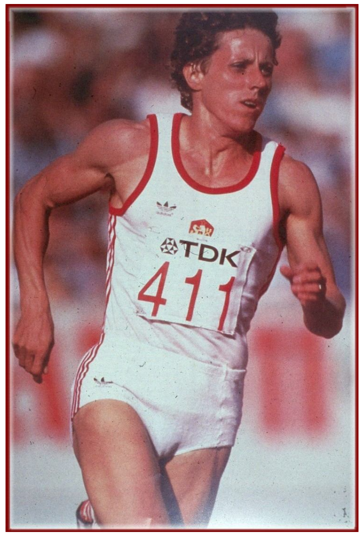
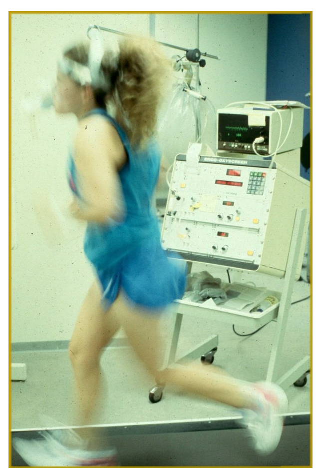
Understanding Heat Production & Dehydration During Exercise



Exercise increases heat production

Heat production during exercise can easily be calculated or estimated

- Metabolic efficiency = ~30%
- Mechanical efficiency = ~30%



Therefore, heat production can be estimated from calorimetry-based determinations of VO_2, VCO_2, and RER.

For example,

Low fitness:

Kcals = VO_2 (L/min) x Kcals/L x Duration (min)

Kcals = 1.0 (L/min) x 4.924 Kcals/L x 60 (min)

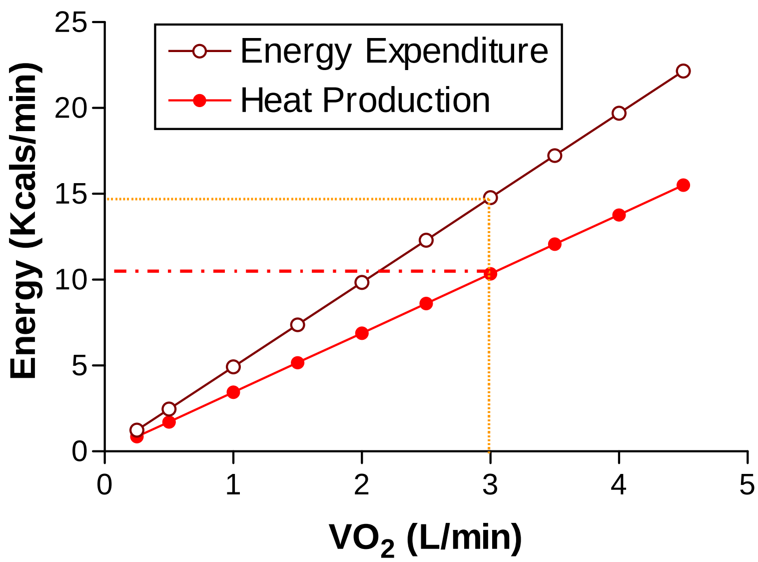
Kcals = 295

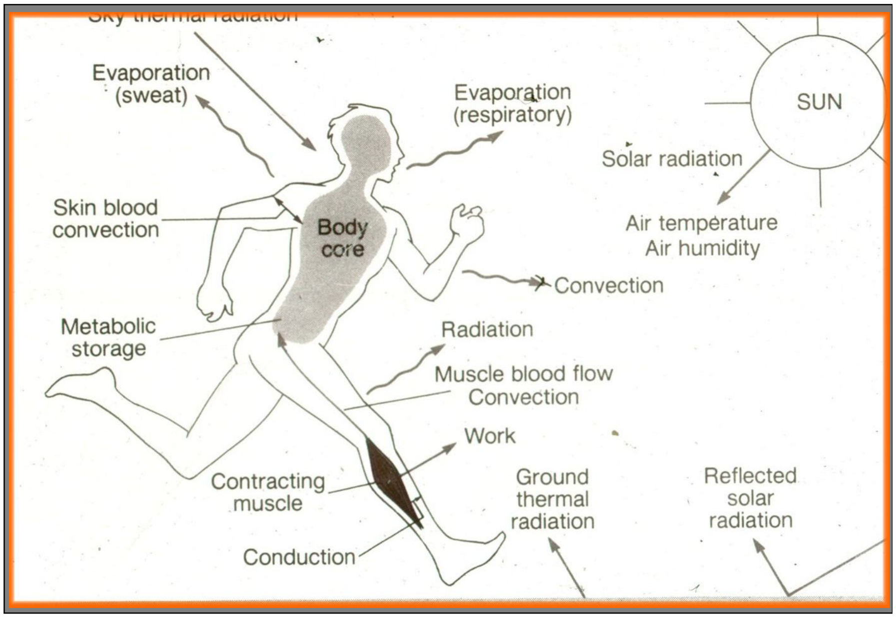
High fitness:

Kcals = VO_2 (L/min) x Kcals/L x Duration (min)

Kcals = 3.0 (L/min) x 4.924 Kcals/L x 60 (min)

Kcals = 886





What does a heat production of 900 Kcals mean for body heat loss and storage?

Body specific heat = 0.83 Kcals/kg/°C

For a 75 kg person,

Potential Heat gain = (900 / 0.83) / 75

Potential Heat gain = 14.5 °C

What if all this heat was to be lost as sweat?

Evaporative heat loss potential = 580 Kcals/L

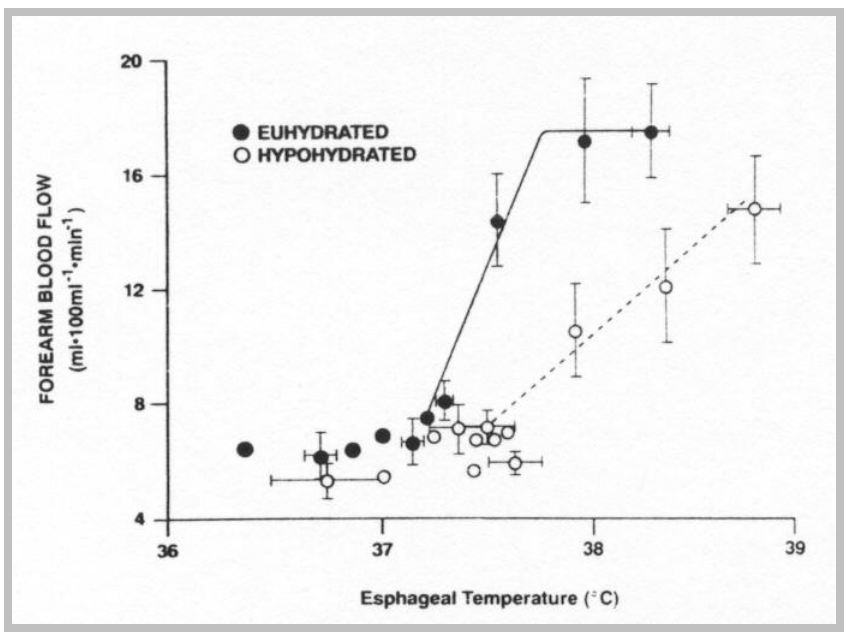
Evaporative Water Loss = 900 / 580 = 1.5 L

If we are 60% efficient at sweat evaporative cooling

1.5 / 0.6 = 2.5 L = 3.3% dehydration

Physiological changes during dehydration

- ↑ Core temperature
- ↓ Plasma volume
- ↓ Venous return
- ↓ Stroke volume
- ↑ Heart rate
- ↓ Cardiac output
- ↑ a-v$O_2\Delta$
- ↓ Skin blood flow
- ↑ Catecholamines
- ↑ Blood lactate
- ↑ VO_2
- CNS dysfunction
- ↓ Exercise tolerance
- ↓ Sweat rate
- ↓ Evaporative cooling



Sawka review, 1992

Improving Exercise Tolerance During Heat Exposure

- Fluid intake (pre-, during and post-exercise)
- Do not rely on thirst mechanism
- Complete heat acclimation or acclimatization

Acclimation - chronic adaptations induced by exposure to artificial environmental conditions

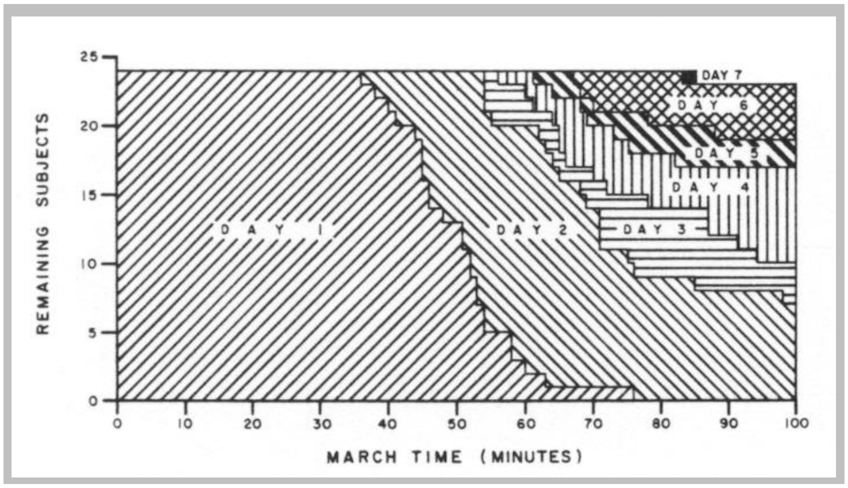
(eg. environmental chambers, sauna, exercise)

Acclimatization - chronic adaptations induced by exposure to a foreign climate

(eg. geographical relocation)

Chronic adaptations to exercise in a hot environment that improve acclimation to exercise in the heat

Acclimation/Adaptation	*Physiological Benefit*
↑ ***Plasma Volume***	↑ Blood Volume ↑ Venous return ↑ Cardiac output @ max ↓ Submaximal heart rate Sustained sweat response ↑ Capacity for evaporative cooling
Earlier onset of sweating	Improved evaporative cooling
↓ ***Osmolality of sweat***	Electrolyte conservation (mainly Na^+)
↓ ***Muscle glycogenolysis***	↓ Likelihood for muscle fatigue



Walking at 1.56 m/s, 49°C & 20% RH, 7 consecutive days

Heat Acclimation/Acclimatization Summary

- Continuous daily 100-min exercise bouts
- Near complete exercise-heat acclimation occurs after 7-10 days of exposure
- High levels of endurance training can partially heat acclimate
- 75% of acclimation occurs within 4-6 days
- Retention of benefits from acclimation are retained longer for dry than humid heat
- High levels of aerobic fitness prolong retention of heat acclimation
- Near complete exercise-heat acclimation occurs after 7-10 days of exposure

Pandolf, 1998

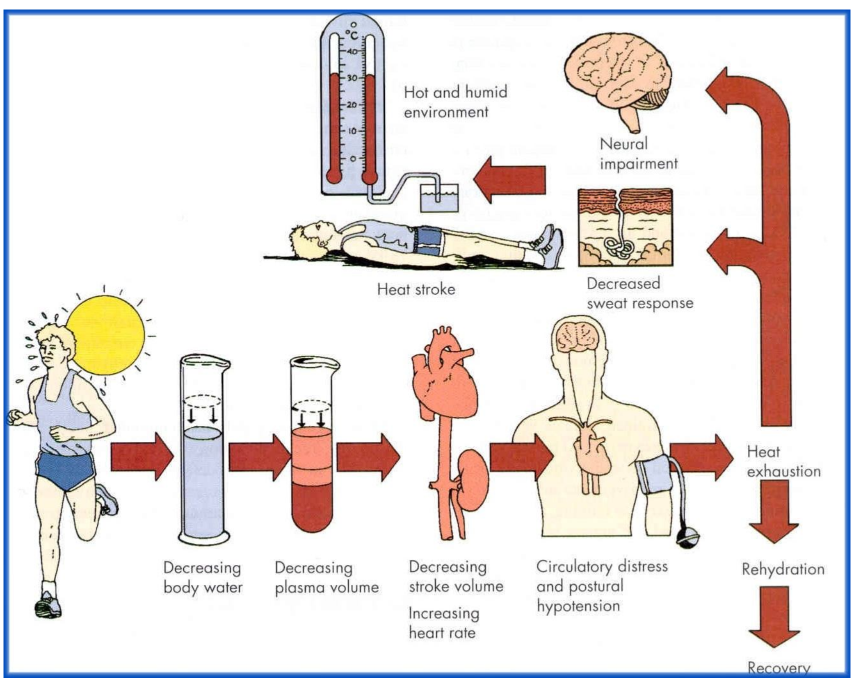
Heat Illness, Heat Exhaustion and Heat Stroke

These conditions are more severe clinical symptoms of heat exposure.

Heat Exhaustion - the decreased cardiovascular function that accompanies dehydration and mild hyperthermia.

Heat Stroke - when heat stress continues, or is worsened beyond that of heat exhaustion (core temp > 39.5 °C), physiological symptoms progress to CNS dysfunction - *disorientation, confusion, psychoses*

Heat exhaustion and heat stroke are both heat illnesses. However, heat stroke can be potentially lethal due potential organ damage and failure.



Evaluating Environmental Conditions For Risk of Heat Injury

An index has been developed that incorporates all contributors to thermal heat stress - **Wet Bulb Globe Index** (WBGI)

***Dry bulb** temperature* - measure of air temperature

***Black bulb** temperature* - measure of the potential for radiative heat gain

Wet bulb temperature - measure of the potential for evaporative cooling

WBGI = (0.7 x Tw) + (0.2 x Tb) + (0.1 x Td)

The relative risks for heat injury at different ranges of the WBGI

WGBI	*Physiological Benefit*
23-28	**High risk for heat injury: red flag** Make runners aware that heat injury is possible, especially for those with a history of susceptibility to heat illness
18-23	**Moderate risk for heat injury: amber flag** Make runners aware that the risk for heat injury will increase during the race
< 18	**Low risk for heat injury: green flag** Make runners aware that although the risk is low, there is still a possibility for heat injury to occur
< 10	**Possible risk for hypothermia: white flag** Make runners aware that conditions may cause excessive heat loss from the body, especially for individuals who will have slow race times and when conditions are wet and windy

GLYCEROL and HYDRATION

What you need to know!

By

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Exercise Science Program
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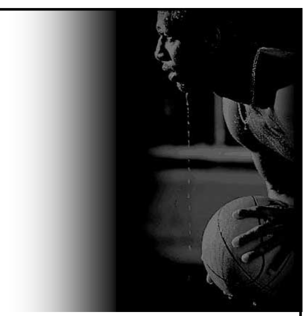
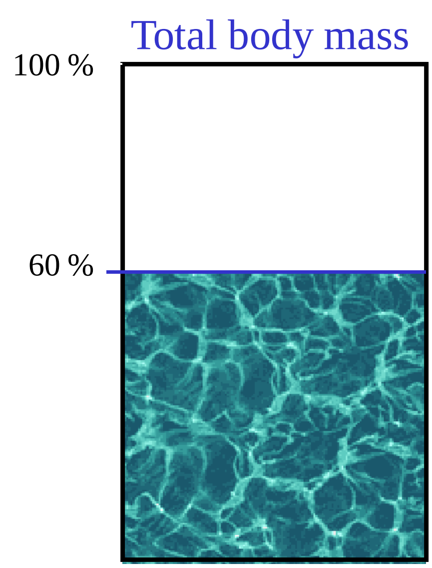
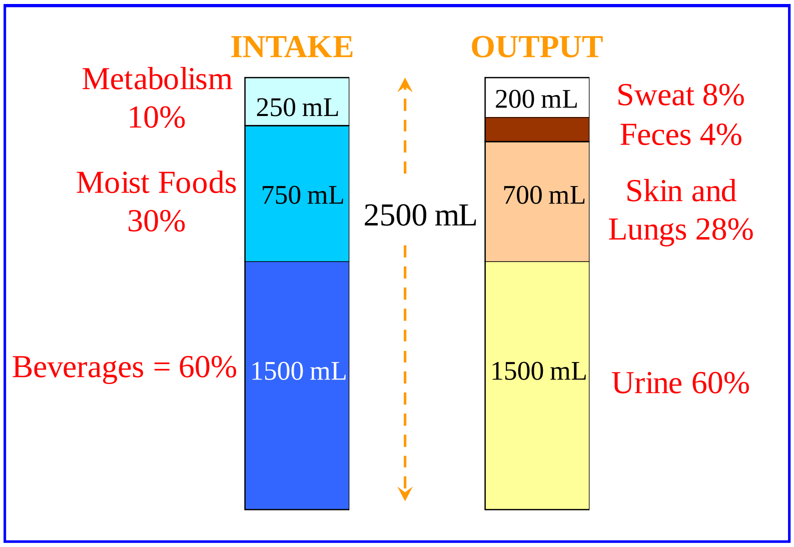
How Much Water is in the Body?

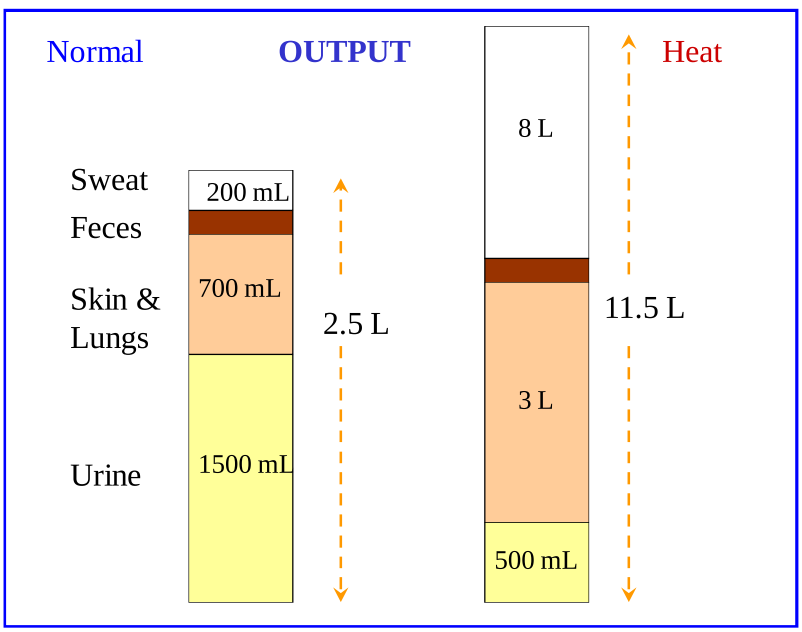




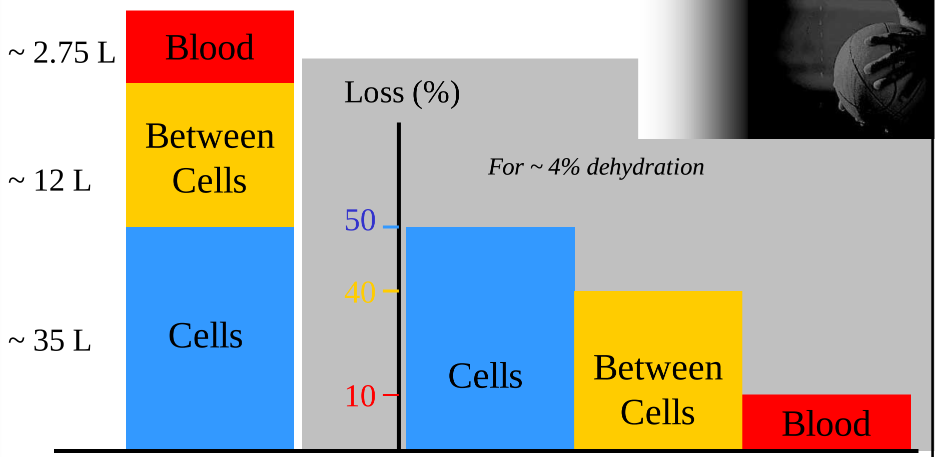
How Much Water is Needed by the Body?



Exercise or a Hot or Humid Environment?



Where is the Water Located?
From Where is it Lost?



Costill & Fink, 1976.

Dehydration

Dehydration is quantified by the amount of body weight lost.

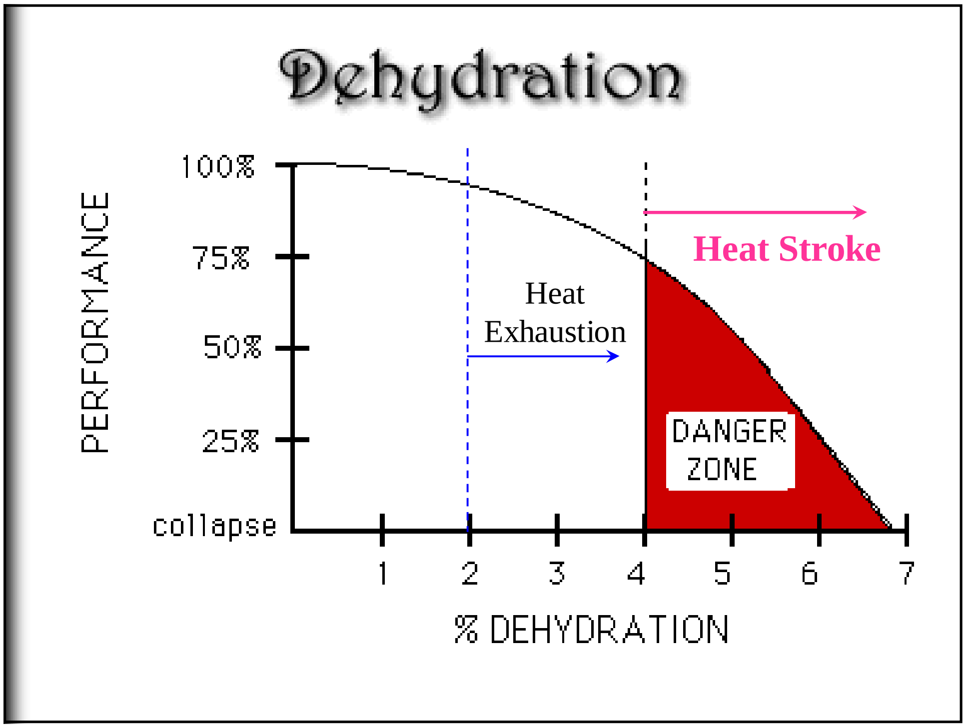
For example

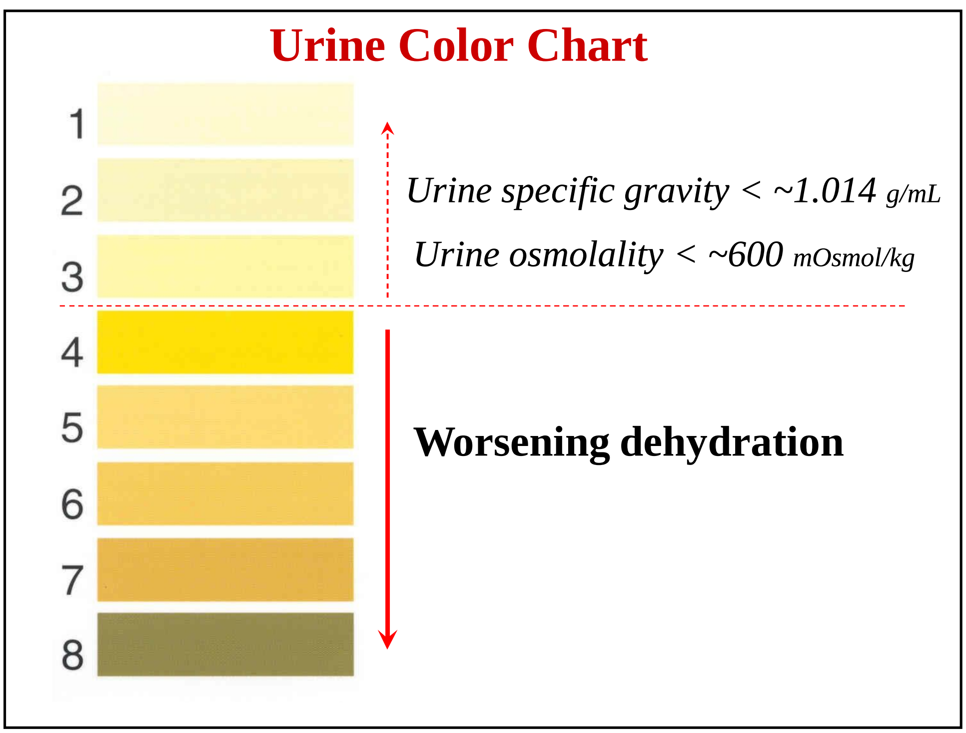
Pre-exercise weight = 70.0 kg

Post-exercise weight = 68.5 kg

Weight Loss = 1.5 kg

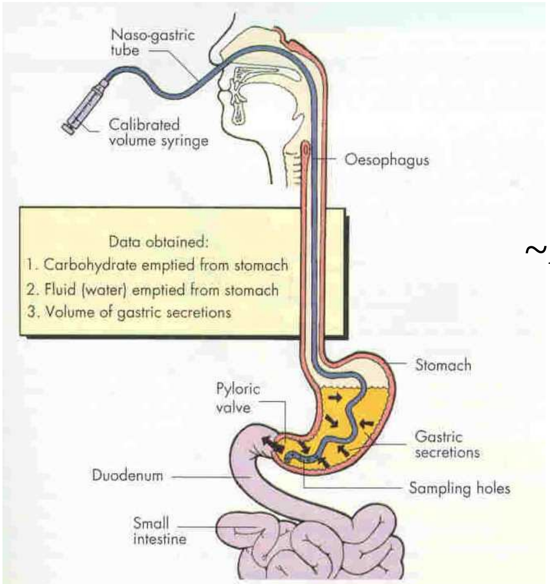
(1.5 / 70) x 100 = **2.1** %


Dehydration
PERFORMANCE
100%
75%
50%
25%
collapse
Heat Exhaustion
Heat Stroke
DANGER ZONE
1
2
3
4
5
6
7
% DEHYDRATION


Urine Color Chart
1
2
3
4
5
6
7
8
Urine specific gravity < ~1.014 g/mL
Urine osmolality < ~600 mOsmol/kg
Worsening dehydration

PROBLEM #1

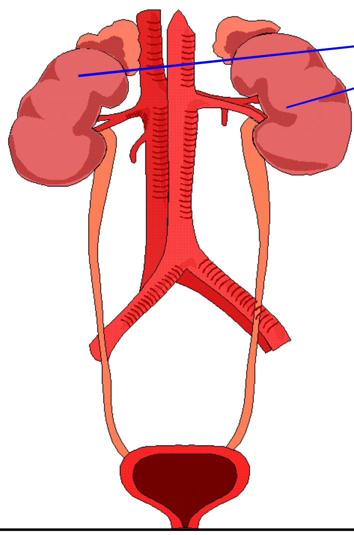
It is very difficult to prevent a significant dehydration



~1200 mL/hr

PROBLEM #2

It is very difficult to regulate the kidneys to maintain hydration



GFR = 120 L/day

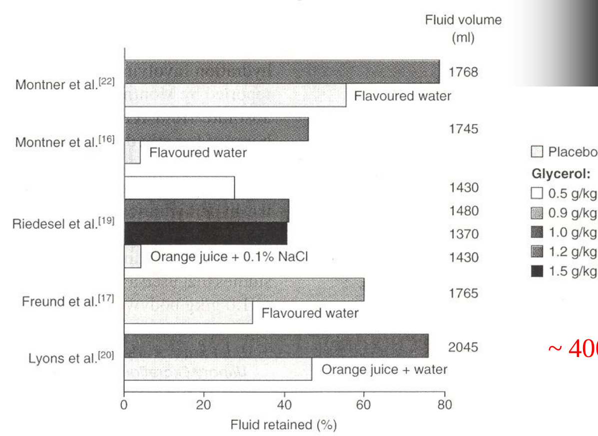
~ 99% of this water is reabsorbed

For most beverages, increasing fluid ingestion causes a decreased effectiveness of water reabsorption

Can Pre-exercise Hydration Be Increased?

YES

Robergs & Griffin. ***Sports Med***. 26(3):145-167, 1998

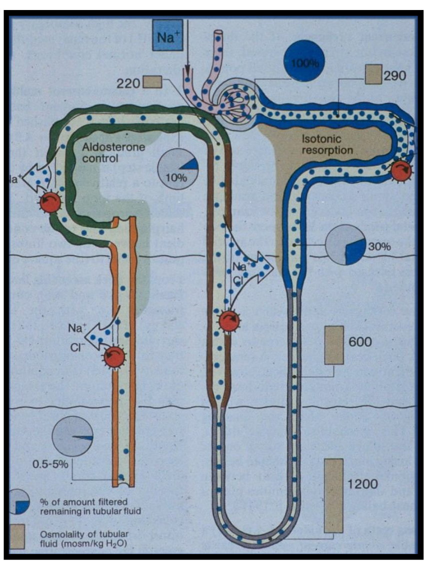


~ 400 – 700 mL

Fig. 5. Relative fluid retention resulting from glycerol hyperhydration during rest conditions. Lyons et al.[20] assessed hyperhydration after 2.5 hours, Freund et al.[17] after 3 hours, Riedesel et al.[19] after 4 hours, Montner et al.[16] after 2.5 hours, and Montner et al.[22] after 2 hours.

How Does Glycerol Work?

1. Glycerol hyper-hydration is accompanied by a decrease in urine volume



Recent Research *(in-review)* from Our Laboratory

Study 1

Compared,

a. Distilled water (DW)

b. 100 mEq/L NaCl (80 mEq), KCl (20 mEq) solution (EL)

c. Gatorade (CHO-EL)

d. Glycerol hyper-hydration (1.2 g glycerol bolus + 26 mL/kg water) (GBol)

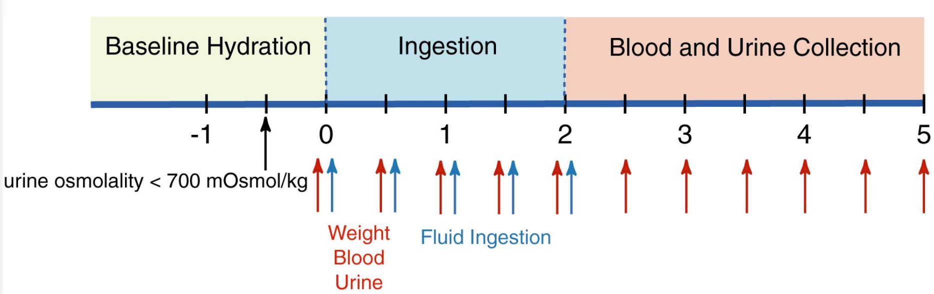
e. Glycerol solution (5.75 g glycerol/100 mL = 5.75 % glycerol) (GSol)

f. d + e (GG)

Subjects and Methods

Male	Female	Weight (kg)	LBM (kg)	Body Fat (%)
9	3	73.2±12.8	62.5±11.2	14.2±7.8

DW, EL,
CHO-EL, GSol = 4.0, 6.4, 5.2, 5.2, and 5.2 mL/kg
GBol = 40% glycerol, 6.4, 5.2, 5.2, and 5.2 mL/kg DW
GG = 40% glycerol, 6.4, 5.2, 5.2, and 5.2 mL/kg GSol

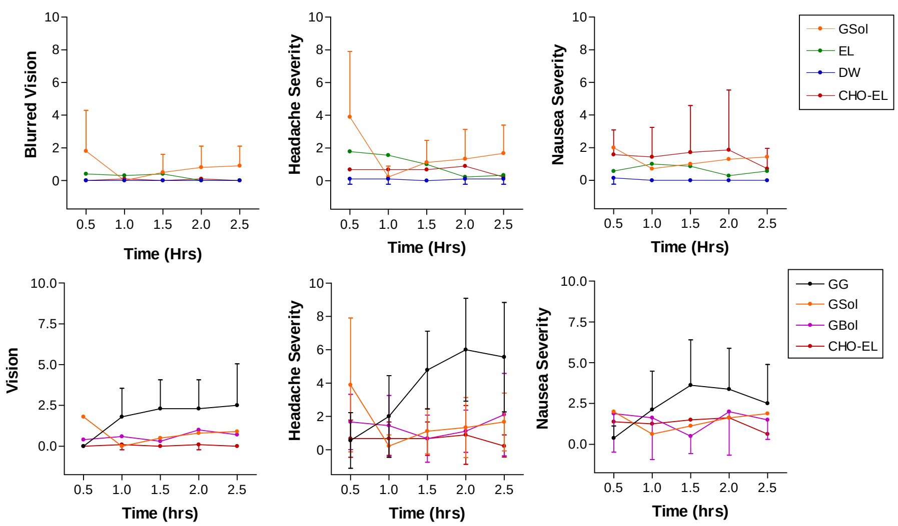


Results

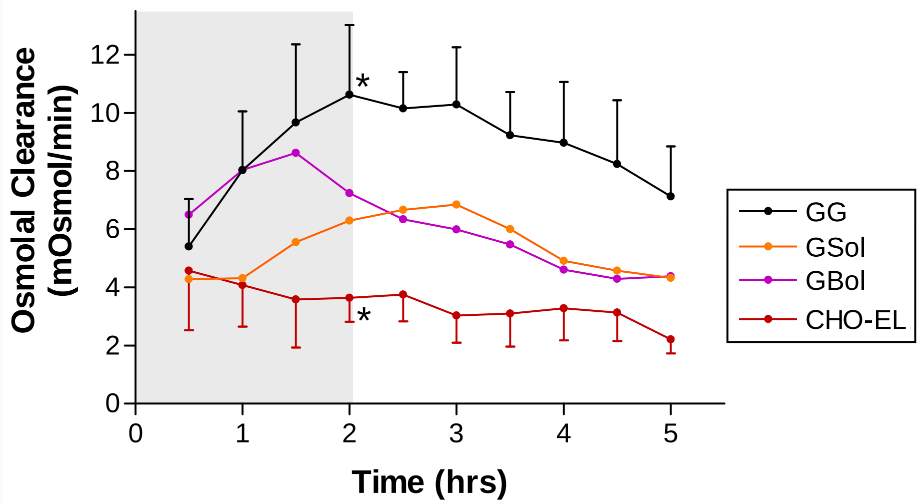
Will be presented as two studies:

1. Comparing methods of glycerol ingestion to CHO-EL.
2. Comparing glycerol solution (Gsol) to EL, CHO-EL and DW

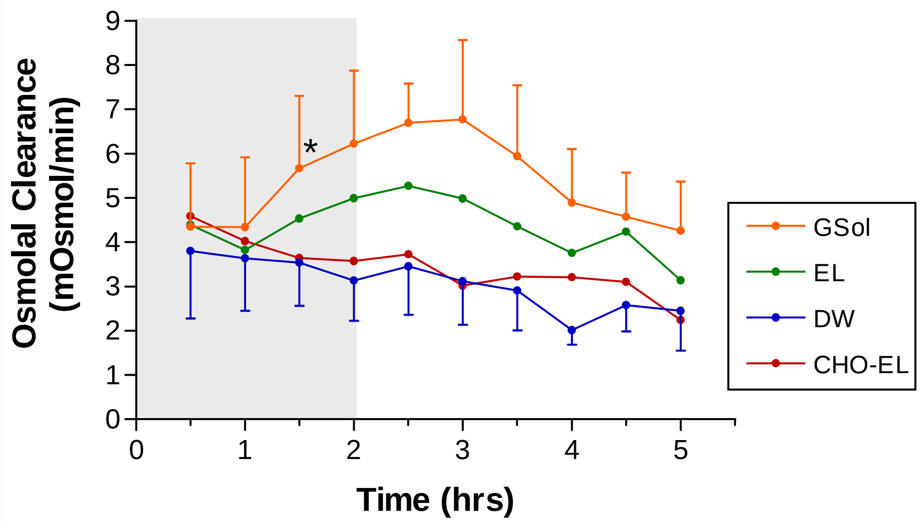
Symptoms



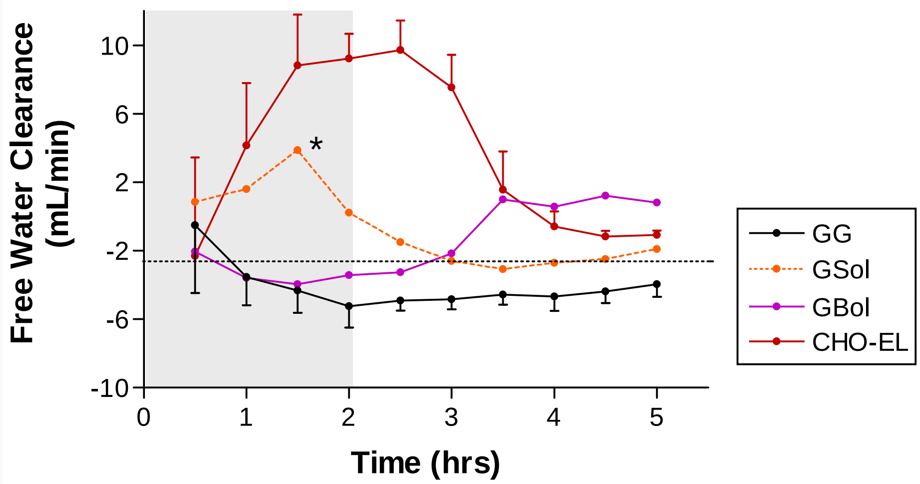
Osmolal Clearance



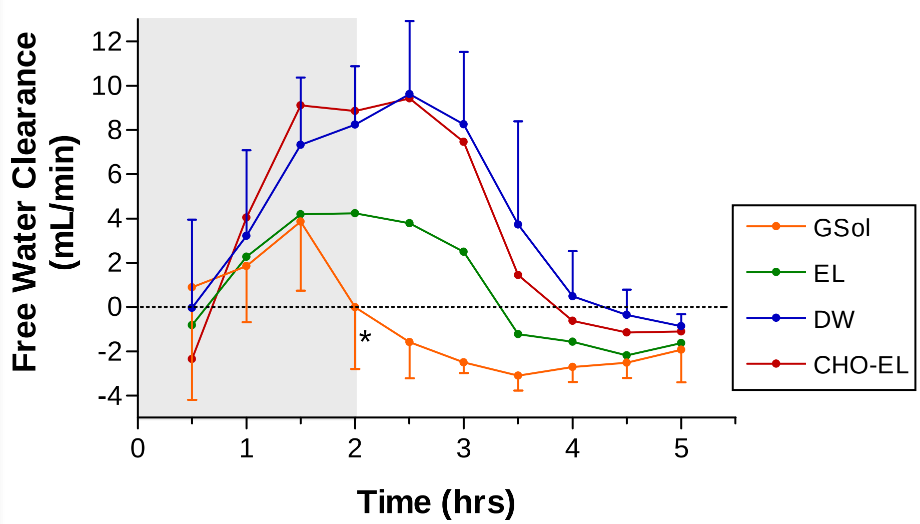
Osmolal Clearance



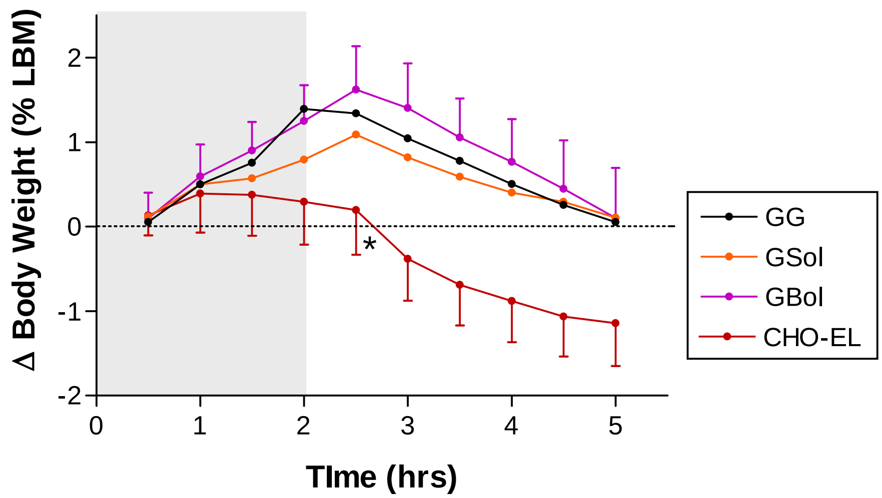
Free Water Clearance



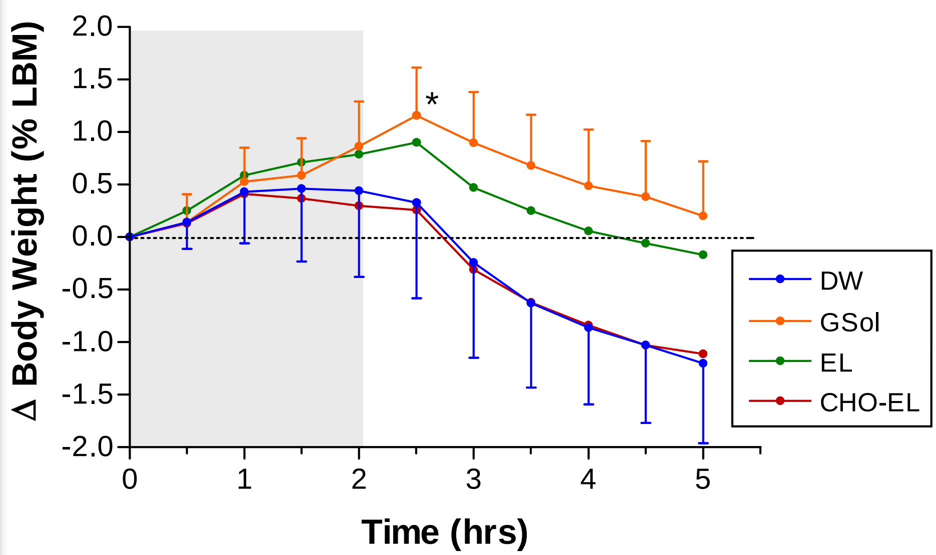
Free Water Clearance



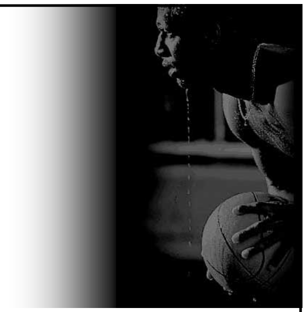
Change in Body Water



Change in Body Water



What we recommend to athletes:



4-5% glycerol solution in
half strength Gatorade

eg: glycerol = 1.25 g/mL

1 L of 5% glycerol solution

5 g or 4 mL of glycerol, and add half strength Gatorade to equal 1 L

Drink prior to exercise (1 to 2 L over 2 hrs)

Drink as needed during exercise

Thank you