

VARIABILITY IN THE SWEATING RATE AND SWEAT SODIUM CONCENTRATION OF ULTRA-ENDURANCE TRIATHLETES DURING EXERCISE



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ABSTRACT

During competition Ironman-distance triathletes can lose large amounts of fluid and sodium through sweating. To date no studies have investigated the variability in sweating rate and sweat sodium concentration in heat-acclimatized Ironman triathletes during exercise.

PURPOSE: Determine the variability in sweating rate and sweat sodium concentration in Ironman-distance triathletes during exercise. **METHODS:** Three to seven days prior to competing in the Ironman World Championship in Hawaii, 71 heat acclimatized subjects (48 male, 23 female, 42.1±1.4y) cycled a stationary ergometer for 30 min at 70-75% of maximum heart rate, following an 8-min warm-up. Sweat rate was calculated from the change in body weight. An absorbent patch (10 x 12cm) was placed on the right forearm and scapula for sweat collection during the 30 min trial. Sweat sodium concentrations were subsequently determined using chemical analysis (Nova 5, Waltham, MA). Trials were performed in a warm, outdoor environment (26.4±0.2°C WBGT) and subjects were fan cooled (3.5±0.4 m·s⁻¹). **RESULTS:** Absolute sweat rate was 1.4±0.1 L·hr⁻¹ with a coefficient of variation (CV) of 30.8%. Between subject variability was similar when adjusted for body weight (19.4±1.7 ml·kg⁻¹·hr⁻¹, CV = 28.5%). Sweat sodium concentrations for the arm and back were 39.6±2.0 mEq·L⁻¹ (CV=42.6%) and 47.2±2.3 mEq·L⁻¹ (CV=41.2%), respectively. Estimated regional sodium loss (whole body sweating rate x regional concentrations) was 56.5±3.9 mEq·hr⁻¹ and 66.8±4.5 for the arm and back, and exhibited high variability (CV_{arm} = 58.7%; CV_{back} = 56.2%). **CONCLUSION:** These results demonstrate that there is large variation in both the sweating rate and sweat sodium concentration of ultra-endurance athletes.

INTRODUCTION

- An Ironman-distance race encompasses a 3.86 km swim, a 180.2 km bike, and a 42.2 km run and can take up to 17 hours to complete.
- Sweating rate in humans can exceed 1.8 L·hr⁻¹ during exercise in the heat (1).
- Sweat sodium concentration in untrained heat acclimated individuals ranges from less than 10 to over 60 mEq·L⁻¹ (2).
- There is a considerable amount of variability in the sweating characteristics of moderately trained individuals when exercising at a low intensity in a temperate environment (3).
- The variability in the sweating rate and sweat sodium concentration of heat-acclimatized ultra-endurance athletes during exercise in a warm environment is currently unknown.

PURPOSE

Determine the variability in sweat sodium concentration and sweating rate in Ironman-distance triathletes during exercise in a warm environment.

METHODS

Subjects

- A total of 71 heat acclimatized men (n=48) and women (n=23).
- All subjects were registered to compete in the 2003 Ironman World Championship in Kailua-Kona, HI three to seven days after the exercise trial.

Table 1. Subject Characteristics

Variable	Mean±SE	Range
Age (y)	42.0±1.4	22-74
Mass-Male (kg)	76.1±1.3	58.5-104.3
Mass-Female (kg)	62.0±1.2	54.0-76.0
Body Fat-Male (%)	10.7±0.6	3.9-25.1
Body Fat-Female (%)	16.6±1.1	10.6-33.5
Resting Serum [Na] (mEq·L ⁻¹)	145.7±0.3	141.0-157.7

Measurements

- All trials were completed in an outdoor field laboratory in Kailua-Kona, HI, in warm conditions (26.4±0.2°C WBGT).
- Blood was sampled prior to exercise. Serum [Na] was measured by chemical analysis (Nova 5/5, Waltham, MA).
- Skin-fold thickness was measured prior to exercise using Harpenden calipers (Model HSK-BI, British Indicators, UK). Percent body fat was calculated using the Jackson and Pollock 3-site method (4, 5).
- Body mass was measured (A & D Medical, Life Source ProFit Scales, Model UC-321, Milpitas, CA) before and after the exercise trial.
- Subjects cycled at 70-75% of heart rate maximum for 30 minutes on a stationary ergometer following an 8 minute warm-up.
- All subjects were fan cooled (3.5±0.4 m·s⁻¹) during the trial.
- Sweating rate was calculated as the change in body mass pre to post exercise.
- A breathable waterproof sweat patch (10 x 12cm) was utilized to capture sweat from the right forearm and upper back during the trial.
- Chemical analysis (Nova 5, Waltham, MA) of the sweat was completed to determine sweat sodium concentration.

Statistics

- To determine the variability in sweating rate, sweat sodium concentration, and sodium loss means, standard deviations, and coefficients of variation (CV=SD/mean) were calculated.
- Regression and correlation analysis were performed to describe the relation between age, gender, sweating rate, sweat sodium concentration, and sodium loss.



RESULTS

Table 2. Sweating Rate and Sweat Sodium Concentration

Variable	Mean±SE	CV (%)
Sweating Rate (L·hr ⁻¹)	1.4±0.1	30.8
Sweating Rate (ml·kg ⁻¹ ·hr ⁻¹)	19.4±1.7	28.5
Sweat [Na] - Arm (mEq·L ⁻¹)	39.6±2.0	42.6
Sweat [Na] - Back (mEq·L ⁻¹)	47.2±2.3	41.2
Mean Sweat [Na] - Arm,Back (mEq·L ⁻¹)	43.4±2.1	40.0
Na Loss - Arm (mEq·hr ⁻¹)	56.5±3.9	58.7
Na Loss - Back (mEq·hr ⁻¹)	66.8±4.5	56.2
Mean Na Loss - Arm,Back (mEq·hr ⁻¹)	61.6±4.1	56.0
Na Loss - Arm (mEq·hr ⁻¹ ·kg ⁻¹)	0.8±0.1	57.5
Na Loss - Back (mEq·hr ⁻¹ ·kg ⁻¹)	0.9±0.1	54.5
Mean Na Loss - Arm,Back (mEq·hr ⁻¹ ·kg ⁻¹)	0.9±0.1	54.0

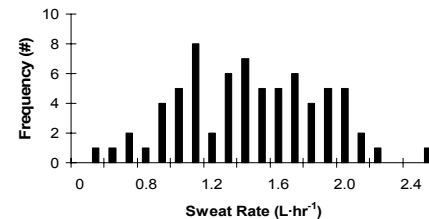


Figure 1a. Sweat rate (L·hr⁻¹) during moderate intensity exercise.

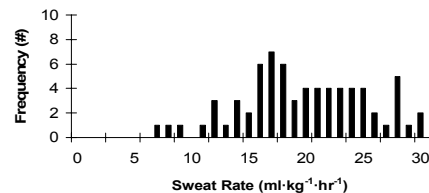


Figure 1b. Sweat rate (ml·kg⁻¹·hr⁻¹) during moderate intensity exercise.

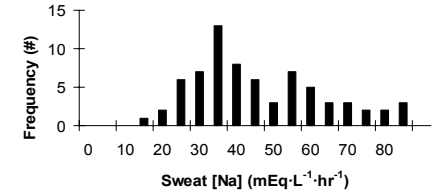


Figure 2. Sweat sodium concentration during moderate intensity exercise. ([Na] values are mean values of the forearm and back)

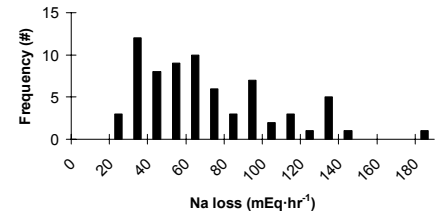


Figure 3. Estimated sodium loss during moderate intensity exercise. (Na loss is calculated as whole body sweat rate x mean sweat [Na]).

- Sweating rate (ml·kg⁻¹·hr⁻¹) is not significantly correlated with age (r=0.05, p>0.05, two-tailed) or gender (r=0.14, p>0.05, two-tailed).
- Sweat sodium concentration is not correlated with age (r=0.04, p>0.05, two-tailed) or gender (r=0.03, p>0.05, two-tailed).
- There is a high correlation between regional sweat [Na] of the arm and back (r=0.83, p<0.01, two-tailed).
- There is a correlation between sweating rate (ml·kg⁻¹·hr⁻¹) and sweat [Na] (r=0.26, p<0.05, two-tailed).

CONCLUSION

There is a large amount of variability in the sweating rate (CV~30%) and sweat sodium concentration (CV~40%) of heat-acclimatized ultra-endurance triathletes during exercise in a warm environment.

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