JOURNAL OF ENDURANCE

NOVEMBER 2005: #11.

How could drops of water know themselves to be a river? Yet the river flows on…*You* can never step into the same river, for new waters are always flowing on...

~ Antoine de Saint-Exupery, French Pilot, Writer, and Author 1900-1944.

Greetings, the following questions are reviewed in this issue:

#1 What solutions sustain endurance exercise?

#2 What is the role of sodium during hyperthermic endurance events?

#3 What is the best core exercise protocol for skiing, cycling, and running athletes?

#1 What solutions sustain endurance exercise?

SOLUTIONS^FLUID-FUEL-ELECTROLYTES FOR ENDURANCE PERFORMANCE

Bill Misner Ph.D.[1]

It is commonly reported that poor fluid intake compromises health. Fluid volume is essential for metabolism, temperature regulation, and numerous other physiological processes consistent with good health[2]. The role of hydration in the maintenance of health is increasingly recognized. Studies in healthy subjects show that even mild dehydration impairs a number of important aspects of cognitive function such as concentration, alertness, and short-term memory[3].

Fluid status is especially vital when exercise raises body metabolism 5–15 times above resting state[4]. Between 70–90% of this heat released is rapidly dissipated to reduce overheating. The relative contributions of evaporative and dry heat exchange to the rate of

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[1] Director Research & Product Development, EMG, Whitefish, Montana, 1-800-336-1977.

[2] Armstrong LE. Hydration assessment techniques. Nutr Rev. 2005 Jun;63(6 Pt 2):S40-54.

[3] Ritz P, Berrut G. The importance of good hydration for day-to-day health. Nutr Rev. 2005 Jun;63(6 Pt 2):S6-13.

heat loss vary according to climatic conditions[5]. In hot, humid climates, a substantial volume of body fluids is lost sweating for evaporative cooling[6]. Chronic dehydration increases the risks for several disorders. During endurance exercise, performance is inhibited in athletes who:

1. **Start exercise poorly hydrated**
2. **Don't drink enough fluid during exercise**
3. **Drink too much during exercise**

Neglecting proper fluid intake increases the risk of muscle cramping, spasms, gastric stress, and eventually performance-ending malaise. In the days or hours prior to exercise, everyone should drink a minimum ½ fluid ounce for each pound of body weight aside from additional fluids required to replace sweat loss.[7]

DETRMINE INDIVIDUAL FLUID REQUIREMENT

The range of water volume that can be ingested is determined by the kidneys' ability to concentrate and dilute the urine. An average adult with normal kidney function requires between 13.5-17.0 fluid ounces (or 400-500 mL) water to excrete the daily solute load in maximally concentrated urine. In addition to these fluids consumed, an additional 6.7-10 fl oz/day of water (or 200-300 mL) is released by tissue catabolism (basal metabolism), requiring a minimum water necessary to prevent renal failure quite low @ 6.7-10 fl oz/day (or 200-300 mL/day). However, a daily intake of 24-27 fl oz (700-800 mL) should be consumed to match total fluid losses and to maintain water balance. Chronically drinking less than the minimal 24-27 fl oz (or 700-800 mL) will result in stimulated thirst. Water loss evaporation occurs from expired air or through the skin, constituting about 0.4-0.5 mL/hour/kg bodyweight or between 22-29 fluid ounces (or 650-850 mL) every 24 hours in a 70-kg athlete. With fever or heat exposure, an additional 1.6-2.5 fluid ounces/day (50-75 mL/day) may be lost for each degree of temperature elevation above normal. Sweat losses are generally negligible but can be significant with fever or in warmer climates. GI water losses are also negligible in health but can be significant in severe diarrhea or protracted vomiting[8]. The exercising body returns only 30-50% of the total fluid volume consumed depending on individual acclimatization level, fitness and response to heat index. What simple tests determine fluid intake adequacy?

SEDENTARY TEST TO EVALUATE HYDRATION STATUS

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[4] Sawka MN, Montain SJ. Fluid and electrolyte supplementation for exercise heat stress. Am J Clin Nutr. 2000 Aug;72(2 Suppl):564S-72S. Review.

[5] Sawka MN, Wenger CB, Pandolf KB. Thermoregulatory responses to acute exercise-heat stress and heat acclimation. In: Fregly MJ, Blatteis CM, eds. Handbook of physiology. Section 4, environmental physiology. New York: Oxford University Press, 1996:157-85.

[6] Sawka MN, Pandolf KB. Effects of body water loss on physiological function and exercise performance. In: Gisolfi CV, Lamb DR, eds. Perspectives in exercise science and sports medicine. Vol 3. Carmel, IN: Benchmark Press, 1990:1–38.

[7] Water.com Hydration Calculator @:
http://www.water.com/learn_about_water/swg1350_hydcalres.asp

[8] From The Merck Manual of Medical Information - Second Home Edition,
http://www.merck.com/mrkshared/mmanual/section2/chapter12/12b.js
edited by Mark H. Beers. Copyright 2003 by Merck & Co., Inc., Whitehouse Station, NJ.
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Under normal conditions (sedentary) drinking of a liter of water will cause 8 times the normal urine output within 45 minutes lasting up to 120 minutes after intake. To measure hydration adequacy, consume a liter of water, then measure urine output for 45-120 minutes. Clear urine color and high volume urine are indicators of adequate hydration. Dark yellow urine combined with a low volume yield indicates a state of dehydration.

EXERCISE TEST TO EVALUATE HYDRATION STATUS

Dr. Gilbert Preston M.D., physician and endurance athlete, said:

> **"I can't think of a practical way to judge state of hydration with/out a sample of urine to inspect for volume and color from the adage: *'Urine White-Do Alright, Urine Yellow, Kill A Fellow.'* If you are doing an 8-hour event and don't pass urine, you could be on the way to renal failure due to low blood volume caused by dehydration. If you pass more than a couple of completely colorless urines, you may be washing out electrolytes, maybe over-hydrated-if you pass more than one dark yellow urine, increase your intake of water until your urine loses most of its color-these are very rough field guidelines.[9]"**

EXERCISE IN THE HEAT COMPROMISES FLUID BALANCE

The average 154 lb (70 kg) person has 2 compartments filled with 85 lbs fluids maintained in constant balance. Stored intracellular fluid volume is 25 liters of water (53 lbs water) wit potassium ions 15 times higher inside than outside. Stored of extracellular fluid volume is 15 liters (32 lbs water) fluid stored outside the cells. These extracellular spaces store sodium ion concentration at 10 times higher than inside the cells. During exercise in the heat, fluid losses of 1 liter per hour are common reflecting 2.2 pounds of water weight loss as 2% of a small 110-pound person or 1% of a larger 220-pound athlete. During exercise, sweat output often exceeds water intake, producing a body water deficit (hypohydration). The water deficit lowers both intracellular and extracellular volume and also results in plasma hypertonicity and hypovolemia. Performance-reducing symptoms appear to be proportionate to the percent of body weight fluids lost via perspiration:

SYMPTOMS RELATED TO FLUID WEIGHT LOSS [10]	
% WEIGHT LOSS	**SYMPTOM**
0%	**None, heat regulation, normal exercise performance**
1%	**Thirst, heat regulation altered, performance begins to decline**
2%	**Further decrease in heat regulation, increased thirst, performance inhibition, aware of decline**
3%	**Performance worsens, awareness of decline increases**
4%	**Performance decreases 20-30%**
5%	**Headache, irritability, "spaced-out" feeling, fatigue extreme**
6%	**Weakness, severe loss of thermoregulation**
7%	**Collapse unless exercise is stopped**
10%	**Comatose**

[9] Gil Preston, M.D., by permission, in a personal communication, e-mail reply on Tue, 06 Apr 99 09:45:20 PDT to the endurance@MailingList.net

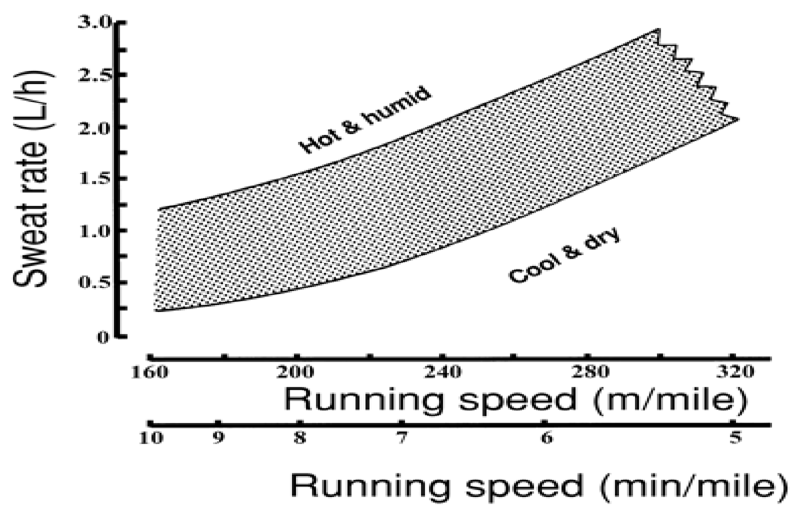
[10] Grandjean & Ruud, Clinics in Sports Med. Vol 13(1);235-246. Jan 1994. (Nutrition for Cyclists)

11%	Death

When -3% water weight is lost through evaporative sweating, the athlete becomes conscious their performance rate is deteriorating. After a 5% fluid loss, mental concentration is difficult. At 10% body weight fluid loss, a real medical emergency presents, resulting in loss of consciousness, and if it continues to -11% fluid loss, death may occur. Balance repletion of fluids must take place during periods of recovery after exercise including fluids consumed during exercise[11 12]:

SOURCE	SEDENTARY (ml)	EXERCISE (ml)
FLUIDS	+1500	+1500
FOODS	+800	+800
URINE	-1400	-500
SKIN	-350	-350
BREATHING	-350	-650
SWEAT	-100	-5000
FECES	-100	-100
TOTALS	-2300 + 2300 = 0	Deficit -6600 = –4300

In this example, no-activity achieved fluid balance, but once exercise in the heat proceeds, nearly 9.08 pounds (–4300 ml) fluid weight loss is 6% of the original 154 lb athlete's body weight. Sport scientists report that a -6% loss is a serious performance-inhibiting situation that impairs temperature regulation and rapidly increases heart rate[13].



[11] Rozelle LT, "All in the Body's Balance", WATER TECHNOLOGY, March 1997:126-132.
[12] TEXTBOOK OF MEDICAL PHYSIOLOGY, AL Guyton, WB Saunders, 1991.
[13] Nieman DC, SPORTS MEDICINE FITNESS COURSE, Bull Publishing, Palo Alto Calif., 1986.

FIGURE 1. An approximation of hourly sweating rates as a function of climate and running speed [14].

Fluids are efficiently replaced by water that has been precisely mixed at or near body fluids osmolality levels. Osmolality is determined by the concentration of specific dissolved substance per unit of fluid. Highly concentrated sugars or sodium solutions are poorly absorbed through the gut until they are reduced to body fluids osmolality levels. Once absorbed, excess sodium can create an edema-like swelling in eyes, hands, and feet. Salt tablets have been eliminated by professional athletic trainers' kits because after intake, salt tablets cause severe stomach cramps. When too much sodium or sugar is consumed, fluids must be drawn into the gut in order to dilute these concentrations to between 280-303 mOsm in order for their absorption. Noakes argues that neglecting the contents of a rehydration solution or overcorrecting it during endurance exercise may contribute to irreversible brain damage[15].

FLUID INTAKE AFFECTS SWEAT RATE

How does exercise in the heat influence fluid loss and how does fluid intake affect the rate sweat loss? Notice how drinking fluids and not drinking effects sweat rate in figure 2.

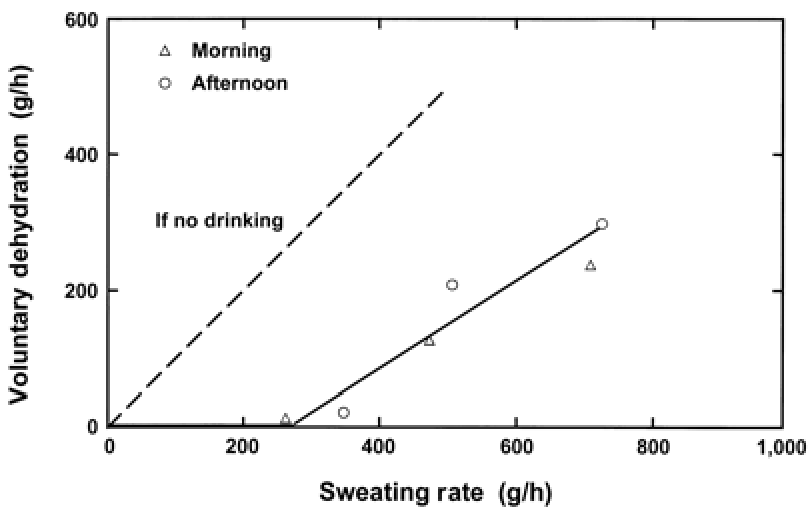


FIGURE 2. Relation between sweating rate and voluntary dehydration (water deficit) during ad libitum drinking by heat-acclimated persons in the desert[16].

FLUID INTAKE AFFECTS CORE BODY TEMPERATURES

[14] Sawka MN, Pandolf KB. Effects of body water loss on physiological function and exercise performance. In: Gisolfi CV, Lamb DR, eds. Perspectives in exercise science and sports medicine. Vol 3. Carmel, IN: Benchmark Press, 1990:1–38.

[15] Noakes TD, [listing 25+ key research studies], THE LORE OF RUNNING, Leisure Press, Champaign, Illinois, 1991: 115-117.

[16] Adolph EF, Associates. Physiology of man in the desert. New York: Intersciences, 1947.

As fluids are lost, body core temperatures increase proportionate to fluid volume loss in Figure 3.

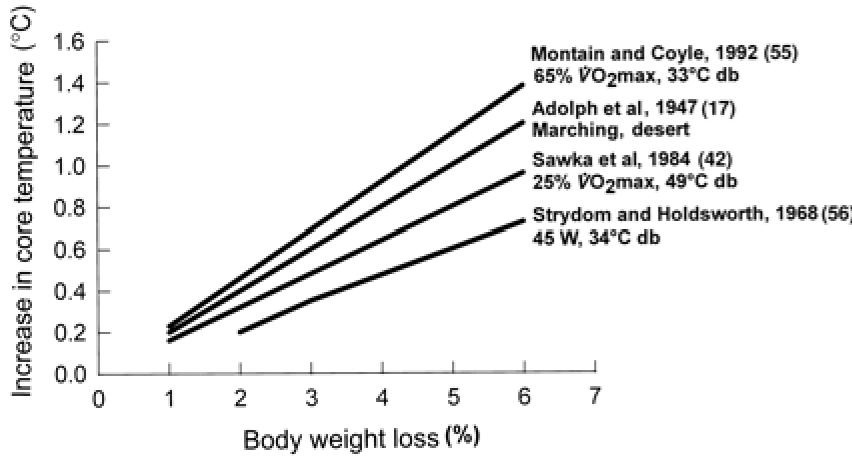
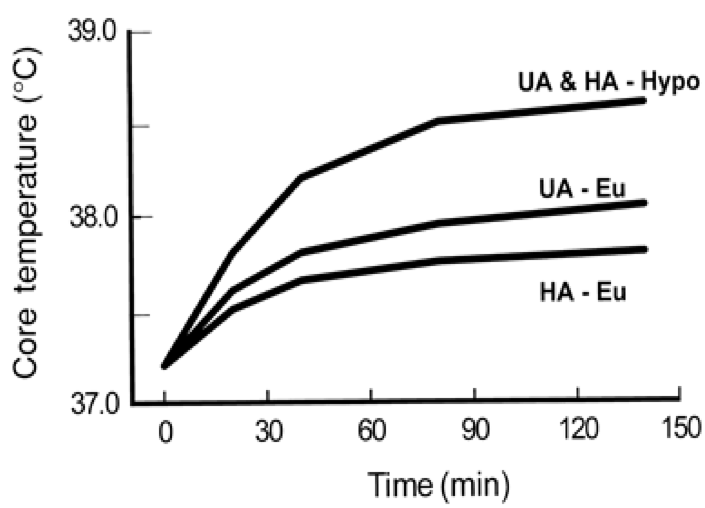


FIGURE 3. Relation between the elevation in core temperature (above euhydration) and hypohydration (measured as percentage body weight loss) during exercise heat stress[17]. $\dot{V}O_2$max, maximal aerobic power; db, dry bulb temperature.

FLUID INTAKE + HEAT ACCLIMATIZATION = PERFORMANCE ADVANTAGE

Notice the differences in a heat-acclimatized athlete consuming adequate fluids during endurance exercise figure 4:



[17] Sawka MN, Montain SJ, Latzka WA. Body fluid balance during exercise-heat exposure. In: Buskirk ER, Puhl SM, eds. Body fluid balance: exercise and sport. Boca Raton, FL: CRC Press, 1996:143–61.

FIGURE 4. Core temperature responses during exercise heat stress in adequately hydrated (i.e. euhydrated - EU) and hypohydrated (hypo; -5% body weight loss) persons both before (UA) and after (HA) being heat acclimated[18].

HYDRATION CONTROLS BODY CORE TEMPERATURE

Core temperatures are better maintained in the hydrated athlete compared to the dehydrated subject in Figure 5:

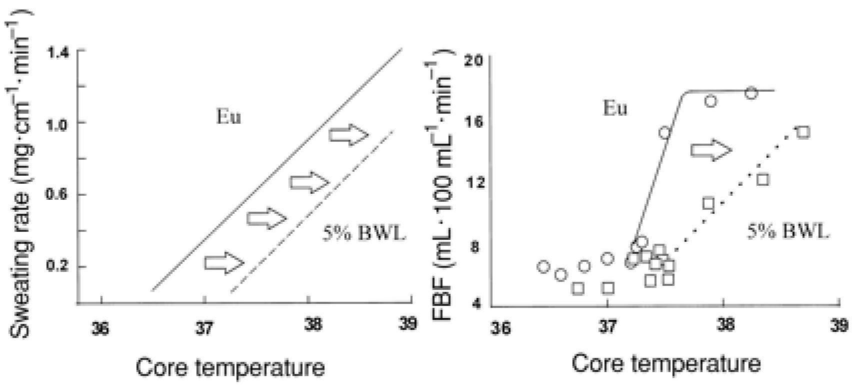


FIGURE 5. Local sweating rate and forearm skin blood flow (FBF) response data for euhydrated (Eu) (○) and hypohydrated (□) [5% body weight loss (BWL)] persons during exercise heat stress[19] [20].

Solutions consumed (at isotonic body fluid level) are required in order to achieve optimal performance. Equilibrium of solution concentrations occurs at 280-300 milliosmoles per liter (mOsm/l.). A change in the osmotic pressure gradient generated by serum solutes or electrolytes is a correction of the pressure deviance that may occur in a single compromised cell space in as little as 60 seconds or up to 60 minutes, depending on individual-specific metabolism, climate, and solute mixture. When subject to "*Exercise Stress*" beyond the normal comfort zone greater than -2% fluid weight loss, 30 minutes of no activity is required to restore 12-14 fluid ounces isotonic fluid-fuel-electrolyte drink. Unfortunately, the competitive endurance athlete will not sacrifice 30 minutes for hydration during an event, but continues on in a mildly dehydrated state.

KIDNEYS CONTROLLING ROLE

Our kidneys filter 180 liters of the vascular fluids daily, and efficiently return over 99% of the fluid filtered, eliminating only 1-1.5 liters waste. As efficient filters, the kidneys continuously work to maintain a constant 280-300 mOsm/l osmolarity with blood serum retained between 7.35-7.45 pH. Our ability to perform exercise consciously decreases as we approach a +1% fluid overdose or a -3% body fluid

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[18] Sawka MN, Toner MM, Francesconi RP, Pandolf KB. Hypohydration and exercise: effects of heat acclimation, gender, and environment. J Appl Physiol 1983;55:1147–53

[19] Sawka MN, Gonzalez RR, Young AJ, Dennis RC, Valeri CR, Pandolf KB. Control of thermoregulatory sweating during exercise in the heat. Am J Physiol 1989;257:R311–6.[Abstract/Free Full Text]

[20] Kenney WL, Tankersley CG, Newswanger DL, Hyde DE, Puhl SM, Turner NL. Age and hypohydration independently influence the peripheral vascular response to heat stress. J Appl Physiol 1990;68: 1902–8.[Abstract/Free Full Text]

weight loss, and including tiny acidic changes -0.1 in alkaline pH 7.35-7.45 pH. When either occurs, several hormone messengers are activated to enable the kidneys to spare fluids, restore osmolarity, and keep pH range strictly alkaline. Before such extreme changes occur, the kidneys correct, monitor, and restore balances well below individual awareness. Frequent sips of a correctly mixed solution serve to anticipate losses during exercise postponing fatigue. Aerobic exercise is adversely affected by hypohydration[21], potentially more so at higher exercise intensities in warm environments[22]. Hypohydration increases heat storage and reduces a person's ability to tolerate heat. Increase in core body heat storage is mediated by reduced sweat rate and lower skin blood flow for a given core temperature[23].

HEAT-INHIBITED PERFORMANCE "SOLUTIONS"

What group of athletes is most affected by exposure to heat? Older athletes, persons with cystic fibrosis, or persons with spinal cord injury all have unique problems associated with fluid and electrolyte balance during exercise associated heat stress. Persons age 55 or over have reduced thirst sensation, less ability to concentrate urine, and reduced potential to dissipate body heat. Note that older athletes are less sensitive to thirst and their dehydration state during the first 3-3.5 hours of exercise, while younger men are more sensitive to thirst and dehydration state (figure 6 below):

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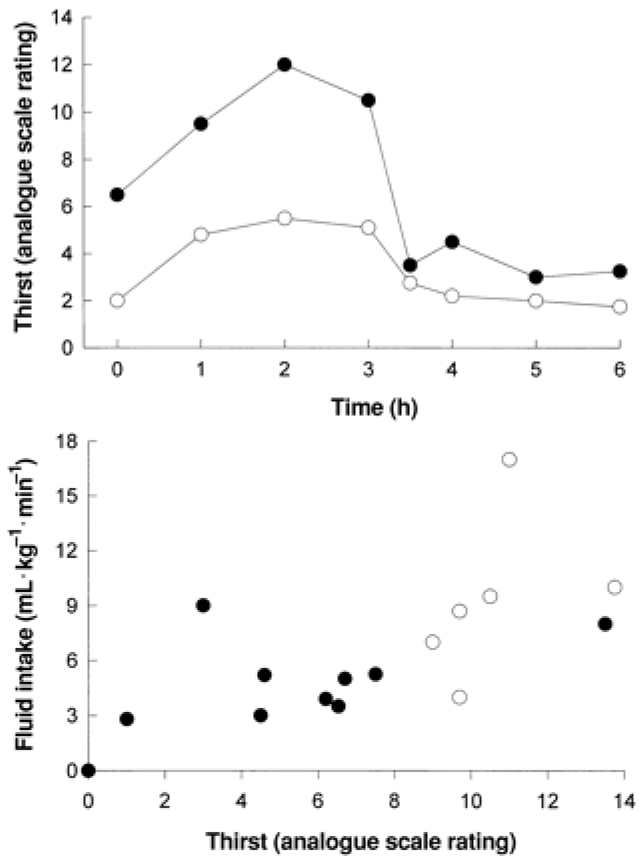
21 Ladell WSS. The effects of water and salt intake upon the performance of men working in hot and humid environments. J Physiol 1955;127:11–46.

22 Montain SJ, Smith SA, Matott RP, Zientara GP, Jolesz FA, Sawka MN. Hypohydration effects on skeletal muscle performance and metabolism. A ^{31}P MRS study. J Appl Physiol 1998;84:1889–94.[Abstract/Free Full Text]

23 Sawka MN, Montain SJ. Fluid and electrolyte supplementation for exercise heat stress. Am J Clin Nutr. 2000 Aug;72(2 Suppl):564S-72S. Review.



[FIGURE 6.](#) Subjective thirst sensation of younger (•) and older (○) men during exercise heat stress and the relation between drinking behavior and thirst sensation[24] [25] [26]. After 3-3.5 hours not sensing need for fluids may create dehydration levels that are severe enough to cease exercise. Our Physiology shouts warning signals of its own when fluid, fuel, or sodium losses reach a certain measure. Restoration of circulating serum fluid volume is therefore dependant upon volume, osmolality, calorie source, electrolytes especially sodium, and timing intake.

THREE PHYSIOLOGY SIGNALS PRECEDE DEHYDRATION
What are the three signals precede excessive fluid and electrolyte loss?

(1) When serum fluids are too concentrated, the Pituitary gland releases ADH (Anti-Diuretic Hormone) causing the kidneys to increase fluid return or decrease fluid filtered out of circulation.

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[24] Kenney WL. Body fluid and temperature regulation as a function of age. In: Lamb DR, Gisolfi CV, Nadel E, eds. Exercise in older adults. Indianapolis: Cooper Publishing, 1995:305–51.
[25] Kenney WL, Fowler SR. Methylcholine-activated eccrine sweat gland density and output as a function of age. J Appl Physiol 1988; 65:1082–6.[Abstract/Free Full Text]
[26] Mack GW, Weseman CA, Langhans GW, Scherzer H, Gillen CM, Nadel ER. Body fluid balance in dehydrated healthy older men: thirst and renal osmoregulation. J Appl Physiol 1994;76:1615–23.[Abstract/Free Full Text]

(2) When plasma sodium concentrations dip low, the Adrenals release Aldosterone, causing the kidneys to reduce sodium filtration so that more will reabsorbed by the blood, producing a more diluted urine.

(3) Thirst increases as similarity rises only 1% increasing drinking, replacing internal serum fluid volume and diluting serum-urine concentrates.

These internal controls are more active as serum levels occur +3% or -3% deviation in sodium and a + or -7% deviation in potassium. Calcium levels are also monitored within a few percentages by the parathyroid gland. It is interesting that normal body fluids in saliva, gastric juices, and small intestine are consistently a 7:3 ratio of potassium to sodium. This ratio parallels the numerical deviation that triggers several mechanisms in electrolyte, fluid, pH for osmotic normal reference ranges. Body fluids electrolyte profiles are maintained by ADH (Anti-Diuretic Hormone), Aldosterone. Each one is affected by drinking correctly mixed solutions at isotonic body fluid 280-300 mOsm. The electrolyte profiles in several body fluids compartments demonstrate the importance of electrolytes for strict control of each at isotonic body fluid level.

ELECTROLYTE PROFILES OF BODY FLUIDS [27] [28]
(8 fluid ounces = 240 ml.)

BODY FLUID	VOLUME (ml/day)	ELECTROLYTE	VOLUME (mg/day)
SALIVA	800-1500	Sodium Chloride➔ Potassium➔ Bicarbonate➔	877 1170 3000-4000
GASTRIC JUICES	1500	Potassium Chloride➔ Sodium Chloride➔ HCL➔	1120 175 5600
SMALL INTESTINE	1800 WATER	Fluctuates by need	Fluctuates by need

How should athletes prepare to overcome the predicted loss in fluids, fuel, and electrolytes? As implied in figures 1-6, hydration during training in the heat reduces the rate of fluid loss resulting in inhibited performance. Verde et al. reported that fit-acclimatized athletes lose only ½ the electrolytes in sweat as fit-unacclimatized athletes[29]. Acclimatization is the most important training intervention to resolve exercise-induced electrolyte and fluid loss effects in the heat.

GLYCEROL HYPERHYDRATION INCREASES EXTRACELLULAR FLUIDS

[27] TEXTBOOK OF MEDICAL PHYSIOLOGY, AL Guyton, WB Saunders, 1991.
[28] Misner WD, NUTRITION FOR ENDURANCE: FINDING ANOTHER GEAR, Dolezal & Associates, Livermore, Calif.,1998: Chapter 8.
[29] Verde, T., et al., Sweat Composition in Exercise and Heat, JOURNAL OF APPLIED PHYSIOLOGY,1982;53(6):1541-1543.

Research reports that a 1:26 glycerol:water ratio increases fluid volume in the extracellular space[30]. This intervention compensates for fluid loss in the heat by increasing the amount of fluids stored in the body's extracellular spaces before the event. Glycerol added to water diverts fluids away from kidney filtration into extracellular fluid stores. The glycerol loading protocol is 1 fluid ounce glycerol in 26 fluid ounce water consumed 4 times daily over a 3-4 day period (during taper). Weighing daily is required to monitor fluid weight gain to no more than +3% of the athlete's original weight. Should water weight gain exceed +3%, the athlete should cease the loading protocol immediately. What happens to this extra water weight? During the first 90-120 minutes exercise, the excess fluid is lost in evaporative sweat. For events lasting less than 2 hours, glycerol loading is not necessary.

FLUIDS, FUELS, AND ELECTROLYTE BALANCE REQUIRED IN THE HEAT

As heat and humidity increase, Professor Noakes recommends 16-24 fluid ounce isotonic solutions during each hour endurance exercise at a 75-85% VO2 Max effort[31]. A 1-ounce (28.3 grams) long-chain carbohydrate diluted in 5-8 liquid ounces of water is roughly 11-16% solution (fluids: fuel, 5-8:1 by weight), produces mOsm at body fluid osmolality of 280-300 mOsm/l for immediate gastric emptying and absorption rate. However, when electrolytes, protein, or fatty acids are added to an isotonic solution, the osmolality increases.

A hospital laboratory[32] measured osmolality of Hammer Gel, Perpetuem, Sustained Energy, and HEED when mixed in solutions including 3-Endurolytes to determine at what solution percent each would approximate body fluid osmolality. In general, a 10% +/-1% solution weight of distilled water to weight of product created solutions at body fluid osmolality:

SOLUTIONS OSMOLALITY MEASURE[33 34]					
SAMPLE #	SOLID PER FLUID RATIO	CALORIE PER FLUID RATIO	CURRENT LABEL DIRECTIONS	SOLUTION PERCENT	mOsm OSMOLALITY
SAMPLE #1 PLAIN HAMMER GEL	HG 25 g per 113.4g DW + 3 ENDUROLYTES[i]	65 K/cal per 4 fl oz	CURRENT HG directions, 1 of 2: Mix 36 g serving with 4 fl oz = 479 mOsm	22%	479 mOsm (Lab Confirmed)
PLAIN	HG 25 g	65 K/cal		11%	298 mOsm

[30] Coutts A, Reaburn P, Mummery K, Holmes M. The effect of glycerol hyperhydration on olympic distance triathlon performance in high ambient temperatures. Int J Sport Nutr Exerc Metab. 2002 Mar;12(1):105-19.
[31] Noakes TD, [from Noakes' research, over 25 studies], THE LORE OF RUNNING, Leisure Press, Champaign, Illinois, 1991: 115-117.
[32] Special thanks to Portland Providence Medical Center, laboratory services; Portland, Oregon & Dr. David Ciaverella D.O., Columbia Imaging Group, 8614 E. Mill Plain Blvd., Suite 200A, Vancouver, WA 98664, for his assistance with lab solution mOsm measures.

[33] Special thanks to Portland Providence Medical Center, laboratory services; Portland, Oregon & Dr.

David Ciaverella D.O., Columbia Imaging Group, 8614 E. Mill Plain Blvd., Suite 200A, Vancouver, WA 98664, for his assistance with lab solution mOsm measures.
[34] Athletes are advised to experiment with solution percents +/- 1-2% to confirm compatibility with individual physiology in a variety of environmental conditions.

HAMMER GEL DILUTED 2 X SAMPLE #1a	**per 227 g DW + 3 ENDUROLYTES[ii]**	**per 8 fl oz**			**(Lab Confirmed)**
PLAIN HAMMER GEL ISOTONIC SOLUTION ESTIMATE (RECOMMEND)	**PLAIN HG 2 servings 72 g per 707 g DW + 3 ENDUROLYTES**	**72 K/cal per 25 fl oz**	***NEW* Recommended HG directions: Mix 186 k/cal 72 g/25 fl oz**	**10%**	***NEW* Estimated 271 mOsm**
SAMPLE #2 HEED	**HEED 25 g per 113.4 g DW +3 ENDUROLYTES[iii]**	**86 K/cal per 4 fl oz**	**CURRENT HEED directions: Mix 1scoop/16 fl oz (6.4%) = too low @ 174 mOsm 2 scoops 24 fl oz (8.5%) = 274 mOsm**	**22%**	**599 mOsm (Lab Confirmed)**
DILUTED 2 X SAMPLE #2a HEED	**HEED 25 g per 227 g DW +3 ENDUROLYTES[iv]**	**86 K/cal per 8 fl oz**		**11%**	**316 mOsm (Lab Confirmed)**
ISOTONIC SOLUTION ESTIMATE (RECOMMEND)	**HEED 29 g per 283 g DW or 58 g per 566 g per DW (1 scoop per 10 fl oz) +3 ENDUROLYTES**	**100 k/cal per 10 fl oz**	***NEW* Recommended HEED directions: Mix 100 k/cal 1 scoop 29 g per each 10 fl oz**	**10%**	***New Estimated* 287 mOsm**
SAMPLE #3 PERPETUEM	**PERPETUEM 25 g per 113 g DW +3 ENDUROLYTES[v]**	**95 K/cal per 4 fl oz**	**CURRENT PERPETUEM directions: Mix 1 scoop per 12 fl oz = 302 mOsm or 2 scoops per 24 fl oz = 302 mOsm**	**22%**	**709 mOsm (Lab Confirmed)**
DILUTED 2.5 X SAMPLE #3a PERPETUEM	**PERPETUEM 25 g per 283 g DW +3 ENDUROLYTES[vi]**	**95 K/cal per 10 fl oz**		**9%**	**262 mOsm (Lab Confirmed)**
ISOTONIC SOLUTION ESTIMATE (RECOMMEND)	**PERPETUEM 69 g per 25 fl oz (708 g DW) +3 ENDUROLYTES**	**260 K/cal per 25 fl oz**	***NEW* Recommended PERPETUEM directions: Mix 2 scoops 260 k/cal, (69 g) per each 25 fl oz**	**10%**	***NEW* Estimated 296 mOsm**
SAMPLE #4 SUSTAINED ENERGY	**SUSTAINED ENERGY 25 g per 113 g DW +3 ENDUROLYTES[vii]**	**100 K/cal per 4 fl oz**	**CURRENT SUSTAINED ENERGY directions: Mix 3 scoops /25 fl oz = 329 mOsm 9 scoops/25 fl oz = 658**	**22%**	**604 mOsm (Lab Confirmed)**

			mOsm		
DILUTED 2 X SAMPLE #4a SUSTAINED ENERGY	SUSTAINED ENERGY 25 g per 227 g DW +3 ENDUROLYTES[viii]	100 K/cal per 8 fl oz		11%	294 mOsm (Lab Confirmed)
ISOTONIC SOLUTION ESTIMATE (RECOMMEND)	SUSTAINED ENERGY 28.3 g serving as 1 scoop per 283 g DW (10 fl oz) +3 ENDUROLYTES	114 k/cal scoop serving per 10 fl oz	*NEW* Recommended SUSTAINED ENERGY directions: Mix 1 scoop, 114 k/cal, (28 g) per each 10 fl oz	10%	*NEW* Estimated 270 mOsm
KEY: RED = mOsm original 4 fl oz: 25 g solution osmolality measured BLUE = mOsm modified as recommended fl oz per 25 g solution set @ isotonic levels (ideal) DW = Distilled Water 113.4 g = 4 fl oz g = Gram ISOTONIC SOLUTION ESTIMATE (RECOMMENDED) solution based on isotonic (280-303 mOsm) osmolality estimates.					

AVOID SUGARED ENERGY FUELS

Athletes consuming simple sugars sucrose, fructose, or glucose fail to realize that simple sugar taken at the same rate as long chain carbohydrate multiplies the osmolality rate by a factor of 2 or 3 X resulting in delayed gastric absorption and predicted stomach upset. When sugared energy drinks or gels are consumed absorption of fuel is delayed, causing the body to draw fluids and electrolytes out of the body across in order to lower the dilute solutions in the gut for transition directly in to the working muscles. If a sugared solution is consumed it should be no higher than 8%. Long-chain maltodextrins are immediately absorbed in up to 16% solutions however when electrolytes, protein, or fat are added, mixing the solutions between 9-11% is advised to achieve approximate body fluid osmolality 280-300 mOsm.

Why avoid simple sugar gels, bars, and drinks? Simple sugars reduce calories absorption for the energy production. Maltodextrin calorie absorption is over double that of simple sugars at body fluid osmolality. The body's strict gastrointestinal controls on osmolality make the higher calorie absorbed maltodextrin the calorie-of-choice:

FUEL SOURCE	CALORIES @ BODY FLUID 280-300 mOsm SOLUTIONS
GLUCOSE	0.2
FRUCTOSE	0.2
SUCROSE	0.4
MALTODEXTRIN	1.0

ELECTROLYTES LOSS INFLUENCES PERFORMANCE

Electrolyte and fluid loss increases dramatically when the heat index approaches 60 degrees heat and 60% humidity. Fluid and electrolyte loss varies significantly between individuals. Sodium is the electrolyte depleted fastest even more than fluids

lost in sweat. Other electrolytes, Chloride, Potassium, and Magnesium, are lost at a lesser rate. Sodium from the average American diet is 6000-8000 mg above the daily life support requirement of 50-500 mg and the upper high-recommended dose 2400 mg/day amount. During high heat or humidity exercise sodium loss can be as high as 2000 milligrams per hour. Hormone signals immediately detect sodium depletion instructing the kidneys to stop filtering (halt excretion), for return to the circulation. Unfortunately, this "cease and desist" message fails to reach the skin, whose survival instincts profusely drive sweating to cool the body and brain. This occurs concurrently in spite of the kidneys emergency effort to preserve sodium from being further depleted through excretion. Exercise in the heat typically requires between 200-600 mg sodium replaced each hour to prevent sodium deficiency causing muscle cramps and inhibited carbohydrate solution absorption through the gut to the working muscles. Good research argues that a sodium-enhanced electrolyte formula should include Calcium, Vitamin B-6, and L-Tyrosine[35].

SEVEN APPLICATIONS FOR REDUCING DEHYDRATION (I-VII)
Individual biochemistry adapts to sport-specific training stress. Long training efforts below or at race-pace in hyperthermic conditions should be repeated at 65-75% of the distance raced once every 7-10 days. This "Long " training effort should be completed while consuming the mixture of fluids, fuels, and electrolytes that are to be used in competitive events. Athletes must train their bodies to adapt to environmental conditions. Heat stress exposure during exercise enables metabolic adaptations to take place as the body "learns" how to balance intake of fluid, fuel, and electrolytes against ongoing loss. There are seven performance failures that can be prevented by simply modifying fluid, fuel, and electrolyte protocols. Of the failures experienced, 90% were preventable by corrected fluid-fuel-electrolyte intake during acclimatization and fitness adaptations attained by during exposure to high heat index conditions:

PERFORMANCE INHIBITORS IN THE HEAT: WHAT I DID I DO WRONG?

I. DRANK TOO MUCH: Average fluid ounce intake exceeded 30 fl oz/hour and consumed to little or not electrolytes resulting in *DILUTIONAL HYPONATREMIA* symptoms:

(a) Strong thirst and loss of appetite.
(b) Increasing hemoconcentration, dry mouth, low urine or high clear urine output depending on individual biochemistry and volume of water loss or water dilution.
(c) Increased effort to exercise even at lower exercise rates.
(d) Difficulty concentrating, dizziness, increased HR, flushed or white skin.
(e) Muscle-spasms and muscle twitching, swollen tongue, inability to balance with eyes closed.
(f) Low plasma serum sodium below 130 mEq/L or mmol/d. Normal plasma serum sodium if highly diluted will be below 130 mmol/d or mEq/L.

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[35] Misner WD, NUTRITION FOR ENDURANCE: FINDING ANOTHER GEAR, Dolezal & Associates, Livermore, Calif.,1998: Chapter 26.

(g) Severe Heat Cramps with excessive salt-stain residue on clothing in an athlete who claims to have hydrated at least +30 ounces of fluids per hour or more each hour of exercise.
(h) Circulatory insufficiency, decreased blood volume, labored breathing.

Runners, or for that matter any athlete, who increases in blood volume but fails to increase sodium will predictably suffer "Water Intoxication" or dilutional hyponatremia. Water intoxication typically occurs to back-of-the-pack athletes in events lasting 4-12 hours. If an athlete lingers in aid stations drinking excessive amounts of fluid without replacing lost electrolytes, specifically sodium, excessive water intake may result in a performance-ending medical emergency. Elite athletes in the front of the pack tend to dehydrate due to poor fluid intake from not stopping to drink during the event. Elite athletes are also more fit, better acclimatized to deal with hyperthermic conditions, through practicing the same fluid-fuel-electrolyte solution replacement during training as consumed during the race.

OVERHYDRATION IS MORE DANGEROUS THAN DEHYDRATION
Failure to drink fluids during exercise is often an unrecognized cause of poor performance during endurance events, particularly when the heat and humidity increase. Fluid replacement has been emphasized to the point that overcompensation, drinking excessive amounts of electrolyte free water, may often lead to more serious and life-threatening hyponatremia (low blood sodium concentration). In fact, overhydration is a far more frequent finding in collapsed runners than dehydration. Overhydration or "water intoxication" including a low blood sodium concentration is accompanied by nausea, fatigue, confusion, and seizures, reduced performance.

DILUTIONAL HYPONATREMIA, occurs only in longer events of five hours or more and is potentially a bigger problem in slower athletes who:

- **Produce less heat, sweat less, experience less nausea, and drink more**
- **Cover the distance over a longer time interval**
- **Drink too much fluid in order to relieve fatigue or overheating**

There are several possible mechanisms for hyponatremia during prolonged exercise:

1. **Sodium losses in sweat are moderate but total body sodium content is near normal and replacement of fluid losses with a large volume of sodium-free fluids further dilutes the blood sodium concentration.**
2. **Both sweat volume (water) and sweat sodium losses are large and the sodium losses are inadequately replaced by electrolytes in snacks or commercial drinks. Water consumed further dilutes blood sodium concentration, but in this scenario, total body sodium is also diminished. (This is common in undertrained individuals or unacclimatized for competing in hot and humid conditions.)**

3. **An inappropriate release of the hormone vasopressin with exercise leads to a decreased urine volume but, unaware of this, the athlete continues water replacement at a normal rate. Total body sodium concentration is normal, total body water content is above normal or baseline. (This may be uncommon alone, but may play a role in combination with either of the above two scenarios in "1" or "2").**
4. **What about sodium? Sodium depletion is not a factor until 3-4 hours heat stress exposure. Low sodium intake foods reduces the sodium stores available to be recruited when needed. Sodium facilitates carbohydrate absorption (optimal concentrations have not been defined) from liquid carbohydrate drinks.**
5. **The body "defends" sodium concentration losses. When sodium replacement fails to keep up with sodium loss, the kidneys will stop filtering sodium from the blood stream. This is only a temporary "fix" for diminishing serum sodium levels. As fluids are consumed during exercise, diluting sodium further, which may inhibit performance.**

RECOMMENDED FLUID VOLUME RE-SOLUTION

A fluid intake of 500-850 ml/hr (16-29 fluid ounces) is appropriate for most athletes during prolonged exercise. Larger athletes, exercise at a high % of VO2 Max, and severe environmental conditions may require higher rates. Except for an unusual case of inappropriate vasopressin, hyponatremia is usually limited to periods of endurance exercise lasting more than 5 hours where it is can be identified by a weight gain from the excessive fluid retention as compared to that lost in the urine or sweat. Adequate hydration state is identified by an ideal weight at the end 2 hours or more exercise by a 2% loss in fluids weight. The 2% loss occurs from metabolized glycogen that release approximately 2-2.5 liters fluid weight.

ASSESSING FLUID INTAKE BALANCE:

1. **Athletes not assume that you can drink unlimited amounts of water or fluid during exercise expecting that it will be absorbed and the excess either lost in sweat or through the kidneys**
2. **Athletes should estimate real sweat and urine losses and replace them accordingly**
3. **Athletes should use a scale during training or during the event itself to answer the question as to whether water loss and replacement have been balanced correctly**

II. CONSUMED TOO MUCH SIMPLE SUGARED ENERGY FUELS (Sucrose, Glucose, Fructose products raise osmolality in the stomach above body fluid levels reducing absorption rates.

III. CONSUMED NO OR TOO LITTLE ELECTROLYTES

IV. CONSUMED CAFFEINE, GINSENG, NSAIDS, OR EPHEDRA-LIKE STIMULANTS

V. FAILED TO ACCLIMATIZE THEIR BODY TO HYPERTHERMIC CONDITIONS.

Heat-acclimatized athletes are cooler at the end of exercise in the heat largely because they are cooler at the start. The lower terminal temperature is not due to a reduction in heat storage. Implication? Slight drops in resting core temperature could be used as an index of the heat adaptation response when training in the heat[36]. Heat acclimatization requires 7-10 days exercising for 2-4 hours in the heat. Once heat acclimatization is accomplished by this grueling practice, the body will attain this adaptability to "handle the heat" for up to 2 weeks. How important is acclimatization by heat training exposure, consuming gastric-compatible fluids-fuels-electrolytes solutions. A review of this sweat composition research shows the adaptive electrolyte sparing effect achieved in fit-acclimatized athletes compared to excessive losses in fit-unacclimatized athletes. This further demonstrates the importance of how fitness and acclimatization impact electrolyte loss[37] during heat stress exposure:

ELECTROLYTE	FIT-ACCLIMATIZED g/l	FIT-UNACCLIMATIZED g/l
SODIUM	1.8	2.60
CHLORIDE	0.9	1.10
POTASSIUM	0.1	0.15
MAGNESIUM	0.1	0.10

Notice how fit acclimatized athletes required considerably less sodium than those did who were fit but not acclimatized to exercise in the heat. Fit-unacclimatized subjects lost nearly 2 times more sodium than those who were fit-acclimatized. There are dozens of electrolyte drinks, powdered mixes, pills, and potions. Chose a fuel, a fluid volume, and electrolyte that supports training through 65-75% of the race distance 1-2 every 3 weeks up to 4-6 weeks prior to the race.

VI. SELF-DESTRUCTED BY ELEVATING INDIVIDUAL BODY CORE TEMPERATURES TOO HIGH WITHOUT PERODIC COOLING

Sponging face, neck, chest, stomach and shoulders with a wet towel or sponge has lowers body temperature effectively. During extreme temperatures take 1-minute breaks for every 5 minutes exercise. Some athletes take 1-minute breaks from exercise, drink fluids, sponge off, and lower their body core temperatures by 3-5 degrees. Core heat accumulates and increases rapidly from metabolism associated with pace intensity and from external heat index exposure. As intensity or rate of exercise increases, the body must pump

[36] Buono MJ, Heaney JH, Leichliter SG, Vurbeff GK., Acclimation to humid heat reduces resting core temperature but not heat storage. Medicine and Science in Sports and Exercise, 1997; 29(5), Supplement abstract 560.

[37] Verde, T., et al., Sweat Composition in Exercise and Heat, JOURNAL OF APPLIED PHYSIOLOGY,1982;53(6):1541-1543.

more blood to dissipate more heat through increased capillary blood flow to the skin. Faced with overheating, the body cools itself by increasing blood flow to working muscles, disposing of heat through evaporative or convective heat dissipation. Reducing the pace 1 out of every 5 minutes or miles increases the rate by which heat is dissipated during extreme 3-digit temperature readings including when the humidity readings 60% or above. Jumping into a cool lake, a stream, or cold shower will also effectively reduce body core overheating. If you are overheated, reducing accumulated heat stores keeps you in the passing lane while all those around you are wasting away, wilting in the heat.

VII. CLOTHING CHOICES

"Fish Net" clothing provides the best heat loss evaporative effect. Light colored clothing dissipates heat far better than dark clothing in the heat. Shade temperatures are 10 degrees less than temperatures recorded in direct sunlight. A wet cotton cloth draped over the head or under a cap with a visor reduces core temperature of the brain by 10 degrees. Shading the head lowers brain temperature, which reduces fluid and electrolyte loss. An overheated head is a physiological trigger that stimulates extraordinary fluid and electrolyte loss. Riding with a helmet produces a greater evaporative cooling effect than riding without a helmet. Direct or high-angle sunlight heat is hottest during the hours of 10 A.M. to 4:00 P.M. and should be avoided by seeking shaded areas.

CONCLUSIONS

Drinking 25-29 fluid ounces per hour prevents most hyerthermic hydration-associated disorders. A significant number of athletes with performance-ending issues in the heat from dehydration, gastric stress, muscle cramps, water intoxication, or diagnosed hyponatremia over the past 9 years, present 3 characteristics:

1. **Fluid weight gain**
2. **Inadequate electrolyte intake**
3. **Drinking 30 ounces fluid per hour or more during a hot or humid event**

Acclimatization during training reduces fluid and electrolyte loss by 50%. Acclimatization is attained by heat exposure training and consuming 25-29 fluid ounces water with 2.5-3.0 ounces Hammer Gel, HEED, Sustained Energy, or Perpetuem (+/-0.5 ounce). Each individual needs to experiment with these solutions to fine tune the optimal mixture for their physiology. The test to determine adequate hydration status is comparing body weight changes before and after exercise. Expect a 2% ideal weight loss to confirm hydration adequacy. As glycogen is metabolized for the energy, water is released. This water released between 90-120 minutes exercise may account for approximately 2% the total body weight. When core temperatures increase, the body's survival priority drives blood volume into dilated capillary beds in the skin, releasing sweat for evaporative cooling. If the athlete's finish weight is the same or more, fluid overdose has occurred. The finishing weight should ideally be 2% lower than pre-exercise weight confirming

adequate fluid intake. Body weight at the finish supports the application favoring small frequent divided doses totaling 20-25 fluid ounces isotonic drink each hour (+/- 4 fluid ounces) for endurance exercise activities lasting 2-hours or more.

Therefore, this is the recommended "Solution for Performance."

#2 What is the role of sodium during hyperthermic endurance events?

THE ROLE OF SODIUM TO PREVENT HYPONATREMIA DURING ENDURANCE EVENTS - A REVIEW OF LOW SODIUM INTERVENTION

Bill Misner Ph.D.[38]

Introduction

This is a review of the relative reference ranges of sodium and fluids required to prevent health-compromising, performance-inhibiting severe or critical hyponatremia in endurance events lasting 4 hours or longer. The rationale concludes that low sodium (12 mg) intake per fluid ounce energy drink at the rate of no less than 13.5 fluid ounces to no more than 27 fluid ounces with 200-300 isotonic carbohydrate calories will prevent severe or critical hyponatremia in 99% of all fit acclimatized athletes. One percent of the athletic population is an exception to this conclusion however that percent increases remarkably if the athlete is either not fit or not acclimatized to the effects from heat and/or humidity on fluids and sodium losses generated.

SODIUM OVERDOSE IMPLICATIONS

Sodium is the principal anion (negatively-charged ion) in intracellular fluid. The average person human body contains 95 grams (mainly from of Sodium Chloride). Sodium comprises 0.15% of human body weight. Approximately 60% or 57 grams of human sodium is stored in the fluids surrounding the cells (extracellular) while only 10% or 9.5 grams concentrates inside the body's cells (intracellular). The average American diet contains 2-20 grams of Sodium per 24-hour period. From over 70 individual dietary analyses, the average dietary sodium intake ranged between 6000-8000 mg daily. Most Americans consume too much sodium. The American Diabetes Association (ADA) recommends limiting sodium intake to 2,400 mg (2.4 g) or sodium chloride (salt) to 6,000 mg (6 g) per day. By contrast, ADA's nutrition scientists have determined that the upper dose limit for Sodium to be 2400 mg (2.4 grams) in a 24-hour period. There is good reason to limit chronic sodium intake. Excess salt use or high dietary sodium has been associated from with congestive heart failure, high blood pressure, gastric ulcers, muscle stiffness, irritability, PMS Syndrome, edema, thirst, liver disorders, and osteoarthritis.

To maintain health, humans require only 8-21 mg sodium available to the circulation each hour (500-2,000 mg 0.5-2.0 grams/24-hours), when not exercising at

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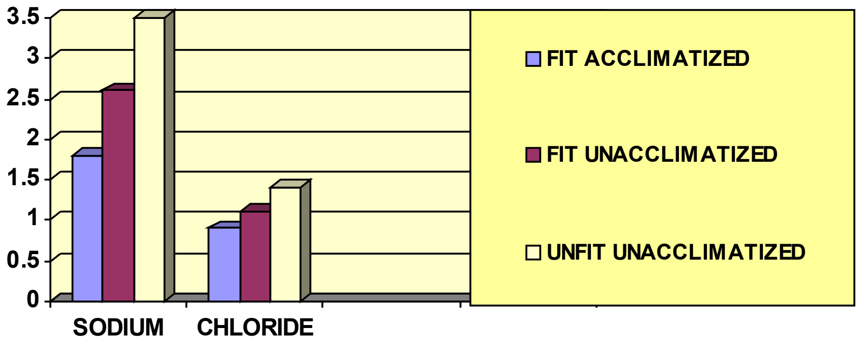
normal body temperature. If a low sodium intake supports sedentary health at a rate of for each 24-hour period, should not a low sodium intake be configured to sustain health during exercise when ambient temperatures increase and core body temperatures increase proportionate to volume oxygen intake. The more oxygen consumed per time unit the more internal heat core body temperatures increase, which increases the rate of sweat (fluids) loss and sodium loss.

According to Brooks & Fahey (1984), a fit-exercising athlete requires 12-20 times the oxygen during metabolic energy production, as does the unfit, sedentary person. When this minimum 8-21 mg sedentary sodium requirement is factored by exercise-induced oxygen increases of 12-20 times O^2, four different sodium repletion dose rates are generated for estimating sodium loss to increased O^2 requirements:

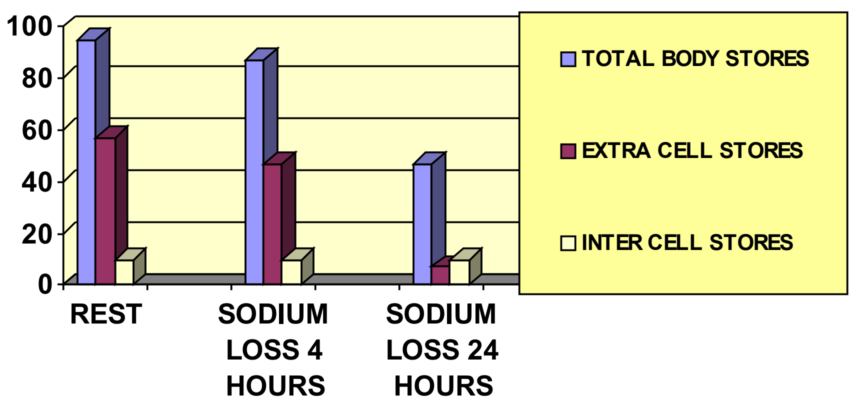
1. 96 mg/hour (12 X 8 mg)
2. 160 mg/hour (20 X 8 mg)
3. 252 mg/hour (12 X 21 mg)
4. 420 mg sodium (20 X 212 mg)

For walking at a light easy pace, sodium required may be as little as 96 mg sodium per hour per 34 fluid ounces (1 liter) to reduce the negative effects from losses at either a slow or all-out effort. With increased O^2 metabolic demand, sodium requirement based on oxygen rate relative to metabolic heat created may increase proportionately to as high as 420 mg sodium per hour per liter fluid intake to reduce negative hyponatremic symptoms. To determine if the low-sodium intervention is merited for prevention of severe or critical hyponatremia in endurance athletes, an intake of 96-420 mg sodium (median – 258 mg per liter 34 fluid ounces), I reviewed a number of research studies that measured sodium and fluid depletion during extreme endurance events. I asked based on collected observations that 99 out of 100 athletes using Endurolytes (1997-2005), a low sodium electrolyte supplement, 160-320 mg sodium per 24-28 fluid ounces or (0.19-0.38 g/l) why this lower sodium dose replaced, balanced serum sodium depletion, and reduced the symptoms of performance-inhibiting hyponatremia during hyperthemic endurance exercise.

EXERCISE-INDUCED SODIUM & CHLORIDE LOSS
GRAMS PER LITER PER HOUR
(Verde et al., 1982)



SODIUM IS DEPLETED THROUGH EXTRACELLULAR FLUID LOSS BY SWEAT-INDUCED EVAPORATIVE COLLING WHEN NOT REPLACED



No one should expose themselves to health compromising, performance-debilitating HYPERNATREMIA or HYPONATREMIA during sedentary or endurance exercise.

HYPERNATREMIA is sodium-toxicity, which generates symptoms shortly after sodium consumption approaches 12,000 mg (12 grams) or more in a 24-hour period.

HYPONATREMIA is defined to the degree that plasma sodium concentrations fall below 135 mmol/L. Normal reference range for plasma sodium concentrations is 135-145 mmol/L. Symptoms of mild hyponatremia begin to appear when plasma sodium progress under <135 mmol x L(-1). Severe hyponatremia symptoms digress as plasma sodium levels deteriorate below < 130 mmol x L(-1). Critical hyponatremia occurs when sodium blood values below 120 mM, and, are often fatal.

EXCESS CHRONIC DIETARY SODIUM (OR SALT) COMPROMISES HEALTH

Excess chronic dietary sodium or salt use has been associated with congestive heart failure, high blood pressure, gastric ulcers, muscle stiffness, irritability, PMS Syndrome, edema, thirst, liver disorders, and osteoarthritis:

1. **CONGESTIVE HEART FAILURE: In congestive heart failure the activation of the renin-angiotensin-aldosterone system causes sodium retention and the secondary hyperaldosteronism may result in elevated intracellular sodium via a direct permeability effect on the cell membrane. In 297 congestive heart failure patients (previously treated with diuretics), 12% were found to have abnormally high blood sodium levels and 57% had excessive muscle sodium (Wester et al. 1986).**
2. **HYPERTENSION CAUSED BY SALT, NOT SODIUM: Many researchers believe that sodium elevates blood pressure and is therefore implicated in hypertension (Haddy et al.1995, Skrabal et al. 1981, Gordon, L. 1995). This aspect of sodium is still being debated and many researchers also believe that sodium has been falsely "blamed" for hypertension when the true cause is the chlorine component of sodium chloride.**
3. **GASTRIC ULCERS: Excessive consumption of Sodium is associated with an increased risk of Gastric Ulcers (Sonnenberg 1986).**
4. **CALCIUM LOSS BONE MINERAL MASS LOSS: Excessive sodium (above 2 grams per day) increases the body's excretion of calcium via the urine (Evans et al. 1995, Matkovic et al. 1995, Heaney 1996). Increasing sodium consumption by 1 gram per day causes 500 mg calcium taken from bone can attribute to bone loss of 1% per annum unless calcium loss is compensated for by supplementation or increased dietary calcium intake (Shortt et al. 1988).**
5. **CATARACTS: Persons who consume the highest amounts of salt (and butter) have double the cataract risk compared with persons who consume the lowest amounts of these foods (Tavani et al. 1996).**
6. **TOXIC METAL EXCESS: Aluminum is often added to commercially manufactured table salt as an anti-caking agent. Avoid or limit all high-salt processed foods. Excess toxic Aluminum deposits have been reported in Alzheimers patients compared to less Aluminum in persons in the same age and locale.**

HYPONATREMIA DEFINED: LOW OR DILUTED SERUM SODIUM
Hyponatremia is defined as a plasma sodium concentration lower than 135 mmol/L. High sweat loss creates even higher proportionate losses in serum sodium. Consuming too much fluid volume dilutes sodium further changing a rapid gain in fluids with a high sodium loss into a medical emergency sometimes called dilutional hyponatremia. Of 371 athletes (62% of all finishers) whose weights were measured before and after the 226 km South African Ironman Triathlon, the athlete who gained the most weight (3.6 kg) during the race was the only competitor to develop symptomatic hyponatraemia. During recovery, he excreted an excess of 4.6 litres of urine. This case report again confirms that symptomatic hyponatraemia is caused

by considerable fluid overload independent of appreciable NaCl losses. Hence prevention of the condition requires that athletes be warned not to drink excessively large volumes of fluid (dipsomania) during very prolonged exercise. This case report also shows that there is a delayed diuresis in this condition and that it is not caused by renal failure (Noakes et al. 2004).

LIMITING FLUID INTAKE PREVENTS HYPONATREMIA

During endurance exercise, about 75% of the energy produced from metabolism is in the form of heat, which cannot accumulate. The remaining 25% of energy available can be used for movement. As running pace increases, the rate of heat production increases. Also, the larger one's body mass, the greater the heat production at a particular pace. Sweat evaporation provides the primary cooling mechanism for the body, and for this reason athletes are encouraged to drink fluids to ensure continued fluid availability for evaporation and circulatory flow to the tissues. Elite level runners could be in danger of heat illness if they race too quickly in hot/humid conditions and may collapse at the end of their event. Most marathon races are scheduled at cooler times of the year or day, however, so that heat loss to the environment is adequate. Typically, this postrace collapse is due simply to postural hypotension from decreased skeletal muscle massage of the venous return circulation to the heart on stopping. Elite athletes manage adequate hydration by ingesting about 200-800 mL/hour, and such collapse is rare. Athletes "back in the pack" are moving at a much slower pace, however, with heat accumulation unlikely and drinking much easier to manage. They are often urged to drink "as much as tolerable," ostensibly to prevent dehydration from their hours out on the race course. Excessive drinking among these participants can lead to hyponatremia severe enough to cause fatalities. A more reasonable approach is to urge these participants <u>not to drink</u> as much as possible but to drink ad libitum (according to the dictates of thirst) no more than 400-800 mL/hour or 13.5-27.0 fluid ounces (Noakes 2003).

Twerenbold' s data (Twerenbold et al. 2003) confirms that intake of 1 liter/hour in female endurance athletes leads to fluid overload and occasional hyponatraemia (in spite that 1 litre/hour is commonly taken and often recommended for fluid replacement in endurance exercise). Each fluid liter provides 33.8 fluid ounces. For 34-fluid ounces to be sodium-effectual, Twerenbold observed that 680 mg sodium/liter reduces the risk of hyponatremia, which calculates @ 20 mg/fluid ounce solution or between 270-540 mg sodium to meet the Noakes' research recommendation 13.5-27.0 fluid ounces (Noakes 2003) What lower sodium/liter or sodium per fluid ounce values inhibit the onset of hyponatremia? Vrijens and Rehrer (1999) found smaller decreases in [Na+-plasma] when subjects drank 1.2 litres of a sodium-containing sports drink (410 mg/l) an hour compared with water. Twerenbold control product (trial L) also contained 410 mg sodium/l and our results support their findings. A 410 mg sodium/l is 12 mg sodium per fluid ounce and if applied to Noakes' lower fluid volume recommendations between 162-325 mg sodium in 13.5-27.0 fluid ounces may also reduce the risk of dilutional hyponatremia. At the lower fluid ounce intake recommendations, the hyponatremia-

preventative sodium requirement is met by consuming 1-2 Endurolytes every 15 minutes even when the temperature and humidity is high and exercise duration exceeds 4 hours or more.

Hyponatremia is a common biochemical finding in ultra distance triathletes but is usually asymptomatic. Typical mild hyponatremia has been associated with variable body weight changes, fluid overload was the cause of most (73%) cases of severe, symptomatic hyponatremia ([plasma sodium] <135 mmol x L(-1))

BODYWEIGHT GAIN MORE THAN LOSS IS CORRELATED WITH HYPONATREMIA

Complete data on pre- and postrace weights and plasma sodium concentrations were available in 330 race finishers out of 605 of the 660 athletes entered in the New Zealand Ironman triathlon (3.8-km swim, 180-km cycle, and 42.2-km run). They were weighed before and after the race. A blood sample was drawn for measurement of plasma sodium concentration after the race. Postrace plasma sodium concentrations were inversely related to changes in body weight (P = 0.0001).

Women (N = 38) had significantly lower plasma sodium concentrations (133.7 vs 137.4 mmol x L(-1); P = 0.0001) than men (N = 292) and lost significantly less relative weight (-2.7 vs -4.3%; P = 0.0002).

Fifty-eight of 330 race finishers (18%) were hyponatremic; of these only 18 (31%) sought medical care for the symptoms of hyponatremia (symptomatic). Eleven of the 58 hyponatremic athletes had severe hyponatremia ([plasma sodium] < 130 mmol x L(-1)) ; seven of these 11 severely hyponatremic athletes were symptomatic.

MILD HYPONATREMIA ([plasma sodium] 130-134 mmol x L(1)), in contrast, showed a relative body weight change in 47 athletes were more variable, ranging from -9.25% loss to +2.2% weight gain (Speedy et al.1999).

SEVERE HYPONATREMIA ([plasma sodium] < 130 mmol x L(-1)) typically increased body weight gain in spite of fluid weight losses, though a few finished the event at the same weight as at the start. Relative body weight increased in these 11 severely hyponatremic athletes ranged from +2.4% to +5.0%; eight (73%) of these athletes either maintained or gained weight during the race.

WHAT IS THE EFFECT OF *LOW SODIUM* VS SODIUM-FREE FLUIDS?

Gatorade generates 11.9 mg sodium per fluid ounce, 405 mg sodium with 240 calories simple sugar per liter. Vrijens & Rehrer (1999) assessed whether replacing sweat losses with sodium-free fluid would lower the plasma sodium concentration and thereby precipitate the development of hyponatremia.

Ten male endurance athletes participated in one 1-h exercise pretrial to estimate fluid needs and two 3-h experimental trials on a cycle ergometer at 55% of

maximum O2 consumption at 34 degrees C and 65% relative humidity. In the experimental trials, fluid loss was replaced by distilled water (W) or a sodium-containing (18 mmol/l) sports drink, Gatorade (G). Six subjects did not complete 3 hours in trial using Water, and four did not complete 3 hours in trial Gatorade. The rate of change in plasma sodium concentration in all subjects, regardless of exercise time completed, was greater with Water than with Gatorade (-2.48 +/- 2.25 vs. -0.86 +/- 1.61 mmol. l-1. h-1, P = 0.0198). Only onee subject developed hyponatremia (plasma sodium 128 mmol/l) at exhaustion (2.5 hours) in the W trial.
A decrease in sodium concentration was correlated with decreased exercise time (R = 0.674; P = 0.022). A lower rate of urine production correlated with a greater rate of sodium decrease (R = -0. 478; P = 0.0447). Sweat production was not significantly correlated with plasma sodium reduction. These results show that decreased plasma sodium concentration can result from replacement of sweat losses with plain water, when sweat losses are large, and can precipitate the development of hyponatremia, particularly in individuals who have a decreased urine production during exercise. Exercise performance is also reduced with a decrease in plasma sodium concentration. They conclusively recommended consumption of this sodium-containing beverage (11.9 mg sodium & 7 carbohydrate calories per fluid ounce) to compensate for large sweat losses incurred during exercise (Vrijens & Rehrer 1999).

COMMENT: If T.D. Noakes' lower fluid intake values are applied to the recommendations reported by Vrijens & Rehrer, sodium requirements to prevent severe hyponatremia for each hour in each 13.5-27.0 fluid ounces is 161-321 mg, or 4-8 endurolytes with 2.4 servings Hammer Gel, 2.4 scoops HEED, 2 heaping scoops Sustained Energy, or 2 scoops Perpetuem.

WHAT ACTUAL BIOCHEMICAL CHANGES OCCUR DURING ENDURANCE EVENTS?

#1 Gastmann et al. (1998) performed a case study on 9 Ultra-triathletes collecting their blood-chemistry & endocrinological responses from a 24-hour endurance event.
A large body of individual hematological, biochemical, and endocrinological parameters was analyzed in the blood taken from ultra-athletes before and after completing the 1993 Colmar ultra triathlon covering 7.5 km swimming, 360 km cycling, and approximately 85 km running. Nine experienced ultra-athletes participated in the study. These 9 athletes finished the ultra-contest at rankings 4, 5, 7, 8, 9, 11, 18, 22, 23 in a total time between 23:38:53 and 27:54:30 hr:min:sec. Their final body mass (68.6 +/- 1 kg) was significantly lower than at baseline (71.9 +/- 4.2 kg). This reflects 3.3 kg average weight loss (7.26 lbs) a large 4.5% body weight loss, <u>yet not one of the athletes made use of medical care.</u>

Data after this contest reflected the following blood-chemistry-endocrinological responses:

1. **Mild Hyponatremia**
2. **Intravascular Hemolysis**

3. **Increased Triglyceride Turnover**
4. **Acute-phase Reaction**
5. **Hyperaldosteronemia 2061 +/- 1013 Pmol.l-1)**
6. **Hypercortisolemia 971 +/- 486 Nmol.l-1)**
7. **Hyper-growth-hormonemia (Median 6.8 Ng.ml-1)**
8. **Hypoinsulinemia**
9. **Hypo-free-testosteronemia (42 +/- 17 Pmol.l-1)**
10. **Protein Catabolism**
11. **Depressed Testicular Function**
12. **Oliguria Muscle Cell Leakage**

In their reported opinion, the above data presented do not reflect any acute health risks in healthy athletes who are well prepared and carefully supplied during such a contest (Gastmann et al. 1998).

FLUID OVERDOSE AND LOW PRE-EVENT SERUM SODIUM INCREASE VASOPRESSIN HORMONE LEVELS RESULTING IN HYPONATREMIA
#2 The etiology of hyponatremia (HN) endurance athletes sometimes is uncertain. A case (Armstrong et al. 1993 report) presents physiologic evidence regarding the etiology and development of HN during exercise in the heat. A 21-yr-old male volunteer (K.G.) unexpectedly experienced symptomatic HN during a research investigation that involved controlled sodium (Na+) intake (137 mEq Na+.d-1 for 7d) and exercise-heat acclimation (41 degrees C; 30 min.h-1, 8 h.d-1 for 10 d).

Fluid balance, physiologic variables, and hematologic/hormone data were measured before and after the HN episode, with similar measurements recorded for nine unaffected volunteers. The results indicated:

1. **HN was verified in K.G. (plasma Na+ < 130 mEq.l-1) after only 4 hours of mild, intermittent exercise in heat**
2. **K.G.'s heart rate, rectal temperature, blood pressure, and Na+ losses in sweat and urine were < or = control subjects at all times**
3. **Between hours 4-7, an inappropriately large release of Vasopressin coincided with a decrease of urine volume to 0 ml.h-1.**

Vasopressin (AVP, ADH, or antidiuretic hormone} is a protein known as a hormone which regulates sodium by effects on the kidney: it increases permeability to water in the distal and collecting tubule, increases permeability to urea in the collecting tubule of the kidney, and increases sodium and chloride resorption of the ascending tubule. The kidney is responsible for most of the excretion of sodium from the body, although large amounts can be lost in sweat and feces. Sodium (Na) is one of the major electrolytes in the body, along with others such as potassium, calcium, magnesium, and chloride. The normal level of serum (blood fraction) sodium is 135-145 mM. Sodium levels below 135 mM are designated hyponatremia, and values below 120 mM are often fatal. They concluded that a large intake (10.3 l.7h-1) and

retention (2.77 l.7h-1) of water and a "low normal" initial plasma Na+ (134 mEq.l-1) were primary factors in the development of HN in K.G., whereas Na+ losses in sweat and urine were normal and served only to exacerbate HN. He consumed nearly 50 fluid ounces per hour for 7 hours while exercising in the heat appears to have been tolerated for 4 hours, but afterwards even large releases of vasopressin were unable to moderate excess fluid overdose resulting in severe hyponatremia.

HYPONATREMIA OF EXERCISE

#3 Noakes et al. (1992) reported that the hyponatremia of exercise might exist in symptomatic and asymptomatic forms. Symptomatic hyponatremia is usually characterized by severe alterations in cerebral function including coma and grand mal seizures; it develops especially in less competitive athletes who have maintained high rates of fluid intake during endurance events lasting at least 5 hours. The hyponatremia becomes symptomatic when the volume of excess fluid retained exceeds 2 to 3 liters. The etiology of the condition is unknown. Possibly as many as three or more pathologies (abnormal fluid retention possibly due to inappropriate ADH secretion, abnormal regulation of the extracellular fluid volume, translocation of sodium into a "third space") must be present for symptomatic hyponatremia to develop. The avoidance of overhydration would appear to be the only certain way that susceptible individuals could prevent symptomatic hyponatremia. Sodium chloride containing solutions ingested in physiologically significant concentrations would likely prevent a possible "third space" effect.

SWEAT COMPOSITION DURING PROLONGED HYPERTHERMIC EXERCISE

#4 Morgan et al. (2004) determined whether acute exercise-heat-induced dehydration affects sweat composition, eight males cycled for 2 h at 39.5 +/- 1.6% VO2peak on two separate occasions in a hot-humid environment (38.0 +/- 0.0 degrees C, 60.0 +/- 0.1% relative humidity). METHODS: During exercise, subjects ingested either no fluid (dehydration) or a 20 mmol L(-1) sodium chloride solution (euhydration). The volume of solution, calculated from whole-body sweat loss and determined in a familiarization trial, was ingested at 0 min and every 15 min thereafter. Venous blood was collected at 0, 60 and 120 min of exercise and sweat was aspirated from a patch located on the dominant forearm at 120 min. RESULTS: Following the 2-h cycling exercise, sweat [Na+] and [Cl-] was greater (P < 0.05) in the dehydration trial (Na+ 91.1 +/- 6.8 mmol L(-1); Cl- 73.3 +/- 3.5 mmol L(-1)) compared with the euhydration trial (Na+ 81.1 +/- 5.9 mmol L(-1); Cl- 68.5 +/-3.3 mmol L(-1)). In addition, dehydration invoked a greater serum [Na+] (142.2 +/- 0.7 mmol L(-1); P < 0.05), [Cl-] (105.8 +/- 0.6 mmol L(-1); P < 0.05) and [K+] (5.27 +/- 0.2 mmol L(-1); P < 0.05) over the euhydration values for [Na+], [Cl-] and [K+], respectively (138.9 +/- 0.6, 102.9 +/- 0.5 and 4.88 +/- 0.1 mmol L(-1)). Plasma aldosterone was also significantly higher during exercise in the dehydration trial compared with the euhydration trial (53.8 +/- 3.8 vs. 40.0 +/- 4.3 ng dL(-1); P < 0.05). CONCLUSIONS: Acute exercise-heat stress without fluid replacement resulted in a greater sweat (Na+) and (Cl-) which was potentially related to greater extracellular fluid (Na+), plasma aldosterone or sympathetic nervous activity.

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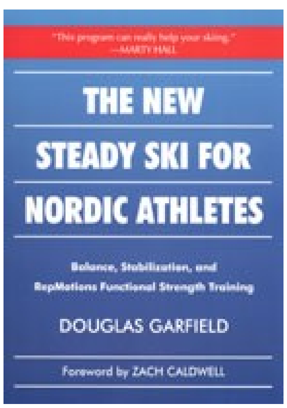
#3 What is the best core exercise protocol for skiing, cycling, and running athletes?

Book Review



LINK

"A must read for all skiers." - Len Johnson

The New Steady Ski for Nordic Athletes

Great Balance, Stabilization & Strength Training Book
By Douglas Garfield 2003, Motioneering, Inc.

"Like me, you've probably heard about core strength and how it's important for skiing. I'd recently received a set of recommended core strength exercises from my coach, Torbjorn Karslen. He said that he'd done a core strength session with Becky Scott and finally realized what a great workout it was. Unfortunately, he never supplied an explanation about why it was important or how it was different than just working the abs." - Mike Muha 2003

"*The New Steady Ski for Nordic Athletes*" is the icing on the cake if you are a half-serious cross-country ski racer. Author Doug Garfield said, 'We know that the more specific the training, the better the results for Nordic skiers.' And this is what this book is all about, specificity and more. The more being

chapter 3 where Doug reveals his new strength training concept, "*RepMotions*." Evolutionary, or is revolutionary, the concept is so logical, why didn't someone come up with it years ago. We'll all be doing it real soon, it is as simple as that!" -Marty Hall, US National Team Coach (1969-1979), Canadian National Team Coach (1981-1992), Bowdoin College Coach (since 1999).

In the last issue of J.O.E., I recommended Dr. Garfield's latest book, *RepMotions*, which reintroduced progressive resistance training as a practical resource for both athletes and medical professionals involved in peak performance training. Many cold-climate cyclists and runners ski during the winter.

The New Steady Ski for Nordic Athletes **is a very well illustrated core-exercise intervention for cyclists, runners, and skiers. It is slanted toward ski-exercise specificity, but the carry-over for runners and cyclists with low back issue needs to be mentioned here. Core strengthening exercises are shown to reduce low back position-related issues that result during cycling or running seasons. These are the latest proprioception exercises and are highly recommended. This exercise method though complex is easy to learn by simply following page after page of illustrated instructions[39].**

[39] Disclosure: I, nor EMG, has competing interests related to the sale of Dr. Garfield's books. Bill Misner, Ph.D., C.S.M.T. AAMA Board Certified Alternative Medicine Practitioner, Certification #38272409 EMG Director Research & Product Development, http://www.e-caps.com/

[i] **ENDUROLYTE mOsm = 25-40 mOsm/capsule solution calorie mix dependant**
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