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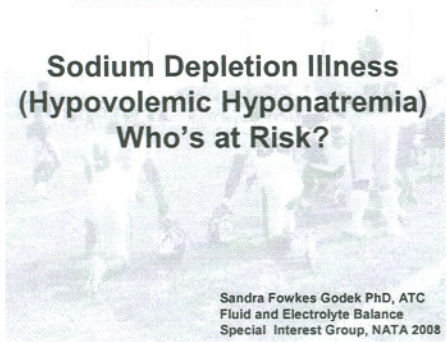
Sodium Depletion Illness (Hypovolemic Hyponatremia) Who's at Risk?



Sandra Fowkes Godek PhD, ATC
Fluid and Electrolyte Balance
Special Interest Group, NATA 2008

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Thank You

PATS Research Fund

Sponsors

3B Orthopaedics Research Fund

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Katherine Alexandra Foundation

Bob and Jennifer McNeil Foundation

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Introduction

- Problems we are faced with - Why has the incidence of hyponatremia increased?
  - The EHS (T_c) and dehydration dilemma
  - Experimental versus Field Studies
- Major fluid regulating hormones
  - The body's response to low blood pressure
- Three forms of hyponatremia
- Electrolyte studies in FB and Ice Hockey
  - Na^+ supplemented versus un-supplemented

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Introduction

- Critical questions to which we don't have all of the answers
- By the numbers – sweat sodium losses
- Hyponatremia versus heat exhaustion
- Hypovolemic hyponatremia
  - Signs/symptoms
  - Management and prevention

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Problem- Which are Heat Illnesses?

- Heat Cramps (EAMC)?
- Heat Exhaustion ?
  - Symptomatic dehydration
- Hyponatremia? ← This can be prevented!!
- Exertional Heat Stroke (EHS) – YES
- A heat illness is defined as a condition in which the primary treatment is rapid cooling!!

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Problem - What causes Exertional Heat stroke?? HS ATC Survey Dombek, Casa, Yeargin et al JAT Suppl 2006

- "ATC rankings of 14 items that predispose athletes to EHS revealed they consider.."
  1. **Dehydration (2.6 rank)**
  2. **High Humidity (3.4 rank)**
  3. **High ambient temperature (4.3 rank)**
  4. **Acclimatization (5.1 rank)**
  5. **Physical fitness (5.7 rank)**
  6. **History of heat illness (6.1 rank)**
  7. **Exercise intensity (6.2 rank)**

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Problem - What causes Exertional Heat stroke?? Dombek, Casa, Yeargin et al JAT Suppl 2006

- **Dehydration was ranked significantly higher than all other factors except high humidity!!**
- **However – The overwhelming expert consensus is that metabolic rate (exercise intensity) is the single most important factor related to elevated core temperature**
  - **Dehydration at best has minimal affect**
- **So why do ATC's still think this way??**
  - **Where does your information come from?**

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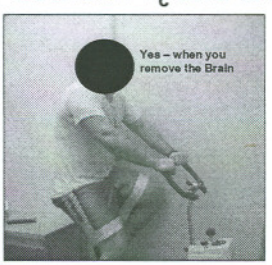
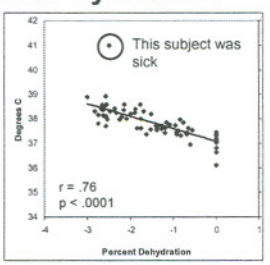
Is there a Significant correlation between T_c and level of Hydration?





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Bartolozzi AR, Fowkes Godek S. Sweat rate and core temperature responses to Dehydration induced experimentally versus during actual pre-season practice in College football players . *J Athl Train* S39(2), 2004.

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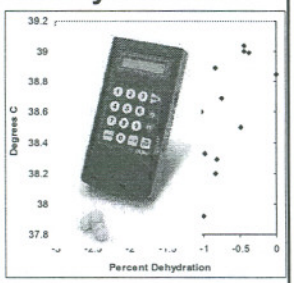
Is there a Significant correlation between T_c and level of Hydration?



r = 0.198, p = 0.294

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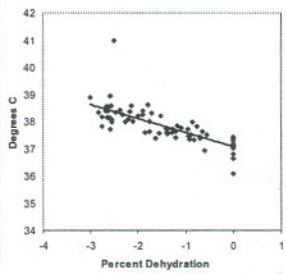
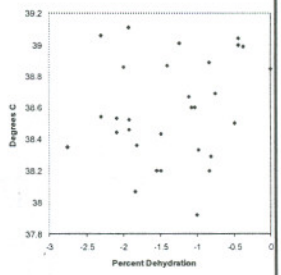
Experimental, fixed workload



r = .76, p < .0001

Field Study during FB Practice



r = 0.198, p = 0.294

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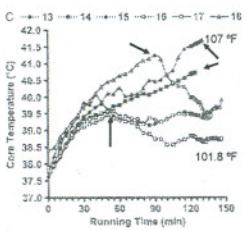
Runners during a Marathon

- When runners get hot, they slow down
- Some reach T_{cmax} early
- Some at the end
- T_c is not related to % dehydration
- T_c max of 104 - 106 °F are common and <u>well tolerated!!!</u>



Byrne, Lee, Chew et al MSSE 06

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Conclusions Byrne, Lee, Chew et al msse 06

- 17 of the 18 runners had a $T_{cmax} \geq 103$ °F
  - In most labs the experiment for them ended
- 10 of the 18 runners had a $T_{cmax} > 104$ °F
  - In nearly any lab the experiment is done
- % dehydration ranged from 0.9% - 3.9%
- "Core temperature responses demonstrated no significant relationship to absolute Δ mass ….or % dehydration"

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Triathletes during a Race

- Mean $T_{c\ max}$ = 38.1ºC (100.6ºF)
- Mean % dehy = 3%
- Change in mass was not related to finishing T_c
- "Body mass loss of 3% was found to be tolerated by well trained tri-athletes ..... without any evidence of thermoregulatory failure"

Laurson et al BJSM 06

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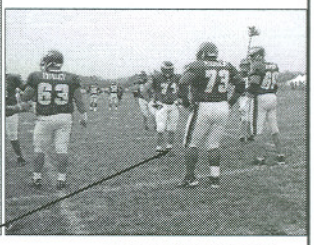
This Cohort is Considerably Different



This athlete weighs 163 kg

These athletes sweat at 2.5 – 3.5 $l \cdot h^{-1}$ Fowkes Godek JAT 2008

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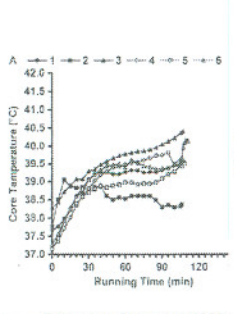
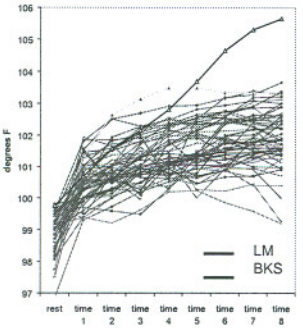


Byrne, Lee, Chew et al MSSE



Fowkes Godek et al, 2003 - 07

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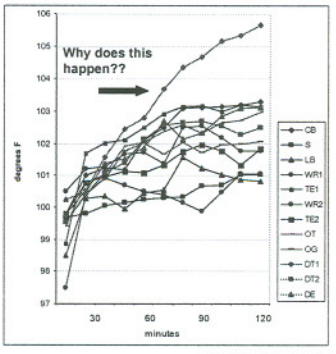
Athletes get hot – so what's the big deal??



12 NFL players LM versus BKS

Fowkes Godek S, et al, JAT 2006

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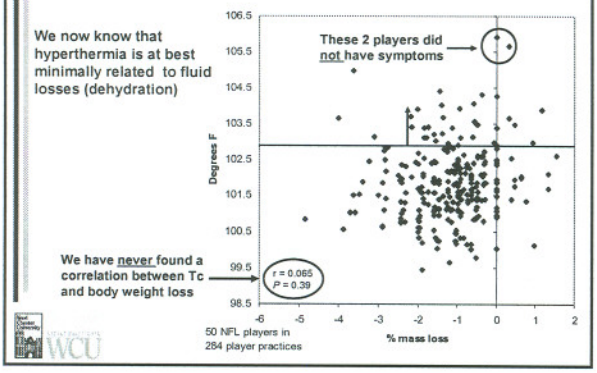

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The EHS and Dehydration Dilemma

- It clouds the fluid/electrolyte balance issue and provides a false sense of security
- It promotes the thinking that drinking to replace all fluid losses will prevent EHS
- We don't know what causes EHS but it is NOT dehydration
- 2 – 3% body mass loss during exercise is normal, expected and well tolerated

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Major Hormones Involved in the control of Blood Volume (BP)

- Released when blood volume and blood pressure are low
  - Vasopressin (ADH)
  - Renin-Angiotensin
  - Aldosterone
- Released when blood volume and blood pressure are high
  - Naturetic Peptides
    - ANP
    - BNP
    - Urodilantin

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The Body's Response to Low BP (Salt/blood volume Depletion)

- Kidneys release Renin
- Renin combines with Angiotensinogen to form Angiotensin I
- Angiotensin I is converted to Angiotensin II by ACE
- Angiotensin II stimulates several mechanisms that raise blood pressure

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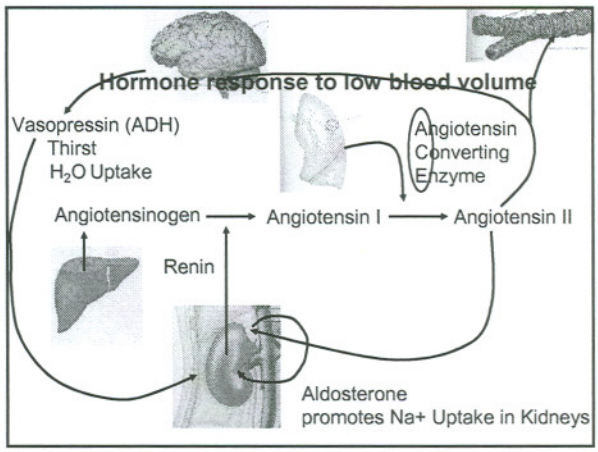
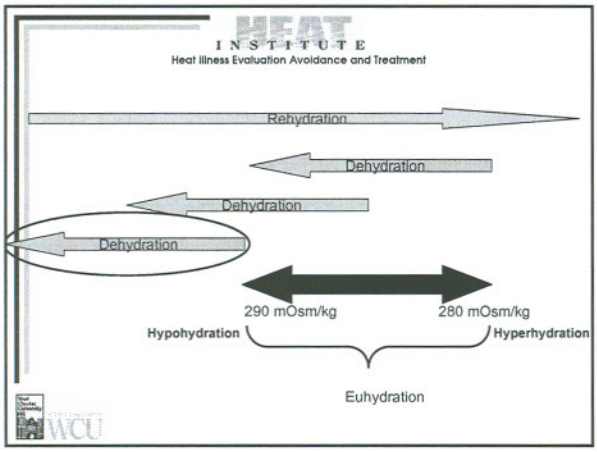
Angiotensin II

- Causes Vasoconstriction of Blood Vessels
- Stimulates Brain to release Vasopressin (ADH)
  - Increases H_2O reabsorption
  - Stimulates Thirst
- Stimulates adrenal cortex to release Aldosterone
  - Increases Na^+ reabsorption

↑ Body Fluids → ↑ Blood Volume → ↑ BP





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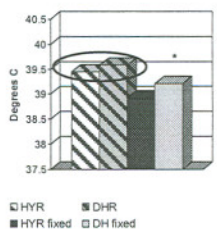
Trail running

- Fluid restricted starting 12 hr before
- Began trials hypohydrated
- No difference in T_{GI} at race pace
- When subjects were kept at fixed workloads, DHS had higher T_{GI}



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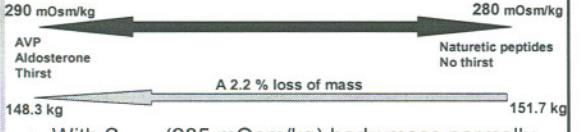
What is Constitutes Normal Hydration?



- With S_{osm} (285 mOsm/kg) body mass normally fluctuates between:
  - 79.2 kg and 80.8 kg in a 80 kg (176 lb) male (5 lbs)
  - 64.4 kg and 65.6 kg in a 65 kg (143 lb) female (~ 3 lbs)
  - 29.7 kg and 30.34 kg in a 30 kg (66 lb) child (1.4 lbs)
  - 148.3 kg and 151.7 kg in a 150 kg (330 lb) FB LM (~ 8 lbs)

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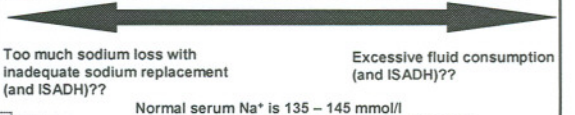
Three forms of Hyponatremia

- Hypervolemic hyponatremia
  Normovolemic hyponatremia
  Hypovolemic hyponatremia
- There is probably a spectrum of etiology



Normal serum Na^+ is 135 – 145 mmol/l
Clinical diagnosis of hyponatremia is 130 mmol/l
Symptoms can begin when serum Na^+ < 135 mmol/l

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Hyponatremia – Na^+ Dilution

- Hypervolemic hyponatremia – blood volume expands and blood Na^+ is diluted
  - This is primarily the marathon/ultra-distance athlete – water intoxication
  - Females and slow runners may be more prone?
  - Probably linked much of the time to ISADH
  - Caused by drinking too much of ANYTHING (including CE drinks)!!

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Hyponatremia – Na^+ Depletion

- Hypovolemic hyponatremia – Low body sodium leads to a contracted blood volume
  - This is the heavy and/or salty sweaters
  - Probably occurs more in males
  - Exacerbated by drinking too much water and/or CE drinks
  - Detection of the hypovolemia in collegiate FB players during two-a-days was the key!

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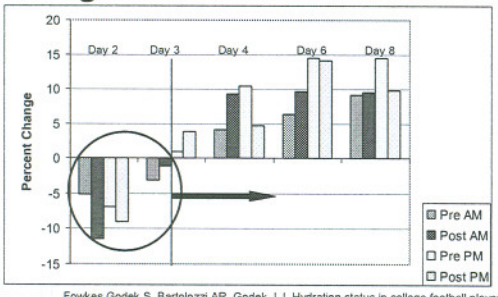
Changes in Plasma Volume



Fowkes Godek S, Bartolozzi AR, Godek J J, Hydration status in college football players during consecutive days of two-a-day preseason practices. *Am J Sports Med.* 2005;33(6):

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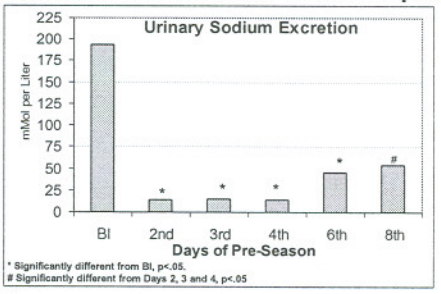
Aldosterone Mediated Na^+ Re-absorption



Fowkes Godek S, Bartolozzi AR, Godek J J, Hydration status in college football players during consecutive days of two-a-day preseason practices. *Am J Sports Med.* 2005;33(6) : 843-851

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Three forms of Hyponatremia

- Hypervolemic hyponatremia
  Normovolemic hyponatremia
  Hypovolemic hyponatremia
- There is probably a spectrum of etiology

Hypovolemic Hyponatremia — Normovolemic Hyponatermia — Hypervolemic Hyponatremia

Too much sodium loss with inadequate sodium replacement

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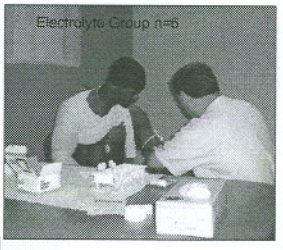
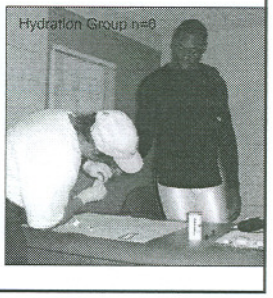
Fluid and Electrolyte Studies 2003 - 2007





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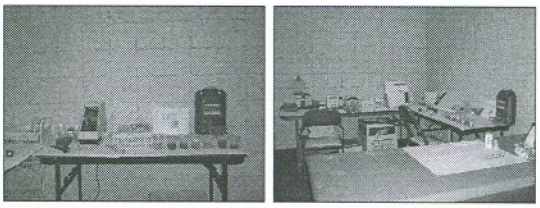
Pre-Season On-site Lab



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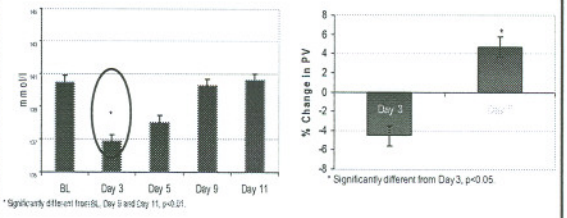
Hypovolemic Hyponatremia



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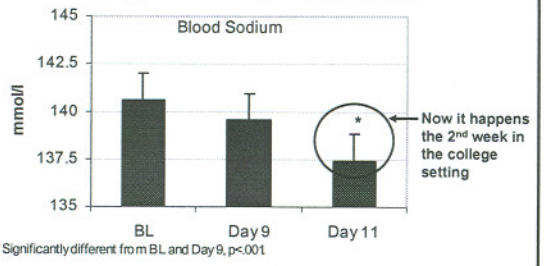
Blood Na^+ in College Players after NCAA Rules Changes for Acclimatization



Day 11 is after 5 practices in 3 days

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Critical Questions

- Can athletes really become sodium depleted?
- Does hyponatremia always have to involve at least some ISADH?
- Why can't CE drinks prevent hyponatremia?
- Can high sweat losses replaced with hypotonic fluids on consecutive days causes hyponatremia?

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FB Players Sweat Heavily

- **Case study in a collegiate football player**
  - **Average sweat losses during practices (3 days and 6 practices) = 13.5 L per day**
  - **Maximal sweat loss = 14.8 L per day**

    That's 35 8oz glasses!!!
  - **Fluids consumed during practices = 8 L/day**

Fowkes Godek, S, A.R. Bartolozzi. Sweat rate, fluid turnover, hydration status and core temperature in an American football player during pre-season training: A case study. *Athl Ther Today*, 2004;9(4):264-270.

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Ice Hockey Players Sweat a lot Too!

And they get hot – some over 103° F

We would never call the illness they get "Hypovolemic Hyponatremia" during the playoffs a heat illness – because it is not a "Heat Illness"!!

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What about CE Drinks?

- Why can't we put all of the salt back with CE drinks??
- They are actually OK for a small population of athletes
  - Average-sized males with average SwtR and low sweat [Na^+]
  - Female??
  - Kids?????? What about the childhood obesity epidemic?

This is non carbonated sugar and salt water

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By the Numbers

- <u>REMEMBER - All fluids</u> that your athletes' consume are hypotonic (not salty)
- CE drinks have $Na^+ < 20$ mEq $\cdot L^{-1}$
- Sweat Na^+ ranges from 15 – 100 mEq $\cdot L^{-1}$
- Just replacing fluids – even with a CE drink does not adequately replace salt in heavy sweaters

[Na+]

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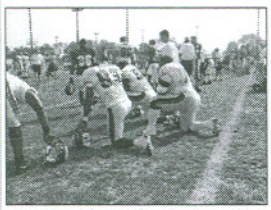
Three Examples – Sweat Studies



Fowkes Godek S, Bartolozzi AR et al. Sweat rates and fluid turnover in professional football players: A comparison of NFL linemen versus backs, J Athl Train, Accepted for publication.

Fowkes Godek S, Godek JJ, Bartolozzi A, McCrossin J. Sweat Sodium losses in NHL players during a pre-season practice versus a game. MSSE 2006

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How much CE is Needed? Ex. #1

- A football player who sweats 3.5 L · h^{-1} and practices 4.5 h per day = 13.5 L sweat loss
- At a sweat Na^+ content of 50 mEq · L^{-1} and 13.5 L per day he loses 15.5 g of Na^+
- Replacing ½ in food (4 tsp salt)
- He needs to consume ~ **17 L** of CE drink
- Won't this promote sodium dilution? Yes!

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How much CE is Needed? Ex. #2

- An NHL player who sweats 2 L · h^{-1} in a 3 hr game = 6 L of sweat loss
- At a sweat Na^+ content of 90 mEq · L^{-1} and 6 L of fluid loss he loses 12.4 grams of Na^+ in one game
- Replacing ½ in food
- He needs to consume ~ **14 L of CE drink** which will make him hyponatremic

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How much CE is Needed? Ex. #3

- An NFL player who sweats 2.9 L · h^{-1} and practices 4.5 h per day lost 13 L sweat
- At a sweat Na^+ content of 99 mEq · L^{-1} and 13 L per day he lost ~ 30 g of sodium (that's 15 tsp of table salt!!!)
- After replacing ½ in food
- He needs to consume ~ **33 L** of CE drink which will make him hyponatremic

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What else will you get??

- Remember – we are assuming ½ of the sodium is replaced with food intake
- **33 L of CE drink** will likely promote hyponatremia – AND provide:
  - 7112 Kcals
  - 1991 g of CHO (glucose, fructose, sucrose)
  - ~~4267 mg of potassium~~

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What is Heat Exhaustion?

- Water depletion
  - Symptomatic dehydration
  - Caused by inadequate replacement of water losses (dehydration beyond 3 - 4%)
  - Beginning a second bout of exercise hypohydrated
  - Untreated it can lead to heat stroke
  - Involves an elevated core temperature

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Salt/volume depletion Illness

- Should **not** be classified as a Heat illness
  - Caused by low serum Na^+ but may not clinically be classified as hyponatremia until $Na^+ \leq 130$ mmol/L (<135 mmol/L is better)
  - Usually occurs in athletes who sweat heavily over several consecutive days
  - Water loss is replaced but Na^+ is not
  - Does not involve hyperthermia
  - Athlete is hypovolemic

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Signs and Symptoms of Salt/Volume Depletion Illness

- Weakness
- Fatigue
- Headache
- Muscle aches
- Anorexia
- Nausea
- Vomiting
- Diarrhea
- Pale, clammy skin
- Low BP
- Tachycardia
- Syncope
- Normal or low body temperature

** The athlete feels "sick"

This illness is probably under diagnosed or misdiagnosed as a viral illness or food poisoning

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Management

- Rest – Do not let them play
- Administer high electrolyte drink orally with meals or sodium supplements
- Consider IV fluid replacement (saline)
- Monitor vital signs (blood pressure)
- Recovery usually within 24 hours
- Educate athletes about replacement of electrolytes (salt food liberally)

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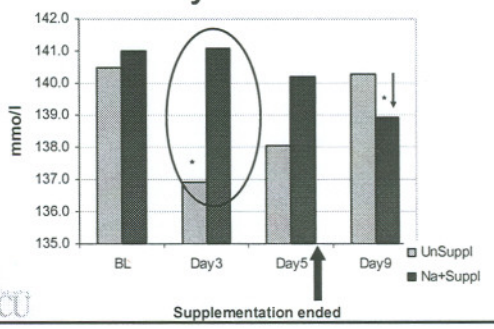
Blood Na^+ with Rehydralyte and Pedialyte in 2004



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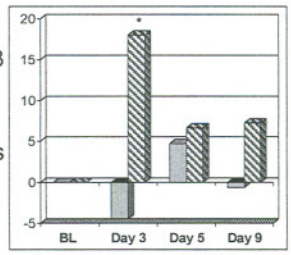
PV in Un-Suppl versus Na+Suppl

- In Na^+Suppl PV expanded 18% by Day 3
- PV was never below BL
- Clinically different from unsupplemented players in 2003



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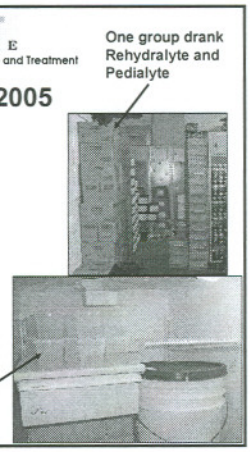
Na^+ Supplementation in 2005

- Two groups of players were supplemented at and between meals with oral electrolyte solutions
  - Pickle Juice
  - Rehydralyte + Pedialyte
- All subjects received 4.5g of Na^+ per day



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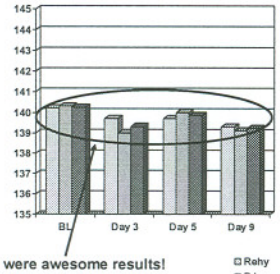
Blood Sodium with Supplementation

- Blood Na^+ was not different between groups
- Blood Na^+ did not change across days



These were awesome results!

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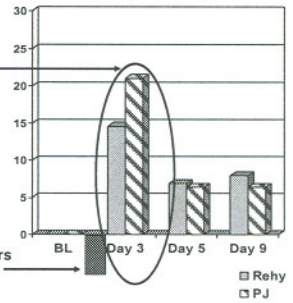
Plasma Volume Increased Perfectly

- Rapid expansion of plasma volume
- There were no differences between groups



In 2003 the unsupplemented players were 5% below baseline on Day 3

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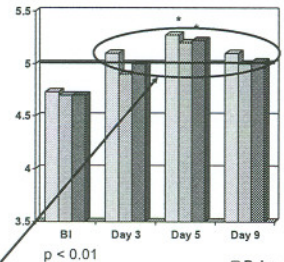
BUT - Blood Potassium was Too High!

- Blood K^+ was not different between groups
- Blood K^+ was elevated from baseline (Bl) to Day 5 and above normal range



This is a BIG problem, especially for football players!!

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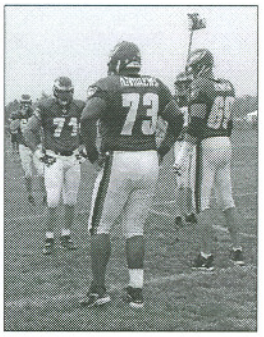
A Problem

- What are the blood K^+ concerns specifically in football?
- Hyperkalemia causes cardiac issues
- These guys are not the "average" male athlete



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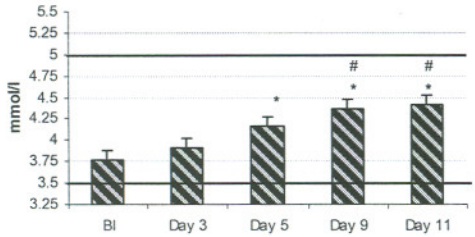
Blood K^+ in Un-supplemented Pro FB Players in 2003



* Significantly different from BI
# Significantly different from Day 3

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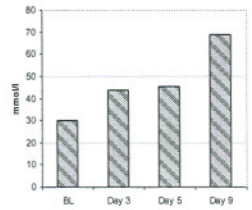
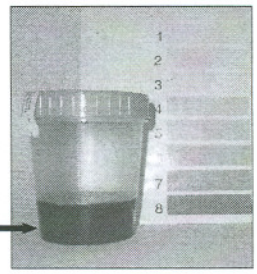
Urine K^+ and Rhabdomyolysis





This is Myoglobin

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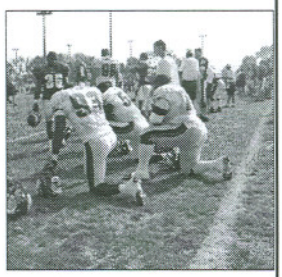
Why is blood and urine K^+ high?

- Playing football in the heat causes muscle cell death (rhabdomyolysis)
  Eylers et al, JAT 2002
- Muscle cells have high [K^+] inside
- When cells rupture they leak K^+ into the blood
- The K^+ has to be excreted



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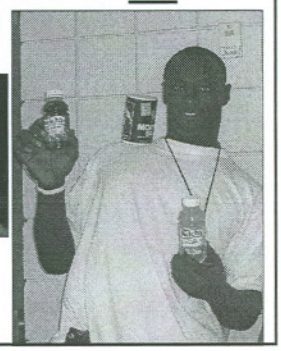
Na^+ supplementation with NO K^+ in 2006 (4.5 g/day)

10 players representing all positions



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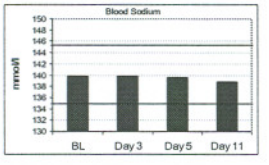
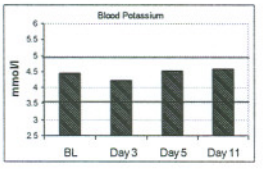
Results

- No differences between days existed for blood Na^+
- No differences between days existed for blood K^+
- Both within normal clinical range





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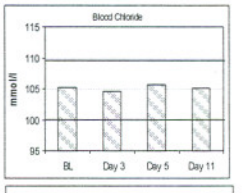
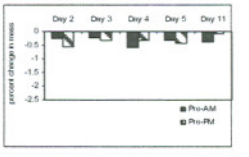
Results

- No differences between days existed for Cl^- and they were within were normal clinical range
- No differences in pre-AM or pre-PM %Δmass





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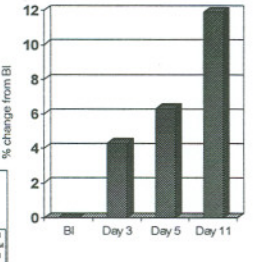
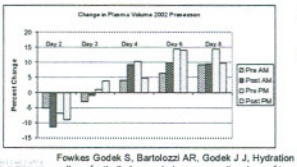
Results

- PV expanded 12% by Day 11





Fowkes Godek S, Bartolozzi AR, Godek J J, Hydration status in college football players during consecutive days of two-a-day Preseason practices. *Am J Sports Med.* 2005;33(6):

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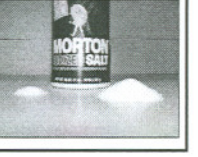
Individualized Na^+ Replacement 07

- The table salt was distributed in 3 to 6 bottles of juice depending on the required supplementation
- Supplementation ranged from 5.1 g to 30.5 g NaCl per day
- Supplementation ended by day 5 – 7
- This worked perfectly!!!



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Prevention – Salt/volume depletion

- It is caused by consecutive days of large daily Na^+ losses not replaced and drinking too much of anything
- Know your athletes' sweat rate
- Know your salty sweaters
- Swt [Na^+] and SwtR are extremely variable
- We have to get rid of consecutive days of two or three/day practices!!

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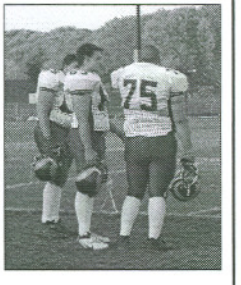
Prevention – Salt/volume depletion

- Know your athletes who are hypertensive
  - Be aware of which athletes are on a low Na^{++} diet
  - Be aware of athletes on ACE inhibitors
  - Medication may need to be altered during preseason



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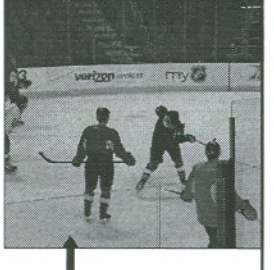
Prevention – Salt/volume depletion

- Require weight charts and monitor them
- Be aware of athletes who cannot maintain body weight
- Think beyond pre-season fall sports



Their issues occur more often in post-season playoffs

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Prevention – Salt/volume depletion

- REMEMBER - 2 – 3 % dehydration is OK
- Hypohydration prior to practice is not – are they gaining wt back?
- Replace lost electrolytes
  - 4 meals per day of sodium rich foods and fluids
  - NaCl supplementation/individualized replacement

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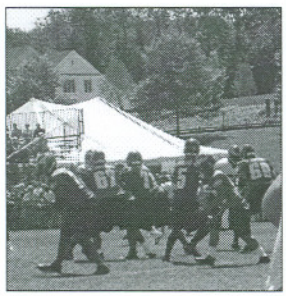
4 meals per day during Pre-season!

- Eat foods high in Na^+ and Mg^{++} and CL^-
- Avoid too much potassium in this population →
- Can consume some Pedialyte or PJ
  - 2-3 bottles pedialyte
  - 3-4 oz PJ



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Breakfast Foods

- Cereals
  - Chex cereal
  - Golden grahams
  - Maple and brown sugar oatmeal
  - Rice krispies
  - Total
  - Frosted wheaties
  - Basic 4
- Breads
  - Corn muffins
  - Bagels
  - Whole wheat English muffins
- Meats
  - Sausage
  - Canadian bacon
  - Ham

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Lunch and dinner foods

- Hotdogs and Lunch meats
- Soups
  - Chicken noodle
  - Onion
  - Vegetable
  - Tomato
  - Cream of chicken or mushroom
  - NE Clam Chowder
  - Chicken gumbo
  - Split pea and ham
- Sauerkraut
- Cheese
  - American
  - cottage
  - Parmesan
- Pizza
- Tomatoes
- Salads with dressing
  - zesty Italian
  - French
  - Caesar

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Lunch and dinner foods

- Sauces
  - Marinara
  - Alfredo sauces
  - Beef or mushroom gravy
- Stir-fry
  - teriyaki and soy sauces
- Chili, stews
- Chow mein vegetables
- Navy beans, chick peas, baked beans
- Peas and carrots
- Pita bread

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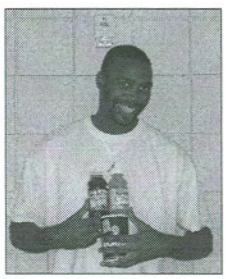
Drinks and Snacks

- Snacks
  - Pickles
  - Pretzels/chips
  - Cheese puffs
  - Chex mix
- Drinks
  - Tomato juice
  - V-8 juice
  - Pedialyte
  - Pickle juice



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Foods to avoid during pre-season

- Orange juice
- Bananas
- Dried fruits
- Baked potatoes
- Raisins
- Nuts
- Spinach
- Mushrooms
- Lima beans
- Black beans
- Lentils
- Cucumbers
- Squash
- Zucchini
- Brussel sprouts
- Gatorade Endurance

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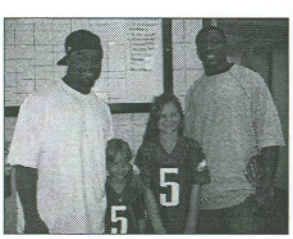
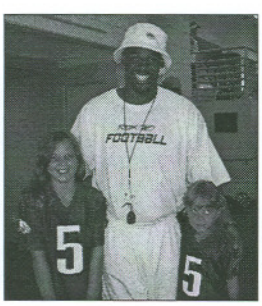
Thank You





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PATS Research Fund

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