BRIEF OBSERVATION

THE AMERICAN JOURNAL of MEDICINE®

High Incidence of Hyponatremia in Rowers During a Four-week Training Camp

Constantin Ulrich Mayer,[a,b,1] Gunnar Treff, PhD,[a,1] Wiebke Kristin Fenske, MD,[c,d] Katja Blouin,[c] Jürgen Michael Steinacker, MD,[a] Bruno Allolio, MD[c,e]

[a]*Division of Sports and Rehabilitation Medicine, Department of Internal Medicine II, University of Ulm, Germany;* [b]*Department of Orthopedics, Medical Faculty, University of Düsseldorf, Germany;* [c]*Department of Internal Medicine I, Endocrine Unit, University Hospital, University of Wuerzburg, Germany;* [d]*IFB Adiposity Diseases, Leipzig University Medical Center, Germany;* [e]*Comprehensive Heart Failure Center, University of Wuerzburg, Germany.*

ABSTRACT

PURPOSE: To investigate the incidence of hyponatremia and its relationship to plasma copeptin, a surrogate marker for arginine vasopressin (AVP) during 28 days of high-volume rowing training.
METHODS: Thirty rowers from the German junior national team (21 male) were studied during a training camp. Serum sodium ($[Na^+]$), osmolality, and copeptin were measured before the beginning of the camp (day 0), and at days 7, 13, 18, 24, and 28. Daily fluid intake, body weight, urine parameters, and training volume were recorded.
RESULTS: Seventy percent of the rowers developed hyponatremia at least once. At day 18, training volume and incidence of hyponatremia (43%) were highest. $[Na^+]$ decreased from 143 ± 9 $mmol \cdot L^{-1}$ (day 0) to 135 ± 5 $mmol \cdot L^{-1}$ (day 18, $P < .01$). Hyponatremia was correlated significantly with weight gain compared with the previous day ($P < .01$). Copeptin decreased from day 0 to 28 (male: 6.7 ± 2.8 to 3.6 ± 1.7 $pmol \cdot L^{-1}$; $P < .05$; female: 4.8 ± 1.1 to 3.2 ± 1.5 $pmol \cdot L^{-1}$; $P < .05$), being only partially suppressed. Relative fluid intake per body surface area increased from day 7 (male: 2.79 ± 0.78 $L \cdot m^{-2}$; female: 2.20 ± 0.70 $L \cdot m^{-2}$) to day 28 (3.88 ± 0.69 $L \cdot m^2$ and 2.65 ± 0.93 $L \cdot m^{-2}$; $P < .05$). No athlete developed symptomatic hyponatremia.
CONCLUSION: Prolonged high-volume rowing training can lead to a high incidence of hyponatremia. Overdrinking and inadequate suppression of AVP contribute to its development.
 • *The American Journal of Medicine (2015) 128, 1144-1151*

KEYWORDS: Copeptin; Exercise-associated hyponatremia; Prolonged exercise; Vasopressin

Hyponatremia is the most frequent electrolyte disorder associated with increased mortality in hospitalized patients.[1-3] Hyponatremia is defined by a serum or plasma sodium concentration ($[Na^+]$) below 135 $mmol \cdot L^{-1}$ and occurs also in healthy athletes, who may develop exercise-associated hyponatremia during or after strenuous endurance exercise.[4] The incidence of exercise-associated hyponatremia in participants of endurance competitions like long-distance running ranges between 2% and 7%.[5] Exercise-associated hyponatremia usually remains asymptomatic, but occasionally causes fatigue, dizziness, noncardiac pulmonary edema,[6] and headache. In the presence of major cerebral symptoms (seizures, brain edema, and encephalopathy), it is termed exercise-associated hyponatremia encephalopathy.[7]

The incidence of exercise-associated hyponatremia in longer-lasting high-volume training with repeated sessions over several weeks has never been investigated. Because arginine vasopressin (AVP) plays a key role in the development of hyponatremia, we measured plasma copeptin, the C-terminal part of the AVP prohormone, as a surrogate

Funding: None.

Conflict of interest: The authors declare they have no conflicts of interest. WKF has received speaker honoraria from B.R.A.H.M.S. AG, Germany, the manufacturer of the copeptin assay.

Authorship: All authors had access to the data and played a role in writing the manuscript.

Requests for reprints should be addressed to Jürgen Michael Steinacker, MD, Division of Sports and Rehabilitation Medicine, University of Ulm, Leimgrubenweg 14, Ulm D-89075, Germany.

E-mail address: juergen.steinacker@uni-ulm.de

[1]These 2 authors contributed equally.

http://dx.doi.org/10.1016/j.amjmed.2015.04.014

marker for plasma AVP, thereby avoiding multiple methodological problems associated with AVP measurement.[8] Copeptin is secreted in equimolar amounts with AVP and has shown a strong positive correlation between copeptin and AVP concentrations in healthy subjects with normal kidney function.[9] Copeptin also is correlated closely to AVP in exercise-associated hyponatremia.[10,11]

Hence, we studied highly trained athletes with the following aims: 1) to evaluate the incidence of hyponatremia during 4 weeks of high-volume rowing training, and 2) to reveal possible correlations among changes of $[Na^+]$, fluid intake, serum osmolality ($[Osm]_S$), serum copeptin, and urine volume.

CLINICAL SIGNIFICANCE

- Exercise-associated hyponatremia can occur not only in healthy athletes after prolonged exercise like marathon running, but also after daily repeated, multiple bouts of shorter exercise (≤ 120 minutes) if total training volume is high.
- The observed kind of hyponatremia may represent an undescribed chronic variant of exercise-associated hyponatremia.
- If symptomatic, such chronic exercise-associated hyponatremia would require slower correction of sodium concentration than that recommended for acute hyponatremia.

METHODS

Data were collected during a 28-day rowing training camp in Berlin before the World Junior Rowing Championships. Participants gave written informed consent. Parental consent was obtained for athletes < 18 years of age. The ethical review board of the University of Ulm approved the study. Physiological and anthropometrical characteristics of the participants are shown in **Table 1**.

Serum copeptin, $[Na^+]$, $[Osm]_S$, and capillary hematocrit (Hct) were measured in the morning in fasted state at the beginning of the training camp (day 0) and on days 7, 13, 18, 24, and 28.

Samples for Hct were taken from the hyperaemized ear lobe and centrifuged for 10 minutes at 10,000 rpm (Laborfuge A, Heraeus, Buckinghamshire, UK). Venous blood was drawn from an antecubital vein and centrifuged at 5000 rpm for 10 minutes (Centrifuge, Braun GmbH, Kronberg, Germany). Serum was aliquoted and immediately frozen at −20°C for further analysis. Serum copeptin was measured using a commercially available immunoluminometric assay (CT-proAVP LIA, B.R.A.H.M.S. AG, Hennigsdorf, Germany), with a normal range between 1.8 and 13.8 $pmol \cdot L^{-1}$.[11] $[Na^+]$ was measured in the Central Laboratory of the University Hospital of Würzburg using ion-selective electrodes (cobas® 8000 modular analyzer, ISE, Roche, Mannheim, Germany). $[Osm]_S$ was measured via determination of freezing point depression using an OSMOMAT 030 Osmometer (Gonotec, Berlin, Germany).

To determine 24-hour urine volume, all urine was collected for 24 hours before each measurement using 2-L containers (Sarstedt, Nürnbrecht, Germany). Urine-specific gravity was immediately determined with a refractometer (TS 400; Reichert, Depew, NY). Urine was aliquoted and 10-mL samples were immediately frozen at −20°C to determine $[Na^+]_{urine}$.

Athletes were given standardized 750-mL bottles with a volume scale and recorded absolute fluid intake with a detailed questionnaire. They consumed mainly mineral water containing 118 $mg \cdot L^{-1}$ $[Na^+]$, which was permanently available. Alcoholic beverages were strictly forbidden.

Relative fluid intake (RFI) was defined as fluid intake per body surface area (BSA) and calculated as follows:

$$RFI\,(L \cdot m^{-2}) = AFI\,(L)\,/\,BSA\,(m^2) \quad [1]$$

where BSA was calculated according to Mosteller[12] and AFI abbreviates absolute fluid intake.

To express the relationship between $[Na^+]$ and copeptin levels, a secretion index (SI) was defined as follows:

$$SI\,(pmol \cdot mmol^{-1} \cdot 100) = Copeptin\,(pmol \cdot L^{-1}) \,/\, [Na^+]\,(mmol \cdot L^{-1}) \times 100 \quad [2]$$

Maximal power output (P_{max}) and maximal oxygen uptake (VO_{2max}) were evaluated on the second and third day of the training camp on a rowing ergometer (Concept 2, Inc., Morrisville, VT) using an incremental test protocol. Body weight was measured after urine sampling, before blood sampling, training, and breakfast. Training parameters (distance, duration, and intensity) were recorded daily. To relate impact of training volume on outcome variables, average daily training volume of 4 days was calculated before each measurement.

Table 1 Athletes' Characteristics

Variable	Male (n = 21)	Female (n = 9)
Age, y	17.9 ± 0.4	17.8 ± 0.6
Height, cm	190.8 ± 5.6	178.8 ± 6.5
Body weight, kg	86.9 ± 7.3	70.6 ± 6.9
VO_{2max}, $mL \cdot min^{-1} \cdot kg^{-1}$	63 ± 4	53 ± 4
P_{max}, $W \cdot kg^{-1}$	5.50 ± 0.34	4.67 ± 0.34
$Lactate_{max}$, $mmol \cdot L^{-1}$	15.9 ± 2.9	14.5 ± 2.2

Data are arithmetic mean ± standard deviation.

$Lactate_{max}$ = highest lactate concentration measured during and up to 7 minutes after cessation of ergometer test.

VO_{2max} = maximal oxygen uptake on rowing ergometer; P_{max} = maximal power output in rowing ergometer test.

Statistical Analysis

Data are presented as arithmetic mean ± standard deviation (SD). A software package (SPSS 19; IBM, Armonk, NY)