Original Article

Heat Illness Symptom Index (HISI): A Novel Instrument for the Assessment of Heat Illness in Athletes

Eric E. Coris, MD, Stephen M. Walz, MA, ATC, LAT, Robert Duncanson, MED, ATC, LAT, Arnold M. Ramirez, MD, and Richard G. Roetzheim, MD

Background: Heatstroke is the third leading cause of death in athletics, and an important cause of morbidity and mortality in exercising athletes. There is no current method, however, for identifying milder forms of heat illness. In this pilot study, we sought to develop and provide initial validation for a Heat Illness Symptom Index scale (HISI) that would facilitate research in the assessment of milder forms of heat illness in athletes.

Methods: The study was designed as a multimodal prospective observational study of Division I football players during twice daily practices in southern Florida. We developed a 13-item scale that assessed symptoms that are suspected to occur during milder forms of heat illness. The resultant scale was assessed for reliability using Cronbach's alpha, and was assessed for construct validity by correlating scale scores with factors that are known to be related to heat illness. HISI scores, as well as data on perceived exertion, player position, and pre and post practice weights were collected from 95 athletes participating in late summer football practices. A total of 557 athlete sessions were analyzed.

Results: The mean score on the heat illness symptom scale was 12.1 (SD 13.8) and the median value was 8.0. Cronbach's alpha confirmed suitable internal consistency of the scale when assessed separately for each of the five morning practices (alpha = 0.91, 0.88, 0.82, 0.92, 0.85). There were statistically significant correlations of the scale score with weight loss during practice ($P = 0.006$), rating of perceived exertion ($P = 0.005$), player position ($P < 0.0001$), and ambient heat index ($P = 0.02$) as hypothesized.

Conclusions: This pilot study provides initial validation for a novel symptom-based tool for use in assessing mild forms of heat illness in an athletic population. Further validation studies of the instrument, and correlating symptom scores with measures of core temperature, are needed and planned.

Key Words: heat illness, athletes, heat stroke, heat exhaustion, heat cramps, exercise

As the third leading cause of death in US high school athletes,[1] heat illness is a significant concern for all persons exercising in the heat.[2,3] Recent deaths of a collegiate and two professional athletes in Florida and Minnesota have emphasized the importance of heat illness to the sports medicine community. Of the five major forms of heat illness, only heatstroke is typically a medical emergency.[5,6] Risk factor awareness, along with early recognition and treatment of milder forms of heat illness, may contribute to the prevention of exertional heatstroke and associated fatalities.[6–11]

Heat illness is generally defined in a dichotomous fashion, either present or absent, reflecting significant symptomatology associated with increased core temperature. While such a definition is useful clinically, it may limit our understanding of potentially milder forms of heat illness. Symptoms of heat illness may in fact occur along a continuum, with only the most serious symptoms captured by our current dichotomous definition.

Identifying milder forms of heat illness may lead to a better understanding of the overall spectrum of disease caused by this condition. A better understanding of milder forms of heat illness may help identify risk factors, as well as potential

From the Division of Sports Medicine, Department of Family Medicine and the Department of Athletics, the University of South Florida College of Medicine and Bayfront Medical Center, Tampa, FL;

Reprint requests to Eric E. Coris, MD, University of South Florida College of Medicine, Department of Family Medicine, Division of Sports Medicine, 12901 Bruce B. Downs, Boulevard, MDC 13, Tampa, FL 33612. Email: ecoris@hsc.usf.edu

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Key Points

- Heat illness is a common problem in athletes exercising in the heat.
- Risk factors exist for increasing risk of heat illness.
- A scale based on athletes' symptoms recalled immediately after practice correlates well with traditional risk factors for heat illness.

relationships between mild heat illness and subsequent progression to more severe forms. Such research might ultimately allow screening tests to identify those at risk for the more severe forms of heat illness, allowing earlier intervention. Independent of its role in predicting severe heat illness, milder forms of heat illness might also contribute significantly to morbidity and performance decrements in athletes.

To further our understanding of heat illness, studies are needed to assess the incidence of the milder forms of heat illness, to determine discriminating risk factors for heat illness, and to assess the effectiveness of interventions designed to reduce heat illness. For these goals to be achieved it is first necessary to develop suitable measures. This pilot study sought to develop and validate a newly created instrument, the heat illness symptom index (HISI), designed to measure symptoms of mild to moderate heat illness experienced by athletes.

Methods

This study took place at the University of South Florida. The University maintains a Division I football program with outdoor training facilities in a typically hot and humid environment. The institutional review board approved this study and informed consent of subjects was obtained.

The HISI was created following a literature review to identify symptoms that are typically correlated with heat illness.[12] Potential symptoms were identified by the authors, experienced with the identification and treatment of heat illness, and assessed for validity. The research instrument originally contained 13 items, each eliciting potential symptoms of heat illness. The 13 symptoms were as follows: feeling tired, swelling, cramps, nausea, dizziness, thirst, vomiting, confusion, muscle weakness, heat sensations on the head or neck, chills, stopping sweating, and feeling lightheaded. For each symptom, athletes were asked to rate the severity of the symptom on a graduated scale after the corresponding practice session. Severity ratings ranged from 0 to 10 and included the following anchors: 0 = no symptoms, 3 = mild symptoms that did not interfere with practice, 5 = moderate symptoms, 7 = severe symptoms requiring a break from practice, 10 = had to stop practice. The initial HISI consisted of the sum of the athletes' ratings to each of the 13 symptoms. To determine if athletes who failed to complete the heat illness symptom scale differed in some systematic fashion, we compared other measures for this group with those athletes who completed the symptom scale.

The internal consistency of the scale was then assessed by first examining how well each individual item correlated with the total score. Two items that correlated poorly with overall scores (swelling $r = 0.26$, stopped sweating $r = 0.17$) were dropped. These symptoms were chosen as specific indicators of heat edema and heatstroke, conditions that are known to be uncommon in the typical football athlete. The remaining 11 items constituted the final heat illness symptom index with possible scores ranging from 0 to 110. Cronbach's alpha confirmed excellent internal consistency of the scale when assessed separately for each of the five morning practices (alpha = 0.91, 0.88, 0.82, 0.92, 0.85).

Data were collected from each practice session during the first week of practice in full gear in early August, 2002. There were 95 athletes on the roster with 9 practice sessions yielding 855 potential observations. Five athletes missed a total of 14 practice sessions due to injuries that occurred during the practice week. The total number of potential observations was therefore 841. Completed symptom scales were returned for 557 athlete sessions (response rate 66.2%). Pre and post practice weights were obtained for 804 of the 841 athlete sessions (95.6%). For 557 practice sessions, there was complete data on both symptom scales and weights, and these observations constituted the final study sample.

Data were also collected on factors that are known or suspected of being related to heat illness. These included medication usage, sleep patterns, conditioning level, fluid intake practices, alcohol use, past history of heat-related illness, dietary supplement intake, and recent upper respiratory/gastrointestinal illness symptoms. The athlete's football position (offensive/defensive lineman, defensive back, linebacker, running back, receiver, quarterback, and kicker) was recorded for each subject using data from the depth chart. We estimated fluid loss during a practice by weighing all athletes at the start of practice and immediately after the completion of practice using two Tanita digital scales (Tanita Corp., BWB-800A, NTEP approved, Class III, range 2 lb–440 lbs). The same scale was used by each player for each pre and post practice data point. Using these measures, we recorded pre and post practice weights for each athlete and the number of pounds lost (or gained) during the practice. The strenuousness of the practice was assessed by self-reported "rating of perceived exertion" in a graduated scale format immediately after each practice. Each athlete assessed the strenuousness of the practice session on a 10-point scale having the following five anchors: 0 – stood on the sideline, 2—mild, 5—average, 7—very hard, 10—hardest ever. Ambient conditions of temperature and humidity before each practice were assessed using a conventional sling psychrometer (Bacharach, Inc, Pittsburgh, PA; 12-7022, accuracy to ± 5% relative humidity). Heat index was then calculated using a National Weather Service calculator via the formula ($HI = -42.379 + (2.04901523 \times T + 10.14333127 \times RH) - (0.22475541 \times T \times RH) - (0.00683783 \times T^2) - (0.05481717 \times RH^2) + (0.00122874 \times T^2 \times RH) + (0.00085282 \times T \times RH^2) - (0.00000199 \times T^2 \times RH^2)$), where HI = heat index, T = dry bulb temperature, and RH = relative humidity.

Construct validity of the scale was assessed by determining whether scores on the symptom scale correlated with other factors known to be related to heat illness including the ambient conditions during the practice (temperature and relative humidity), the strenuousness of the practice session as perceived by the athlete, and fluid depletion as assessed by weight loss during the practice.

The degree to which heat illness affects athletes is also dependent on individual body type, level of conditioning, acclimatization and work rate. After discussions with coaches, players, and training staff, we hypothesized a priori that offensive and defensive linemen would experience heat illness to the greatest extent, and that quarterbacks, punters, and kickers would experience heat illness to the least extent. Other positions (defensive backs, linebackers, receivers, running backs) were judged to be at intermediate risk for heat illness. Validity of the heat illness scale for this construct was therefore assessed by comparing scale scores for the three types of player positions.

Since the data were both clustered (by practice session) and contained repeated measures from the same athlete, the data were thought likely to violate an assumption of independence necessary for most statistical tests. We therefore used a multivariate model to account for repeated measures and correlations within the data to confirm the statistical significance of relationships. The PROC MIXED in SAS program (SAS version 8, Cary, NC) was utilized to fit a linear model adjusting P-values and confidence intervals for clustering of observations by practice and repeated measurements by athlete.

Results

Characteristics of the athlete practice sessions are presented in Table 1. Athletes who did not complete the symptom scale during a practice experienced lower degrees of weight loss during the practice (mean weight loss 2.5 pounds versus 2.8 pounds, $P = 0.03$), a slightly lower percent body weight lost during the practice (mean 1.2% versus 1.3%, $P = 0.01$), lower weight loss relative to baseline weight (mean 3.5 pounds versus 4.0 pounds, $P = 0.001$) and lower percent body weight loss relative to baseline weight (mean 1.6% versus 1.8%, $P = 0.001$). Although not statistically significant, athletes who did not complete a symptom scale reported slightly lower levels of physical exertion during the practice (exertion scale mean = 6.3 versus 7.3, $P = 0.20$). Athletes who did not complete the symptom scale were more likely to have a low risk player position (kicker/punter/quarterback, 14.7% versus 8.1%, $P = 0.003$) and less likely to play in an intermediate risk position (running back/receiver/linebacker/defensive back, 50.8% versus 62.5%, $P = 0.001$).

Table 1. Descriptive statistics of practice sessions (n = 557 athlete sessions)

Player position	
Defensive back	143
Defensive lineman	117
Kicker/punter	45
Linebacker	90
Offensive lineman	152
Quarterback	45
Running back	63
Wide receiver/tight end	207
Mean weight loss during practice	
Total (pounds)	2.7 (SD 1.7)
Percent body weight	1.24 (SD 0.7)
Mean perceived exertion (0–10)	7.3 (SD 2.5)
Mean heat index (degrees)	92.1

The mean score on the heat illness symptom scale was 12.1 and the median value was 8.0. The frequency distribution of heat illness symptom scale scores was heavily skewed (Fig. 1). For purposes of analysis, therefore, this outcome was transformed by taking the natural log of raw symptom scores. The new outcome log scale scores was normally distributed (with mean = 2.04, SD 1.13) allowing parametric analysis (Fig. 2).

The risk of heat illness is influenced by dehydration.[9–11,13–15] Athletes having greater degrees of dehydration are known to experience greater degrees of heat illness.[9,13,14] In addition, independent of ambient temperature and external heat stressors, internal heat production is directly related to the degree of physical exertion.[3,4,14,15] Finally, heat illness is known to be associated with ambient conditions (temperature and humidity).[16] We assessed construct validity of the heat scale by examining correlation coefficients between the log of heat illness symptom scale scores and the following measures: weight lost during the practice session, percent of body weight lost during the practice, weight lost relative to athlete's baseline weight, percent body weight lost relative to athlete's baseline weight, athlete's perceived physical exertion during the practice, and heat index (Table 2). The log of scale scores correlated with each of the constructs assessed as hypothesized.

Average log scale scores for the three player positions were as follows: low risk positions (quarterbacks/punters/kickers) mean = 1.42, intermediate risk positions (defensive backs/running backs/linebackers/receivers) mean = 1.96, highest risk positions (offensive lineman/defensive lineman) mean = 2.40 (ANOVA $F = 16.5$, $P < 0.0001$).

Finally, we assessed the above relationships in a multivariate model (Table 3). Linear relationships were observed between the log of symptom scores and several, but not all, of the constructs that were thought to be related to the likelihood of heat illness. Relationships were statistically significant for amount of weight lost during the practice, perceived exertion, player position, and heat index, with statistically nonsignificant trends for the other variables assessed (Table 3). Other than a past history of mild heat-related illness, no other preseason risk factors were identified that independently predicted HISI scores.

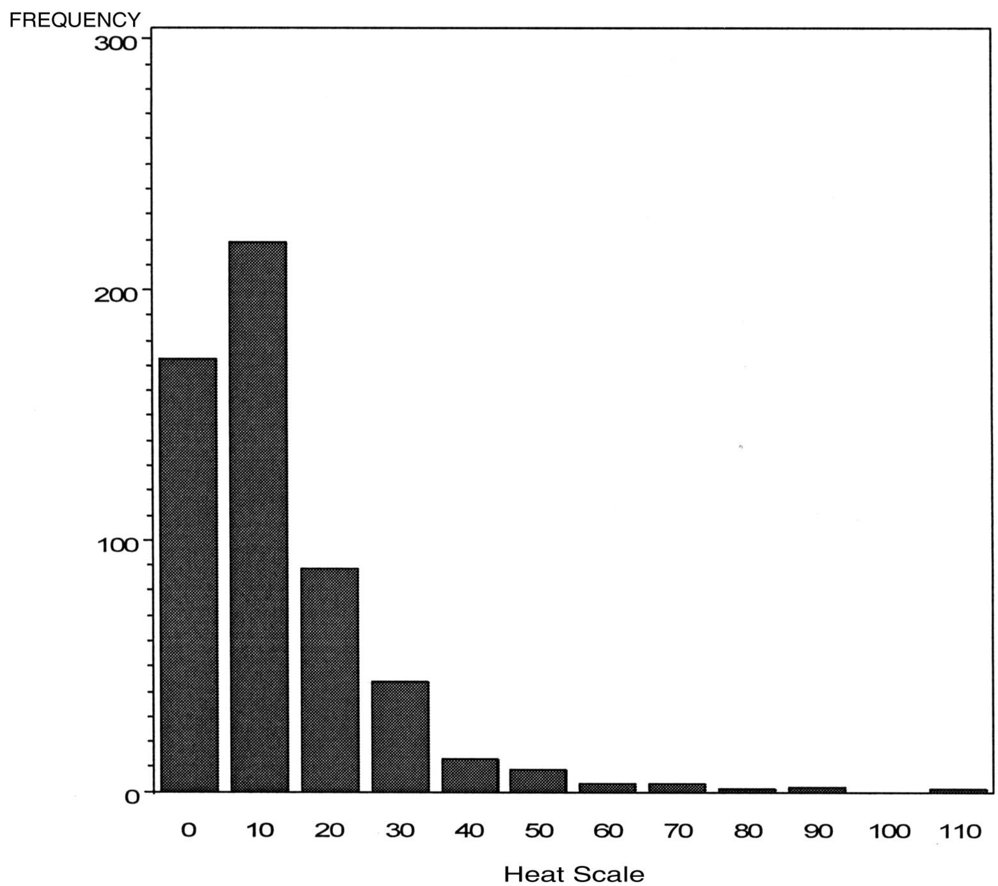

Fig. 1 **Frequency distribution for Heat Illness Symptom Scale.**

Discussion

The HISI may provide a quantitative assessment of symptoms that occur with milder forms of heat illness. The instrument demonstrated good reliability and reasonable construct validity, with symptom scores varying as predicted with factors that are known to correlate with heat illness. While results of this initial pilot study are encouraging, further validation of the instrument will be necessary.

HISI scores correlated with body weight change, as would be expected given the relationship between degree of dehydration, heat stress, and subjective symptoms. The correlation between core temperature and dehydration while exercising in the heat has been well-established in previous studies.[13–15,17]

There are also a number of other factors that influence risk of heat illness in any athlete.[9,11] In this study, HISI scores correlated with player position, likely due to individual body type, work rate, and level of conditioning that varies greatly by position. The HISI scores varied in the expected fashion, with offensive and defensive lineman exhibiting the highest HISI scores.

Ratings of perceived exertion are well established measures used to assess subjective work effort in a particular exercise session.[18–20] The degree of dehydration, one of the primary risk factors for heat illness, has been shown to strongly correlate with ratings of perceived exertion.[21–24] As hypothesized, we found that HISI scores correlated with measures of perceived exertion.

In retrospect, a lack of correlation of two of the initial variables that correlated poorly with the overall scale is not surprising. Swelling, a symptom of heat edema, is very uncommon among athletes. The symptom "stopped sweating" is also primarily an indicator of heatstroke, an uncommon condition and one that is not reflective of mild heat illness. No clinical cases of heatstroke were noted during this study, which was reflected in the data.

There are several important limitations to our attempt to validate the Heat Illness Symptom Index. First and foremost, there is no gold standard measure for the diagnosis of the hypothesized milder forms of heat illness. Thus, it was not possible to establish true criterion validity of the scale. Absent this, it will be important to correlate HISI scores with measures of core body temperature, a study that is currently being planned. Secondly, this scale was assessed among Division I collegiate football players and its applicability to other athletes and populations is uncertain. Finally, we did not have complete data on all participants, which may have created response bias.

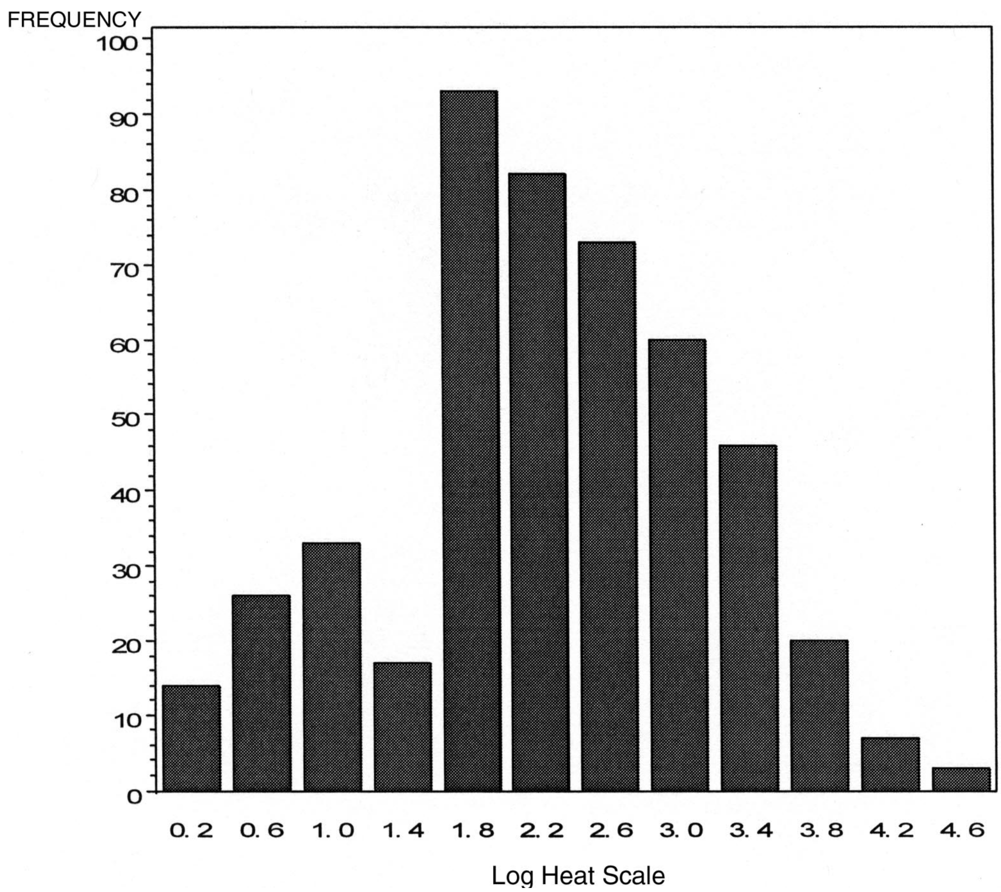

Fig. 2 **Frequency distribution for Log-transformed scale.**

Table 2. Heat Illness Symptom Scale correlations (n = 557)

Variable	Correlation Coefficient	*P* value
Weight loss during practice	0.21	<0.0001
Percent body weight lost	0.14	0.001
Weight loss from baseline weight	0.13	0.003
Percent body weight lost from baseline	0.09	0.04
Perceived exertion during practice	0.16	0.0003
Heat index[a]	0.13	0.002

[a] *Heat index calculated from ambient temperature and relative humidity.*

Table 3. Multivariate analysis (n = 557)

Variable	Coefficient (95% CI)	*P* value
Weight loss during practice	0.19 (0.06–0.33)	0.006
Percent body weight lost	0.29 (−0.04–0.63)	0.09
Weight loss from baseline weight	0.09 (−0.03–0.20)	0.15
Percent body weight lost from baseline	0.21 (−0.07–0.50)	0.14
Perceived exertion during practice	0.05 (0.02–0.09)	0.005
Player position	0.50 (0.31–0.68)	<0.0001
Heat index	0.012 (0.002–0.22)	0.02

CI, confidence interval.

Conclusion

In conclusion, this pilot study presents preliminary validation of a novel symptom-based tool for use in assessing mild heat illness in an athletic population. These results provide support for future studies correlating HISI scores with measures of core body temperature, studies that are currently planned. If validated, this tool may offer the ability to study milder forms of heat illness, potentially leading to a better understanding of the pathophysiologic and symptomatic progression of heat illness.

References

1. Lee-Chiong TL Jr. SJ. Heatstroke and other heat related illnesses: the maladies of summer. *Postgraduate Medicine* 1995;98:26–36.
2. Broad EM BL, et al. Body weight changes and voluntary fluid intakes during training and competition in team sports. *International Journal of Sports Nutrition* 1996;6:307–320.
3. Armstrong LE MC. The exertional heat illnesses: a risk of athletic participation. *Med Exerc Nutr Health* 1993;2:1–35.
4. Bar-Or O. Temperature regulation during exercise in children and ado-

lescents. In: Gisolfi C LD, ed. Perspectives in Exercise Sciences and Sports Medicine. Vol. 2. Indianapolis: Benchmark Press, 1989:335-367.

5. Bouchama A KJ. Heat stroke. *New England Journal of Medicine* 2002; 346:1978–1988.
6. Costrini A. Emergency treatment of exertional heat stroke and comparison of whole body cooling techniques. *Medicine and Science in Sports and Exercise* 1990;22:15–18.
7. Barrow MW CK. Heat-related illness. *American Family Physician* 1998; 58:749–756.
8. Convertino VA AL, Coyle EF, et al. American College of Sports Medicine position stand: exercise and fluid replacement. *Medicine and Science in Sports and Exercise* 1996;28:I–vii.
9. Epstein Y. Heat intolerance: predisposing factors. *Medicine and Science in Sports and Exercise* 1990;22:29–35.
10. Galloway S. Dehydration, rehydration, and exercise in the heat: rehydration strategies for athletic competition. *Canadian Journal of Applied Physiology* 1999;24:188–200.
11. Wexler RK. Evaluation and treatment of heat-related illness. *American Family Physician* 2002;65:2307–2314.
12. Coris EE RA, Van Durme DJ. Heat illness in athletes: the dangerous combination of heat, humidity, and exercise. *Sports Medicine* 2004;34: 9–16.
13. Coyle EF MS. Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *Journal of Applied Physiology* 1992; 73:1340–1350.
14. Murray R. Dehydration, hyperthermia, and athletes. *Journal of Athletic Training* 1996;31:248–252.
15. Werner J. Temperature regulation during exercise: an overview. In: Gisolfi C LD, Nadel ER, ed. *Exercise, Heat, and Thermoregulation.* Dubuque: Brown and Benchmark, 1993:49–77.
16. Armstrong L. Keeping your cool in Barcelona: the effects of heat, humidity, and dehydration on athletic performance, strength, and endurance. United States Olympic Committee, Colorado Springs, Colorado 1992:1–29.
17. Nadel ER, RM, Wenger CB, et al. Physiological defenses against hyperthermia of exercise. *Annals of New York Academy of Science* 1977; 301:98–109.
18. Herman CW, NP, Pivarnik JM, Womack CJ. Regulating oxygen uptake during high-intensity exercise using heart rate and rating of perceived exertion. *Medicine and Science in Sports and Exercise* 2003;35:1751–1754.
19. Garcin MWM, Bejma T. Reliability of rating scales of perceived exertion and heart rate during progressive and maximal constant load exercises till exhaustion in physical education students. *International Journal of Sports Medicine* 2003;24:285–290.
20. Batte AL DJ, Evans J, Lance LM, Olson EI, Pincivero DM. Physiologic response to a prescribed rating of perceived exertion on an elliptical fitness cross-trainer. *Journal of Sports Medicine and Physical Fitness* 2003;43:300–305.
21. Carter JE GC. Fluid replacement during and after exercise in the heat. *Medicine and Science in Sports and Exercise* 1989;21:532–539.
22. Kenefick RW MN, Mattern CO, Kertzner R, Quinn TJ. Hypohydration adversely affects lactate threshold in endurance athletes. *Journal of Strength and Conditioning Research* 2002;16:38–43.
23. Mudambo KS LG, Rennie MJ. Dehydration in soldiers during walking/running exercise in the heat and the effects of fluid ingestion during and after exercise. *European Journal of Applied Occupational Physiology* 1997;76:517–524.
24. Meyer LG HD, Lotz WG. Effects of three hydration beverages on exercise performance during 60 hours of heat exposure. *Aviation, Space, and Environmental Medicine* 1995;66:1052–1057.

Please see Randy Wexler's editorial on page 334 of this issue.

April hath put a spirit of youth in everything.

—William Shakespeare