Fluids, Electrolytes & Exercise

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Introduction

- One of the most important factors in maintaining performance
- Slight dehydration (~1% of wt.) can adversely effect physical activity
- Greater dehydration is known to impair performance significantly
- Hydration before, during and after activity can help replenish and maintain performance in athletes

History

- 1930's and WW2
  - dehydration by less than 3-4% body weight is detrimental
- Through 1960's
  - Athletes ignored thirst and advised to consume minimal fluids
  - dehydration of 3-4% body weight was okay
- 1996
  - Athletes should replace all lost fluids

Control of Fluid Balance: Renin-Angiotensin System

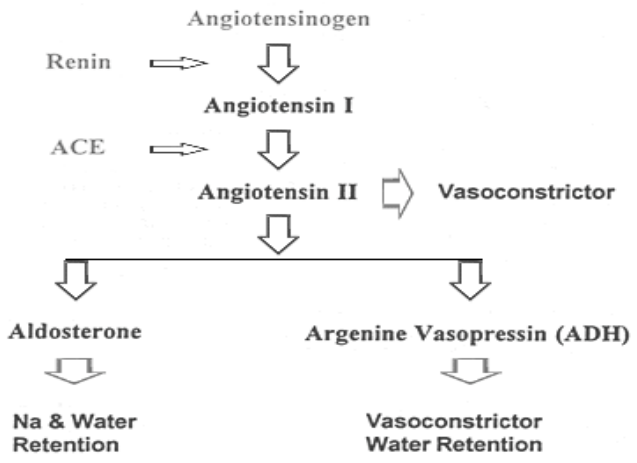


Image: http://www.vetgo.com/cardio/concepts/concsect.php?conceptkey=20242

Control of Fluid Balance

- Thirst is not an accurate indicator of need
  - Athletes will voluntarily consume about 50% of fluid lost during exercise

Image: http://manch.me/?m=201003

Adequate Intake

- Sedentary adults
  - 3.7 liters/day for males (130 oz/day)
  - 2.7 liters/day for females (95 oz/day)
- Athletes
  - It depends…
  - 7-10 liters/day in warm environment
  - Lose 1-2 liters of sweat/hr during exercise

Daily Body Fluid Loss

- Urine
- Feces
- Sweat
- Respiration
- Menstrual flow in women

Image: http://www.getfrank.com.au/your-body/?start=10

Factors that Affect Daily Fluid Loss

- Environment
- Temperature
- Humidity
- Metabolic rate
- Diet
- Fluid excretion
- Activity level

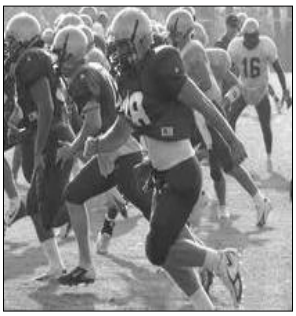


Image: http://health.usf.edu/medicine/orthopaedic/smart/researchprojects.htm

Where Can Fluids Come From?

- Fruits
- Vegetables
- Meals/soups
- Milk
- Juice
- Coffee
- Tea
- Sports drinks
- Water

Typical Fluid Losses (ml) for 70-kg Athlete

	Normal Weather 68^0F	Warm Weather 85^0F	Exercise in Warm Weather 85^0F
Skin	350	350	350
Respiratory	350	250	650
Urine	1400	1200	500
Feces	100	100	100
Sweat	100	1400	5000
TOTAL	**2300**	**3300**	**6600**

Cold Weather & Fluid Loss

- Cold air contains limited water vapor
- Body must humidify inhaled air
- Water loss can exceed 1 liter/day

Image: http://www.zone4.ca/skifaster/article.asp?DocumentID=1295

Electrolytes

- Lost anytime body excretes fluid
  - Urinary excretion
  - Sweat
- Range: 4-10 liters daily
  - Na^+ Cl^- → main electrolytes lost in sweat
  - Potassium myth
  - Sodium loss range → 460 – 1840 mg/L
  - DRI Sodium = 2300mg/day
  - DOES NOT APPLY TO ATHLETES

Electrolyte Losses in Sweat

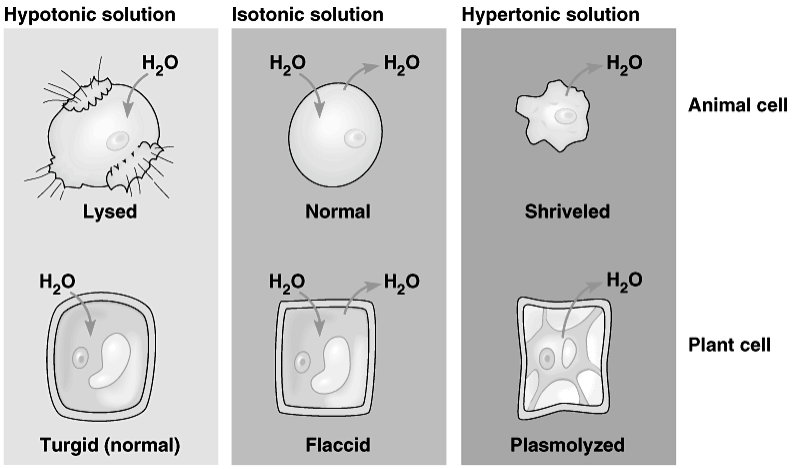
Mineral	Sweat Conc. (mg/L)	AI Values (mg/d)	Range of AI Lost in Sweat (%/L)
Sodium	460 – 1840	1300	35 – 140
Chloride	710 – 2840	1300	35 – 140
Potassium	160 – 390	4700	3 – 8
Magnesium	0 – 36	240 – 420	0 – 15
Calcium	0 – 120	1000 – 1300	0 – 12

Electrolytes

- Salt craving in humans
  - No mechanism to detect loss of K, Ca, Mg
- Adequate intake (kcal/macro) → positive mineral balance
- Inadequate intake → negative mineral balance
- Adequate intake + high activity → ? mineral balance
  - Possible hyponatremia and muscle cramping

Electrolytes

- Balance is crucial for fluid retention
- Allows proper cellular function
  - ex: hyperkalemia → fatal rx of cardiac muscle
- Kidney functions to sort out minerals
  - Absorption vs. Excretion



Environmental Extremes

- Heat
  - Severe fluid loss via sweat.
  - Can require up to 10L H_2O & 20g NaCl
- Humidity
  - Unacclimatized athletes decrease heat release
- Water immersion
  - Increases plasma volume → baroreceptors → inc. urine output
  - Sweat threshold
- Altitudes
  - Increased ventilation (as in cold weather)
  - Increased urine output (baroreceptors)
- Reduced gravity

Fluid Needs Before Exercise

- Goal: Begin exercise euhydrated
- ADA: 7mL/ kg BW of water 2 hours before exercise.
- 70 kg athlete- 500 mL of fluid
- ACSM: begin hydration 4 hours prior
- Allows time for fluid excretion
- Excess water – cramps, hyponatremia

uncooped.com

Fluid Needs During Exercise

- Goal- Replace fluid losses
- Drink early and at regular intervals
- 10-30 minute intervals
- Thirst imprecise regulator
- Flavored and sweetened
- Sodium and Potassium-
- Sodium intake 1 g/ hr in heavy sweating

TABLE 6.4 Beneficial Responses to Adequate Fluid Intake During Exercise

Characteristic	*Response*
Heart rate	Lower
Stroke volume	Higher
Cardiac output	Higher
Skin blood flow	Higher
Core temperature	Lower
Perceived exertion	Lower
Performance	Better

Source: Data are from references 7 and 42.

Fluids Needs After Exercise

- Goal: Replace lost fluids
- Plain water not effective rehydrator
- Food
- May need to ingest fluid in excess of loses- urine output (25-50% more)
- Don't restrict sodium
- Avoid alcohol and caffeine

Box 6.2 Tips to Encourage Fluid Intake

- Educate coaches, trainers, supervisors, parents, and athletes about the benefits of proper hydration.
- Create educational posters, flyers, brochures, or presentations.
- Have palatable fluids readily available.
- Establish individualized fluid replacement regimens.
- Compare pre- and post-exercise weights.

Images.google.com

Recommendations

- **Do**
- Weigh yourself
- Drink during exercise
- Ingest sodium during exercise
- Follow your own plan
- Drink with meals

- **Don't!**
- Rely only on water
- Over-drink
- Gain weight during exercise
- Don't restrict salt

Estimation of Prepractice Hydration Status of National Collegiate Athletic Association Division I Athletes

Volpe, S., Poule, K., & Bland, E. (2009). Estimation of prepractice hydration status of National Collegiate Athletic Association Division I athletes. *Journal of Athletic Training*, *44*(6), 624-629. Retrieved from CINAHL Plus with Full Text database.

wiki-land.wikispaces.com

Purpose

- Prepractice hydration status of college athletes
- Men and women
- Team Sports

Methods

- Cross-sectional study
- 138 male, 125 female athletes
- New England University
- One urine sample 1 hr before practice
- Fluid intake

Table 2. Collegiate Team Sports Represented in the Sample

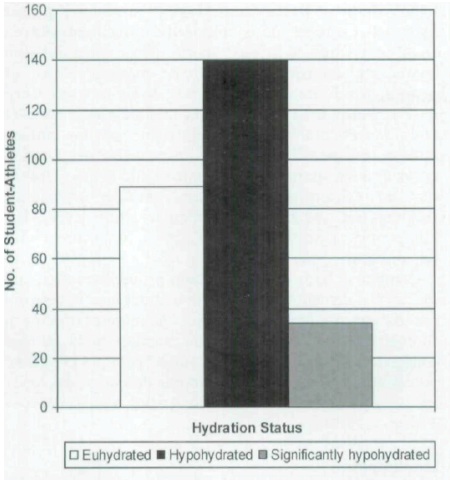
	Sport	n
Men (n = 138)	Baseball	29
	Football	66
	Lacrosse	36
	Tennis	7
Women (n = 125)	Varsity crew	11
	Novice crew	23
	Gymnastics	9
	Field hockey	16
	Lacrosse	23
	Soccer	10
	Swimming	9
	Tennis	5
	Water polo	10
	Volleyball	9

Hydration Status

- Urine Specific Gravity- Measures concentration of particles in urine
- Normal level < 1.020 Euhydrated
- Dehydrated I 1.020-1.029 Hypohydrated
- Dehydrated II >1.030 Significantly Hypohydrated

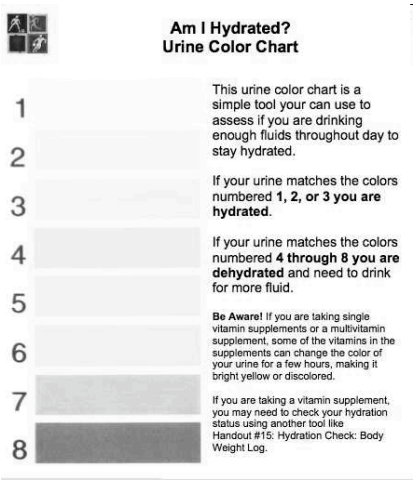
Results

- 13% significantly hypohydrated
- 53% hypohydrated
- 34% euhydrated
- More men than women hypohydrated



Discussion

- Education
- Hydration schedules
- Urine color chart
- Sport specific hydration needs
- Proper hydration could improve athletic performance



Care2.com

Strengths and Limitations

Strengths

- Large sample size
- Men and women
- Urine specific gravity is validated measure

Limitations

- Didn't use first morning void
- Participants were informed of the study subject matter
- Only measured one variable

Voluntary drinking and hydration in trained, heat –acclimatized girls exercising in a hot and humid climate

Rivera-Brown,A.M.,Ramirez-MarreroF.A.,Wilk,B., and Bar-Or,O. (2008). Voluntary drinking and hydration in trained, heat acclimatized girls exercising in a hot and humid climate, European Journal of Applied physiology, 103;109-116

Purpose

- Purpose of this study was to assess the simulative effect of beverage composition on voluntary fluid intake, rehydration, and body temperature response during outdoor exercise sessions.

Materials and Methods

- Twelve trained, heat acclimatized girls participated in this study.
- All the subjects had engaged in six months exercise training program prior to the study
- Each subject had three preparatory sessions and three experimental sessions.
- During the preparatory sessions their health status was assessed in terms of maturation stage

Preparatory sessions cont.

- Age
- Height
- Weight
- %Body Fat
- Maximal aerobic power (VO2max)

- Beverages used in this study were
- Unflavored water(W)
- Flavored water (FW)
- Flavored+ 6% carbohydrate+18mmol/l NaCl (CNa)
- One of the above beverages was assigned to each session.
- FW and CNa have the same flavor
- Tasting session was conducted to determine flavor preference of each child

Experimental sessions

- Three experimental sessions were conducted outdoors at the same time of the day (10.00 am to 1.00pm), one week apart during the summer.
- In each experimental session subjects completed four 20 min exercise bouts alternating with 25 min rest periods for a total of 180 min.
- During each session subjects could drink when they wanted.

Results

- A negative body fluid balance was observed for the three beverages.
- Intake of carbohydrate +electrolyte drink showed lower tendency of hypo hydration.
- Lower volumes of urine excretion were reported, girls who drank carbohydrate +electrolyte drink.
- Fluid retention was greater with intake of CNa drink compared to other beverages.

Conclusion

- Flavoring of water or addition of 6% carbohydrate +18mmol/l NaCl didn't prevent mild hypo hydration.
- Greater fluid retention tendency with the intake of CHO +electrolyte beverage.

Prior Research

- Little information found regarding to the body temperature and fluid balance of trained, heat acclimatized girls exercising in outdoor conditions.

Strength and Limitations

Strengths

- Each subject served as own control.
- Specialized in different sports categories.

Limitations

- Smaller sample size.
- Subjects didn't participate prolonged exercise sessions.

Anaerobic performance when rehydrating with water or commercially available sports drinks during prolonged exercise in the heat

- Coso, J.D., Estevez, E., Baquero, R.A.,and Mora-Rodriguez M, (2008) Anaerobic performance when rehydrating with water or commercially available sports drinks during prolonged exercise in the heat, Journal of Applied Physiology. Nutrition. Metabolism,33;290-298.

Purpose

- Purpose of this study was to assess the effect of commercially available sports drinks on performance enhancement and rehydration during prolonged exercise.

Materials and Methods

- Seven endurance – trained cyclists participated in this study.
- All the participants completed a 9 days of training session in a hot environmental conditions prior to the experiment.
- Subjects ingested a high carbohydrate meal three hours before the experiment.

Experimental design

- Subjects performed five experimental trials pedaling for 120 mins in a hot, dry environmental conditions.
- In the first trial no fluid was ingested during whole exercise time (DEH).
- In the remaining four trials following beverages were ingested to rehydrate during exercise sessions
- Mineral water
- Sports drink with 6% CHO + 22mmol/l Na.
- Sports drink with 8% CHO + 22mmol/l Na.
- Sport drink with 8% CHO+ 10mmol/l Na.

Experimental design

- Following parameters were used to evaluate the effects different sports beverages/water.
- Fluid balance
- Rectal temperature
- Maximal cycling power
- Leg maximal voluntary isometric contraction (MVC) or leg force.

Results

- Commercially available sports drinks showed better preservation ability of leg force (MVC) with compared to water and DEH.
- Maximal cycling power among the trials was similar and remain stable throughout the exercise.
- Final rectal temperature was higher in DEH compared to other trials.
- Sport drinks with low Na conc. resulted in decreased power output in comparison to drink with a higher Na conc.

Conclusion

- Commercially available sports drinks tends to preserve the leg power and force during prolonged exercise compared to mineral water.

Prior research

- Several research studies suggested that endurance performance is enhanced by sports drinks during exercise compared with water.
- No significant different has been found on performance enhancement, among different brands of sports drinks.

Strength and Limitations

- Strengths
- Endurance –trained and heat acclimatized cyclists participated for this study.

- Limitations
- Smaller sample size (n=7).
- Didn't evaluate the separate effects of Na and CHO on leg force.

Pre-Exercise Hyperhydration Delays Dehydration and Improves Endurance Capacity during 2 h of Cycling in a Temperate Climate

Image: odessaapartments-ukraine.com

Goulet, E.D., Rousseau, S.F., Lamboley, C. R., Plante, G. E., Dionne, I. J. (2008). Pre-exercise hyperhydration delays dehydration and improves endurance capacity during 2 h of cycling in a temperate climate. *Journal of physiological anthropology*, 27(5), 263.

Background

- The association between pre exercise hyperhydration and performance is not fully understood
- Dehydration >2% body mass is believed to compromise performance
- It is difficult for athletes to drink during exercise
- Hyperhydration?

Purpose

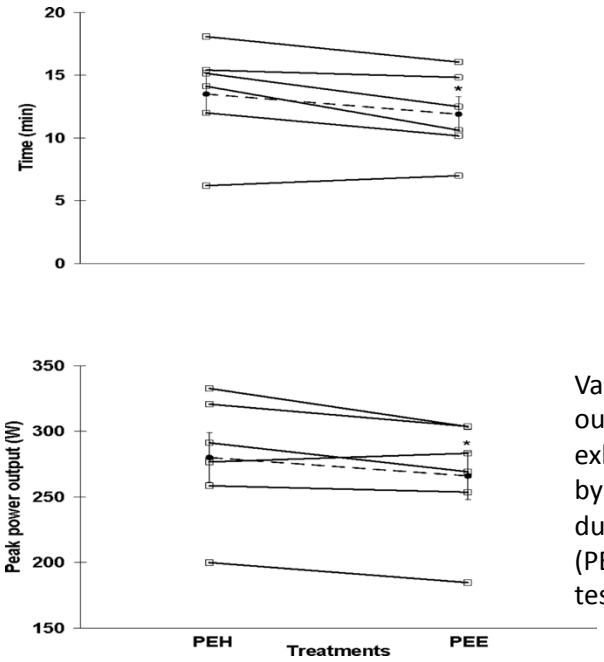
- Compare the effects of pre-exercise hyperhydration (PEH) and euhydration (PEE) Endurance Capacity during 2 hr bike ride
  - Peak Power Output
  - Heart Rate
  - Fluid Balance
  - Rectal Temperature
  - Perceived Thirst

Methods

- Randomized crossover experimental design
- 6 endurance athletes (5 men, 1 female)
- 2 experimental trials (PEH & PEE)
  - PEH: 26ml fluid/kg + 1.2g glycerol/kg
- Cycle for 2 hours at 78^0F-80^0F
- 65% VO_{2max} and 85% VO_{2max} intervals
- Incremental test to exhaustion

Results

- Perceived thirst was ↓ in PEH
- Incremental test to exhaustion
  - PEH ↑ peak power output
  - PEH ↑ time to exhaustion
- Body mass loss at post exercise
  - PEH ↓ 1.7% → delayed dehydration
  - PEE ↓ 3.3%



Values of peak power output and time to exhaustion reached by each subject during the (PEH) & (PEE) incremental tests to exhaustion.

Discussion

- Pre exercise hyperhydration may improve cycling endurance capacity and peak power output during intense long distance rides
- Loss of body mass > 2% may decreased performance
- Dehydration is delayed

Evaluation

Strengths

- Endurance athletes
- Programmed cycles
- Semi-real environment
- Trials 1 week apart
- Athletes were similarly hydrated prior to treatments
- Body mass loss is a validated measure to monitor dehydration status

Limitations

- Small sample size (n=6)
- 1 woman
- Glycerol in fluids
- Author cited his previous work
- Subjects not blinded
- Limited studies with similar results

Voluntary Dehydration in Runners Despite Favorable Conditions for Fluid Intake

Passe, D., Horn, M., Stofan, J., Horswill, C. & Murray, R. (2007). Voluntary dehydration in runners despite favorable conditions for fluid intake. *International Journal of Sport Nutrition and Exercise Metabolism, 17,* 284-295.

IMG:http://www.ransacker.co.uk/blog/wp-content/uploads/ 2008/03/ dehydration1.jpg

Purpose

- To investigate the relationship between runners' perceptions of fluid needs and drinking behavior under a desirable environment

Methods

- 18 seasoned marathon runners
  - 15 men & 3 women
  - average 40y.o.
  - ~12 competitive events/year
  - 8hr of training/week
  - Familiar with hydration and sport drinks
- Asked to run 16-km (10-mile) run
  - Instructed to eat and drink as usual prior to an event
  - 5PM
  - 400-m outdoor track
  - 20.5°C (68.9°F)
  - 76.6% relative humidity

Methods

- 6% CHO-electrolyte drink available @ miles 2, 4, 6, 8
- Body weight recorded pre- & post-race
- 100-point scale administered pre- & post-race
  - Assessed thirst:

1. How much sweat did you lose?
2. How much fluid did you ingest?
3. Was this enough to replace your sweat loss?
4. If not, what percentage of sweat loss did you replace?

Results

- Perceived sweat loss : 12.0 ± 7.4 mL/kg/h
- Actual sweat loss: 21.6 ± 5.1 mL/kg/h
  - Underestimation of 42.5% ± 36.6%
- Voluntary replacement of total fluids lost: 30.5% ± 18.1%
- Voluntary dehydration: 1.9% ± 0.8% body weight
- No correlation between
  - Sweat loss and fluid intake
  - Perceived sweat loss and fluid intake
- Perceived fluid intake and actual fluid intake were accurate.
- 12/18 felt they did not hydrate enough

Implications

- Runners' thirst mechanism is not an accurate tool to assess hydration levels or fluid loss.
- Voluntary dehydration observed in previous studies implies room for more research regarding this phenomenon.

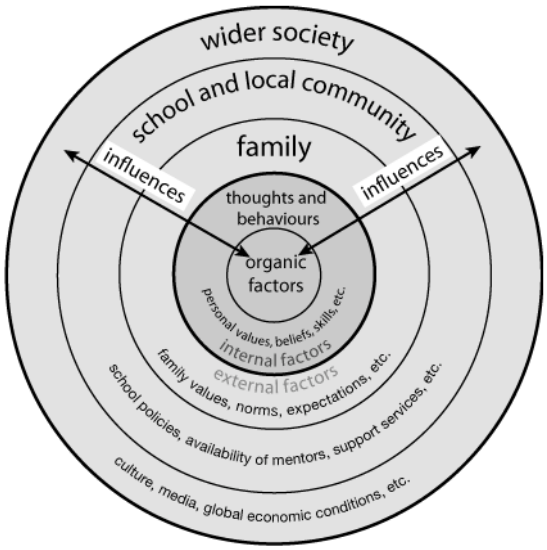
Limitations

- Small sample size
- Average age deviates only ~3 years
- Method of fluid intake during race not specified.
- Method dispensing fluids
- Favorable conditions may alter perception of dehydration
- Didn't interview subjects *why* they felt they didn't hydrate enough or *why* they chose not to hydrate at certain stations

Common themes

1. Proper hydration maintains endurance and strength during athletic performance
2. Sodium is the most essential electrolyte regarding fluid retention
3. Varying factors affect overall hydration status
4. Athletes' self-assessment of hydration cannot be relied to maintain proper hydration.

Human Ecological Theory



http://www.embracethefuture.org.au/resiliency/images/ecological-diagram.gif

Conclusion

- Human body relies on water for all physiological and biochemical processes.
- Essential for physically active individuals replace fluids lost via sweat and urine output.
- Rule of thumb:
  - 7mL/kg H_2O or Sports drink
  - 2hr prior and leading up to an event
- Individual patterns of sweat (light, moderate, heavy) should be assessed and replenished to counter balance total loss.