Hyponatremia among Runners in the Boston Marathon

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ABSTRACT

BACKGROUND

Hyponatremia has emerged as an important cause of race-related death and life-threatening illness among marathon runners. We studied a cohort of marathon runners to estimate the incidence of hyponatremia and to identify the principal risk factors.

METHODS

Participants in the 2002 Boston Marathon were recruited one or two days before the race. Subjects completed a survey describing demographic information and training history. After the race, runners provided a blood sample and completed a questionnaire detailing their fluid consumption and urine output during the race. Prerace and postrace weights were recorded. Multivariate regression analyses were performed to identify risk factors associated with hyponatremia.

RESULTS

Of 766 runners enrolled, 488 runners (64 percent) provided a usable blood sample at the finish line. Thirteen percent had hyponatremia (a serum sodium concentration of 135 mmol per liter or less); 0.6 percent had critical hyponatremia (120 mmol per liter or less). On univariate analyses, hyponatremia was associated with substantial weight gain, consumption of more than 3 liters of fluids during the race, consumption of fluids every mile, a racing time of >4:00 hours, female sex, and low body-mass index. On multivariate analysis, hyponatremia was associated with weight gain (odds ratio, 4.2; 95 percent confidence interval, 2.2 to 8.2), a racing time of >4:00 hours (odds ratio for the comparison with a time of <3:30 hours, 7.4; 95 percent confidence interval, 2.9 to 23.1), and body-mass-index extremes.

CONCLUSIONS

Hyponatremia occurs in a substantial fraction of nonelite marathon runners and can be severe. Considerable weight gain while running, a long racing time, and body-mass-index extremes were associated with hyponatremia, whereas female sex, composition of fluids ingested, and use of nonsteroidal antiinflammatory drugs were not.

Table 1. Baseline Characteristics of the 2002 Boston Marathon Study Population.*

Characteristic	Male Runners (N=473)		Female Runners (N=295)	
	Reporting at Finish Line (N=336)	Not Reporting at Finish Line (N=137)	Reporting at Finish Line (N=175)	Not Reporting at Finish Line (N=118)
Age — yr	40.4±9.6	40.4±10.0	36.3±8.8	35.7±8.8
Nonwhite race — %	9	10	6	6
Prerace weight — kg	74.6±9.5	76.6±10.7	58.9±6.7	58.7±7.1
Body-mass index†	23.7±2.6	24.5±2.7	21.4±2.0	21.4±2.1
Training pace — min:sec/mi	7:53±1:02	8:04±1:09	8:40±1:01	8:41±1:02
Previous marathons — median no. (interquartile range)	5 (2–12)	4 (1–12)	4 (2–8)	3 (1–6)
Self-reported water loading — %‡	75	79	70	85
Self-reported use of NSAIDs — %§	51	54	60	61
Race duration — hr:min¶	3:37±0:42	3:46±0:40	4:02±0:36	4:02±0:32

* Plus–minus values are means ±SD. The temperature and humidity at noon, at the start of the race, were 53°F (12°C) and 96 percent, respectively, at 2 p.m. at the finish line, they were 55°F (13°C) and 83 percent.
† The body-mass index is the weight in kilograms divided by the square of the height in meters.
‡ Water loading was defined as an increase in fluid consumption above baseline specifically in preparation for running the Boston Marathon.
§ NSAIDs denotes nonsteroidal antiinflammatory drugs. Use of NSAIDs was defined as any use within the week before the Boston Marathon.
¶ Race times of runners who did not report at the finish line were obtained by means of the Boston Marathon tracking Web site.

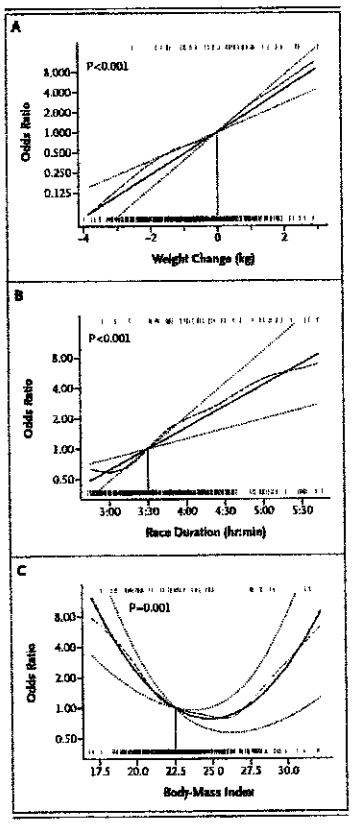

Figure 2. Adjusted Odds Ratios for Weight Change (Panel A), Race Duration (Panel B), and Body-Mass Index (Panel C) as Predictors of Hyponatremia among Runners in the 2002 Boston Marathon.

Results from a logistic-regression model showing the linear relationships of weight gain and race duration with hyponatremia, and the quadratic relationship of body-mass index with hyponatremia, were overlaid on the plot of the generalized additive model, demonstrating that the simpler parametric model adequately described the covariate effects. Dashed lines represent the fit of the generalized additive model. Solid lines represent the parametric logistic-regression fit (quadratic for body-mass index and linear for race duration and weight change). Dotted lines represent pointwise 95 percent confidence limits for the parametric fits. P values denote the overall effect of the covariate in predicting hyponatremia in the parametric logistic-regression fit. Tick marks above the odds-ratio curve represent runners with hyponatremia (defined as a serum sodium concentration of 135 mmol or less), whereas tick marks below the odds-ratio curve represent runners without hyponatremia. All models were constrained to cross at an odds ratio of unity.

Table 2. Univariate and Multivariate Predictors of Hyponatremia.*

Variable	Univariate Predictors			Multivariate Predictors	
	Hyponatremia (N=62)	No Hyponatremia (N=426)	P Value†	Odds Ratio (95% CI)	P Value†
Demographic characteristics					
Age (yr)	38.1±9.5	39.0±9.4	0.52	—	—
Nonwhite race (%)‡	8	8	1.00	—	—
Female sex (%)	60	30	<0.001	—	—
Body-mass index	22.8±3.7	23.0±2.5	0.68	—	—
Category of body-mass index			0.01		
<20 (%)	25	8	—	2.5 (1.1–5.8)	0.03
20–25 (%)	54	73	—	1.0§	—
>25 (%)	21	19	—	1.0 (0.4–2.0)	0.90
Training and performance					
Previous marathons (no.)	3	5	0.008	—	—
Training pace (min:sec/mi)	8:52±1:11	8:02±1:01	<0.001	—	—
Race duration (hr:min)	4:12±0:47	3:42±0:42	<0.001	—	—
Category of race duration (hr:min)			<0.001		
<3:30 (%)	13	44	—	1.0§	—
3:30–4:00 (%)	35	31	—	3.6 (1.4–11.5)	0.01
>4:00 (%)	52	25	—	7.4 (2.9–23.1)	<0.001
Fluids and electrolytes					
Self-reported fluid intake					
Frequency (%)			<0.001		
Every mile	75	54	—	—	—
Every other mile	25	36	—	—	—
Every third mile or less often	0	9	—	—	—
Volume, >3 liters (%)	42	26	0.01	—	—
Composition, 100% water (%)	8	11	0.66	—	—
Self-reported water loading (%)¶	82	73	0.16	—	—
Self-reported frequency of voiding during race (%)			0.047		
None	51	63	—	—	—
Once	27	25	—	—	—
Twice	8	8	—	—	—
Three times or more	14	5	—	—	—
Postrace weight > prerace weight (%)	71	29	<0.001	4.2 (2.2–8.2)	<0.001
Self-reported use of NSAIDs (%)‖	61	53	0.34	—	—

* Hyponatremia was defined as a serum sodium concentration of 135 mmol per liter or less. Plus–minus values are means ±SD. CI denotes confidence interval, and NSAIDs nonsteroidal antiinflammatory drugs. Dashes indicate not applicable. Percentages may not sum to 100 because of rounding.
† For the univariate analysis, all continuous variables were analyzed with the use of t-tests, all categorical data were analyzed with the use of Fisher's exact test, and the number of previous marathons was analyzed with the use of the Wilcoxon rank-sum test. For the multivariate analysis, P values were determined by Wald tests, and profile-likelihood confidence intervals were determined with the use of logistic regression.
‡ Race was self-reported.
§ This group served as the reference group in the multiple logistic-regression analysis.
¶ Water loading was defined as increasing fluid consumption above baseline specifically in preparation for running the Boston Marathon.
‖ Use of NSAIDs was defined as any use within the week before the Boston Marathon.

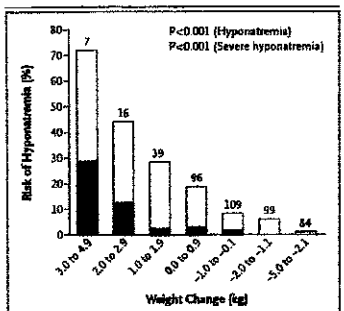

Figure 1. Risk of Hyponatremia and Severe Hyponatremia According to Weight Change among Runners in the 2002 Boston Marathon.

The total height of the bar represents the percentage of runners in a given stratum of weight change with hyponatremia (serum sodium concentration at race completion, ≤135 mmol per liter), whereas the black area of the bar represents the percentage of runners with severe hyponatremia (serum sodium concentration at race completion, ≤130 mmol per liter). The numbers above each bar denote the sample size in each weight-change category. The numbers do not sum to 488 because of missing data. On the x axis, positive numbers denote weight gain, and negative numbers weight loss. P values were determined by a test for trend.