. Eight reported corneal edema as the cause of their vision impairment. Two participants without corneal edema had examination findings consistent with corneal damage from contact lenses. No additional diagnoses were reported from examinations undertaken while symptoms of visual impairment persisted.

Discussion

The key finding of this work is that ultramarathon-associated visual impairment generally consists of painless clouding or blurring of vision that resolves spontaneously within 24 to 48 hours after cessation of running. Refractive surgery was significantly associated with the development of visual impairment during ultramarathons. Refractive surgery results in a thinning of the cornea. Vision impairment[9,10] and increased corneal thickness[11] have been reported at high altitude after refractive surgery. Thin corneas, purportedly due to higher oxygen consumption, tend to have increased swelling (edema) during hypoxic stress.[12] That would appear consistent with an underlying pathology of corneal edema, which was the most common diagnosis from ophthalmological examination while symptoms persisted.

The present work also found that the percentage of women reporting ultramarathon-associated visual impairment was greater than for the reference group. The WSER may be considered a unique event, and the proportion of women participating in the event is less than the general percentage of women accounting for ultramarathon finishes, which was 29.8% in 2013 considering all ultramarathons in North America.[1] Nevertheless, on statistical analysis, the percentage of women reporting visual impairment was greater ($P = .013$) than the percentage accounting for all ultramarathon finishes. Women have repeatedly been shown, however, to participate more often in epidemiological studies than men,[13,14] so we would interpret this finding cautiously.

Numerous environmental factors were examined for a link with ultramarathon-associated visual impairment, but none appeared prominent. The historically very cold 100-km Hellgate ultramarathon (Virginia, in December) has a long-standing reputation for inducing vision impairment (personal communication, George Wortely, MD, July 2013), and it would thus stand to reason that cold weather is a risk factor. However, our data demonstrate that ultramarathon-associated vision impairment can occur across a wide range of ambient temperatures.

Previous research has suggested that stresses to the cornea such as hypoxia,[12,15] cold,[4,5] and dehydration[6] can lead to the buildup of lactate,[15] which acts as an osmolyte, drawing more fluid into the corneal stroma. The corneal acidosis from lactate buildup may further contribute to the swelling by inhibiting the function of the endothelial ion and fluid pump.[12] Our data are not inconsistent with this mechanism, but whether one or several variants of this are responsible for the corneal edema seen in ultramarathon runners deserves further investigation.

Interestingly, we did not find our respondents who ran with contact lenses to be at increased risk for vision impairment. Indeed, contact lenses have been shown to be effective in preventing recurrent cycling-induced corneal edema.[7] Contact lenses have also been shown to prevent corneal swelling from hypoxic stimuli,[16] apparently because they prevent an increase in corneal metabolic activity.[16] Indeed, a possible explanation for many cases of vision impairment during ultramarathons is increased metabolic activity of the cornea due to potential environmental and biological stimuli, leading to corneal swelling. Preventive strategies mentioned by survey respondents that are potentially effective for preventing this mechanism of corneal edema, include use of eye drops, oral hydration, resting or stopping, and protective eyewear. Decreased exertion or rest and closing of the eyes appear to be the most effective treatments.

This study has some important limitations. It was survey based and subject to both selection and recall

bias. Certain ultrarunners may have been more motivated to respond to this survey, for example, those with repeated episodes of vision impairment. We were not able to reach all demographic groups of ultrarunners, our survey was only available in English, and more than 90% of our respondents were American. Recall bias is expected to have had some effect on the details reported about each specific incident of vision impairment, including environmental conditions, associated symptoms, and time to recovery. We do not expect recall bias to have impacted the association with refractive surgery or the confirmed patient diagnoses.

In summary, we describe 218 episodes of ultramarathon-associated visual impairment among 173 ultramarathon runners. The condition occurs most often during the 161-km race distance, and frequently appears to be the result of corneal edema, although other conditions should be considered depending on the respondent's ocular history. It is a self-limited condition, and vision impairment is, almost without exception, regained within 24 to 48 hours, provided the participant has stopped racing. The roles of environmental irritants, hydration, and exertion in the development of this condition need to be further defined in future studies. Refractive surgery may predispose participants to corneal edema during ultramarathons, possibly because of the relative thinness of the corneas after the procedure. Eye drops, proper hydration, decreased exertion, and protective eyewear may offer protection from the development of visual impairment.

Acknowledgments

This work was supported by resources and use of facilities at the VA Northern California Health Care System; the work was also supported by the Western States Endurance Run Foundation. The funding sources had no role in the design and conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication. The authors would like to give special thanks to Dr Alfred Solish for sharing his clinical experience with ultramarathon-associated corneal edema.

References

1. Ultrarunning 2013—the year in review. *UltraRunning*. January/February 2014:30–47.
2. Hoffman MD, Fogard K. Factors related to successful completion of a 161-km ultramarathon. *Int J Sports Physiol Perform*. 2011;6:25–37.
3. Krachmer JH, Mannis M, Holland E. *Cornea*. 2nd ed. St. Louis, MO: Mosby Year Book; 2005.
4. Kolstad A. Corneal sensitivity by low temperatures. *Acta Ophthalmol (Copenh)*. 1970;48:789–793.
5. Kolstad A, Opsahl R. Cold injury to corneal epithelium. A cause of blurred vision in cross-country skiers. *Acta Ophthalmol (Copenh)*. 1969;47:656–659.
6. Hosseini K, Kholodnykh AI, Petrova IY, Esenaliev RO, Hendrikse F, Motamedi M. Monitoring of rabbit cornea response to dehydration stress by optical coherence tomography. *Invest Ophthalmol Vis Sci*. 2004;45:2555–2562.
7. Ettl AR, Felber SR, Rainer J. Corneal edema induced by cold. *Ophthalmologica*. 1992;204:113–114.
8. Hoffman MD. Ultramarathon trail running comparison of performance-matched men and women. *Med Sci Sports Exerc*. 2008;40:1681–1686.
9. White LJ, Mader TH. Refractive changes at high altitude after LASIK. *Ophthalmology*. 2000;107:2118.
10. Mader TH, White LJ. Refractive changes at extreme altitude after RK. *Am J Ophthalmol*. 1995;119:733–737.
11. Morris DS, Somner JEA, Scott KM, McCormick IJC, Aspinall P, Dhillon B. Corneal thickness at high altitude. *Cornea*. 2007;26:308–311.
12. Nguyen T, Soni PS, Brizendine E, Bonanno JA. Variability in hypoxia-induced corneal swelling is associated with variability in corneal metabolism and endothelial function. *Eye Contact Lens*. 2003;29:117–125.
13. Dunn KM, Jordan K, Lacey RJ, Shapley M, Jinks C. Patterns of consent in epidemiologic research: evidence from over 25,000 responders. *Am J Epidemiol*. 2004;159:1087–1094.
14. Galea S, Tracy M. Participation rates in epidemiological studies. *Ann Epidemiol*. 2007;17:643–653.
15. Klyce SD. Stromal lactate accumulation can account for corneal oedema osmotically following epithelial hypoxia in the rabbit. *J Physiol*. 1981;321:49–64.
16. Bonanno JA, Nyguen T, Biehl T, Soni S. Can variability in corneal metabolism explain the variability in corneal swelling? *Eye Contact Lens*. 2003;29(suppl):7–9.