HYDRATION ASSESSMENT & RECOMMENDATIONS

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Body Water and Electrolyte Basics

Total body water

Hydration terminology

Fluid compartments

Role of sodium in fluid balance

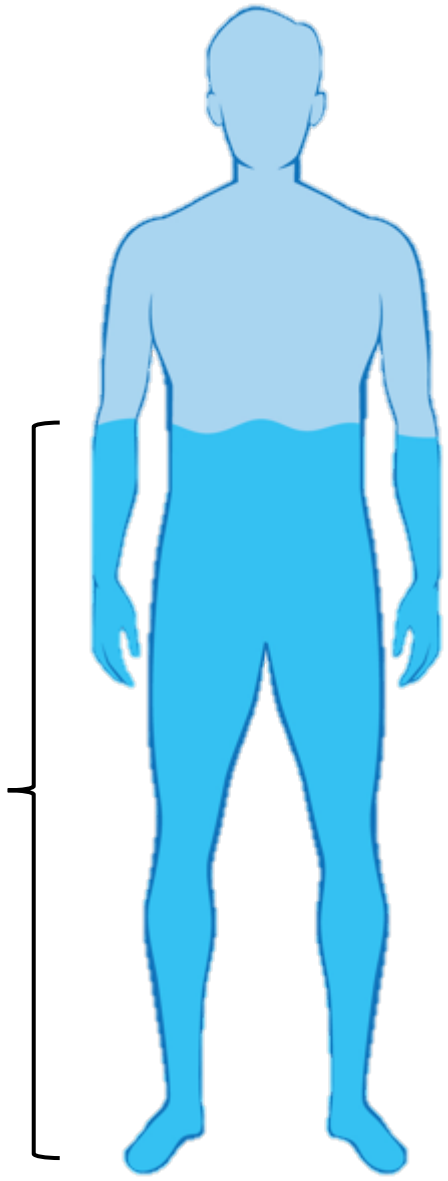
Hydration physiology

Hydration and performance

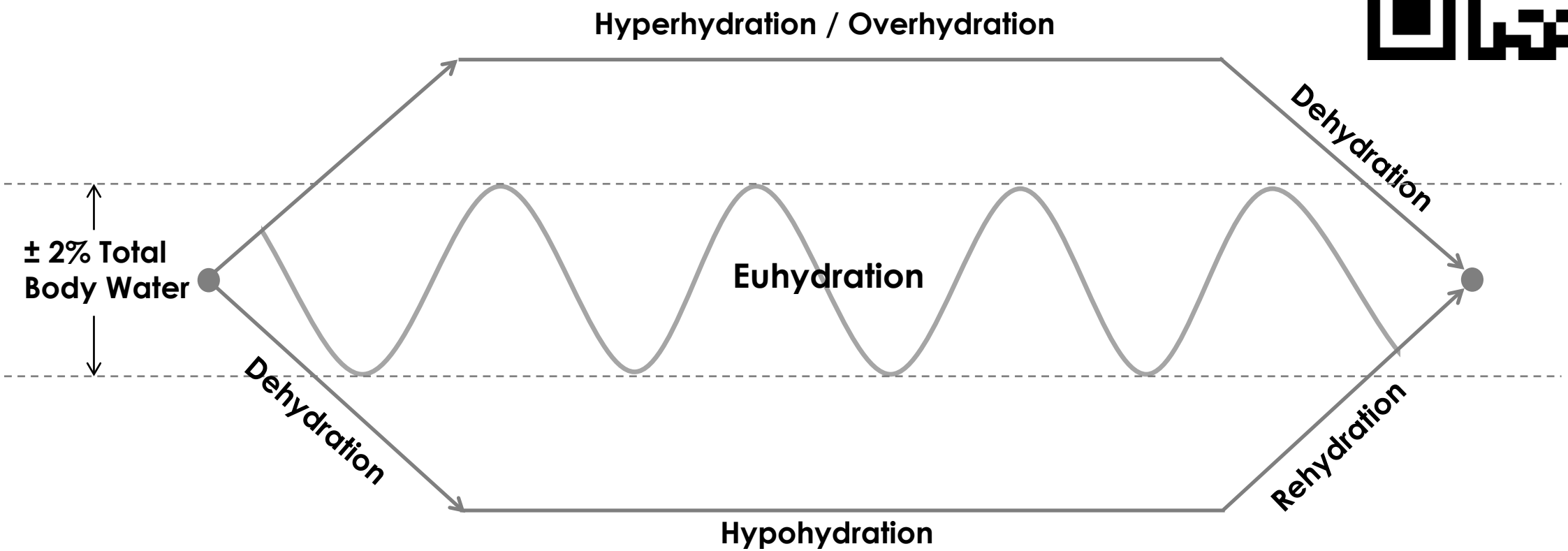
Total Body Water

~50-70% of body mass

TBW = ~0.73 x fat free mass



Hydration Terminology



Hydration Terminology

Euhydration – "normal" body water content within homeostatic range

Dehydration – the process of dynamic loss of body water – e.g., the transition from euhydration to hypohydration

Rehydration – the process of dynamic gain of body water (via fluid intake) – e.g., the transition from hypohydration to euhydration

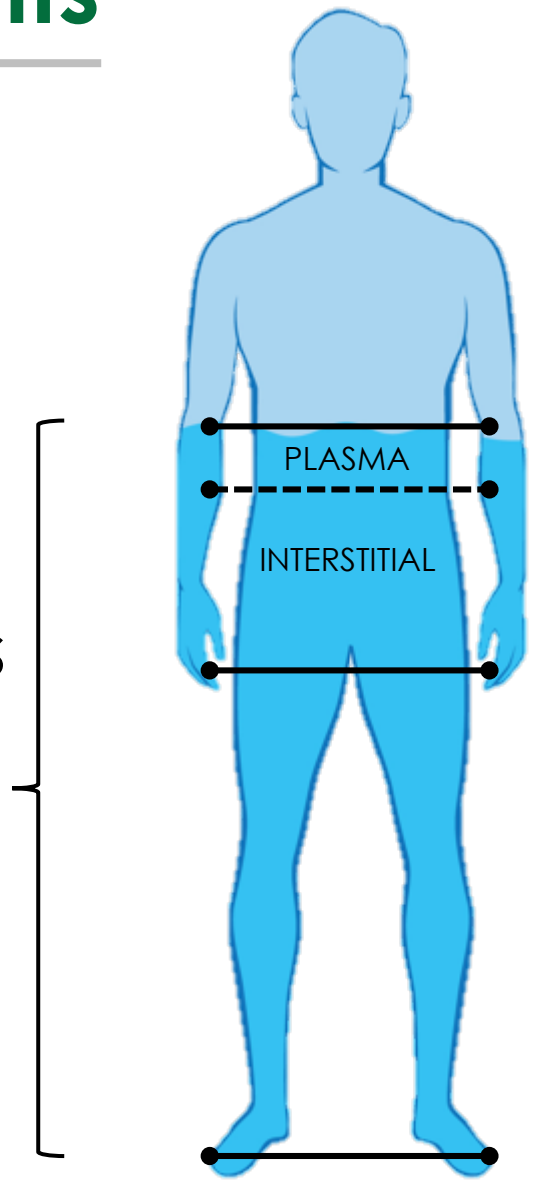
Hypohydration – state of body water deficit

Over- or Hyperhydration – state of body water excess

Fluid Compartments

~50-70% of body mass

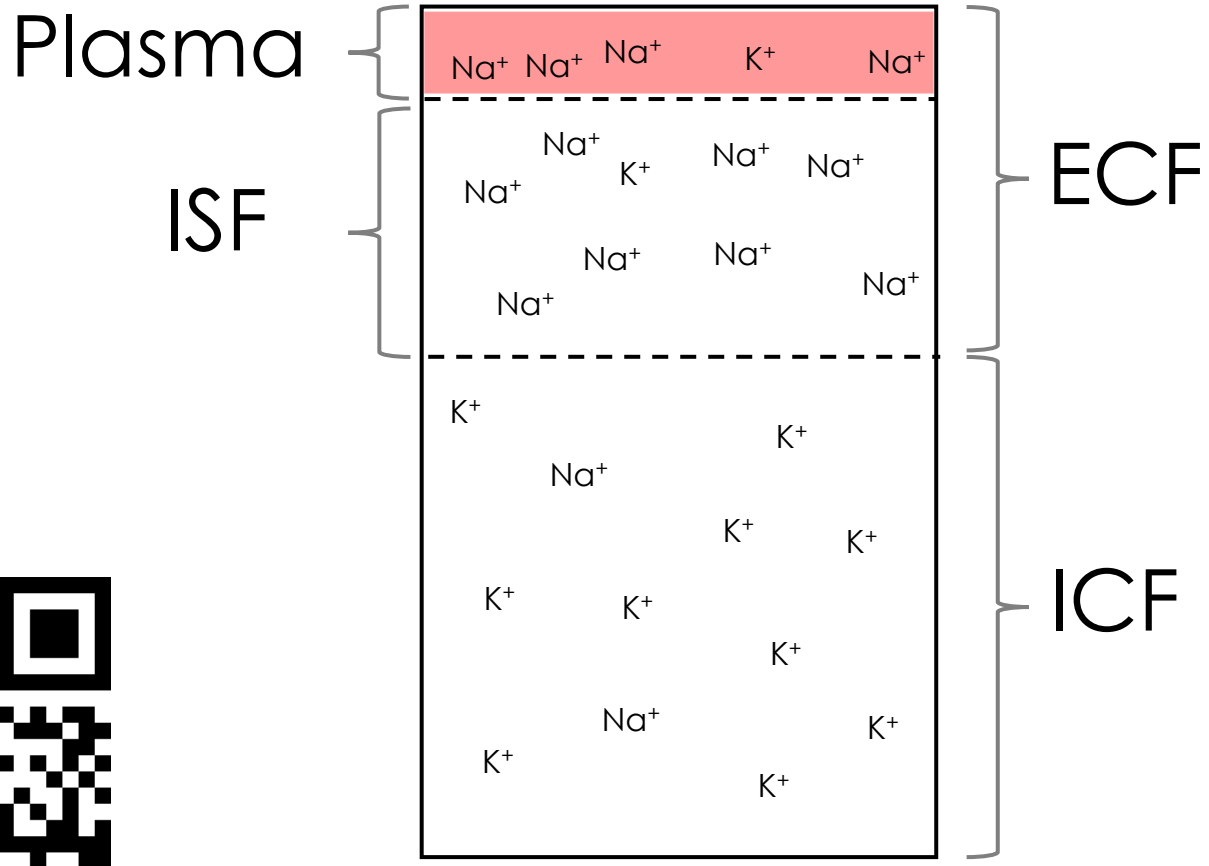
TBW = ~0.73 x fat free mass



Extracellular Fluid (ECF)
35-45% of TBW

Intracellular Fluid (ICF)
55-65% of TBW

Role of Sodium in Fluid Balance



Sodium (Na^+) is the most abundant electrolyte in the extracellular space

Sodium controls water movement between fluid compartments

Water follows solute to maintain osmotic equilibrium

Role of Sodium in Fluid Balance

SSE #111

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- Stimulates thirst – leading to increased fluid intake and better maintenance or restoration of euhydration
- Helps maintain proper fluid and electrolyte balance among fluid compartments
-  Supports cardiovascular function during exercise via better maintenance of plasma volume
-  Promotes whole body rehydration by stimulating renal fluid retention (decreased urine loss)

Hydration Physiology - Hypohydration

Hypohydration – body water deficit

↓

Hypovolemia – decreased plasma volume
Hyperosmolality – increased plasma osmolality (concentration of dissolved solutes, mostly sodium, in the blood)

↓

↑ **Cardiovascular strain** – lower stroke volume and higher heart rate

↑ **Body core temperature** – decreased ability to dissipate body heat through sweating and skin blood flow

↑ **Fatigue** - early onset of fatigue leading to reduced performance

Hydration Physiology - Overhydration

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Overdrinking low or no sodium fluids

↓

Overhydration – body mass gain because of a fluid surplus

↓

+ prolonged exercise (>4 hours)
+ smaller individual (low baseline total body water)
+ excessive sodium loss

} Additional risk factors

Exercise Associated Hyponatremia – dilution of plasma sodium concentration to < 135 mmol/L

↓

Water flux into the ICF –severity of symptoms related to cell swelling depends on how much and how fast plasma sodium [Na^+] decreases

Noakes TD, Goodwin N, Rayner BL, et. al. *Med Sci Sports Exerc.* 1985;17(3):370-375
Hew-Butler TD, Godek SF, Rosner M, et. al. *Br J Sports Med.* 2015;25:303-320

Hydration and Performance

Cognition

Team Sports

Aerobic Exercise

Muscle Endurance, Strength, & Anaerobic Power

SSE #128, 152, 165

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Hypohydration can impair performance, especially if exceeds 2-3% body mass loss and in hot/humid conditions

Laitano et. al. *Sports Science Exchange*. 2014;27(128)
Sawka et. al. *Sports Science Exchange*. 2015;28(152)
Baker. *Sports Science Exchange*. 2016;28(165)

McDermott BP, Anderson SA, Armstrong LE, et. al. *J Athl Train*. 2017;52(9):877-895
Thomas DT, Erdman KA, Burke LM. *Med Sci Sports Exerc*. 2016;48(3):543-568

Fluid Balance

Assessment before exercise

Hydration status

Sweat loss

Sweating rate

Data collection

Example calculations

Can you think of a simple way for an Athletic Trainer or Sports Dietitian to monitor the hydration status of their athletes?

Monitoring Hydration Status: Urine Color

Urine color can be used as a reliable marker of hydration status

Athletes with a urine color of 5 on a urine color chart are 6 times more likely to be hypohydrated

A mean urine color of 3 provides a reasonable assurance the athlete is hydrated

Urine color can be monitored by the athlete or by the ATC

Post urine color charts in bathrooms

McKenzie AL, Muñoz CX, Armstrong LE. *J Athl Train*. 2015;50(12):1306-1309

Hydration Assessment Before Exercise

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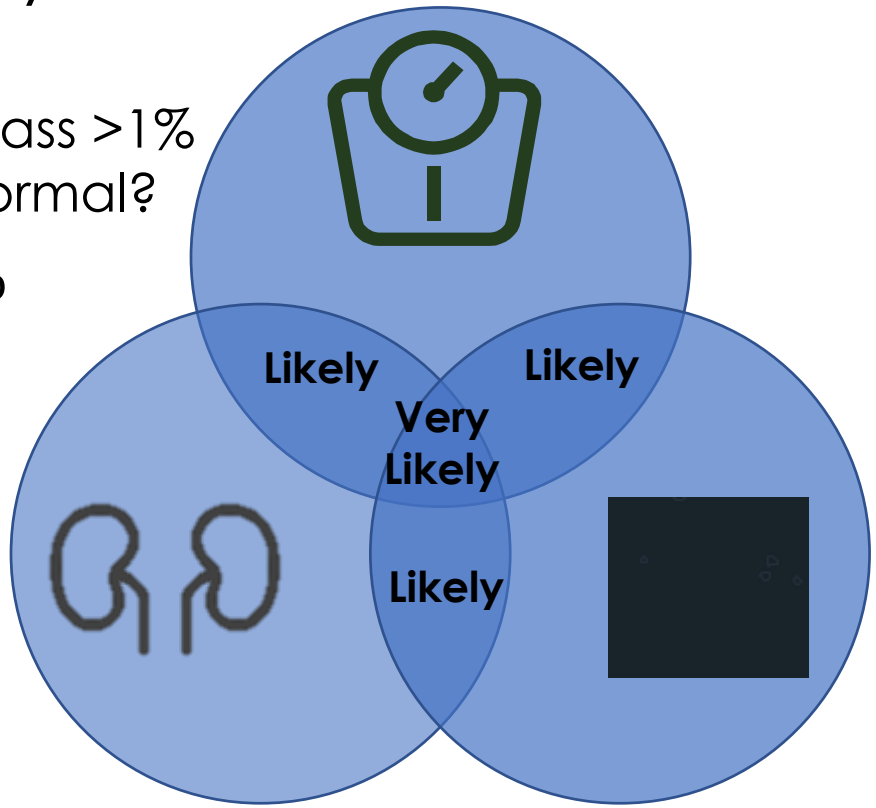
Are you hypohydrated?

Is my body mass >1% lower than normal?

Yes / No

Is my urine dark yellow?

Yes / No



Am I Thirsty?

Yes / No

Assess first thing in the morning (before breakfast)

Urine Specific Gravity (USG)

USG is sensitive to changes in hydration state

ACSM & NATA recommend cut-off points for dehydration of ≥1.020 for USG.

Medications can alter urine color and USG including vitamins

Best to use more than one measure (ie: change in body weight, urine color and USG)

Armstrong LE, Johnson EC, McKenzie AL, Muñoz CX. *J Clin Nutr*. 2013;67(3):249-253

MONITORING HYDRATION DURING PLAY

Hydration Status

Body mass loss

Sweat

Urine

Respiration
(fuel oxidation, water vapor)

Body mass gain

Drinking

Eating

Hydration status = % change in nude body mass

Calculation: [(Δ body mass) / baseline body mass]*100

Example: 2% hypohydration = 2% body mass deficit through fluid loss

Hydration Status

2007 Fluid Replacement Position Stand

Acute body mass change can be used to calculate sweating rate and perturbations in hydration status when corrected for urine losses, drink volume, and trapped sweat.

Other non-sweat factors (fuel oxidation and respiratory water loss) can overestimate sweating rate but do not require correction for < 3 h exercise.

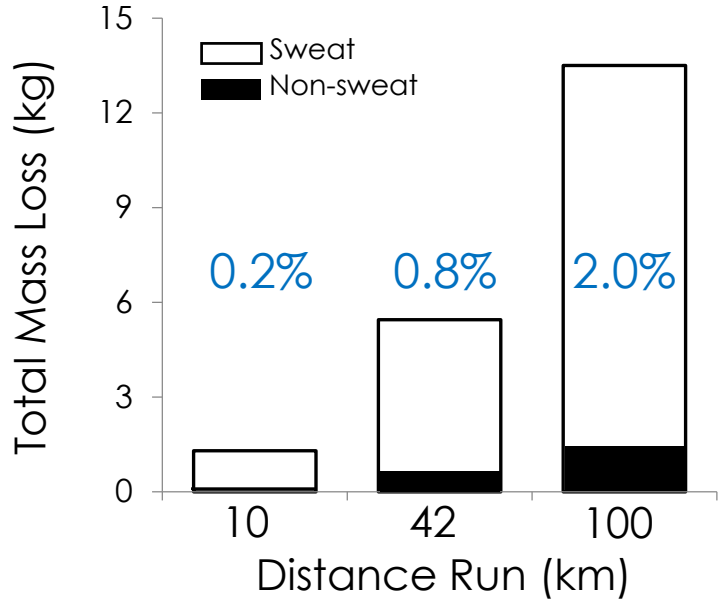
Therefore, using acute body mass change to estimate hydration status is appropriate for most individual and team sports, since practices and games are typically < 3 h.

Sawka MN, Burke LM, Eichner ER, et. al. *Med Sci Sports Exerc.* 2007;39(2):377-390

Hydration Status

Using change in body mass to determine hydration status becomes less accurate with longer events

For example, during ultraendurance events ≥ 2% of body mass loss can occur through non sweat sources:



161-km mountain ultramarathon running competition (~25-30 h)

1.2-3.5% of body mass loss due to non-sweat sources

Hoffman et al. *Sports Med,* 2017
Correction in *Sports Med*, 2018.

Data Collection - Change in Hydration Status

Supplies needed

- ✓ Digital platform body weight scale with precision of 0.10 kg or better
- ✓ Towels

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Instructions

Before Exercise

- ✓ Ask athlete to use restroom, void bladder and bowels
- ✓ Weigh athlete while they are wearing minimal clothing (e.g., compression shorts, sports bra)

After Exercise

- ✓ Ask athlete to towel dry thoroughly
- ✓ Weigh athlete while wearing the same minimal clothing as before exercise

Example #1

Data

- Baseline body mass: 104.55 kg
- Post-exercise body mass: 101.00 kg

Example #1

Calculate the athlete's % change in hydration status after practice

Body mass decreased from 104.55 kg to 101.00 kg, so Δ body mass = -3.55 kg

Hydration status = [(Δ body mass) / baseline body mass]*100

(-3.55 kg / 104.55 kg) *100

-3.4% change in body mass

Example #2

Data

- Baseline body mass: 56.35 kg
- Post-match body mass: 55.45 kg

Example #2

Calculate the athlete's % change in hydration status after the match

Body mass decreased from 56.35 kg to 55.45 kg, so Δ body mass = -0.90 kg

Hydration status = [(Δ body mass) / baseline body mass]*100

(-0.90 kg / 56.35 kg) *100

-1.6% change in body mass

Example #3

Data

- Baseline body mass: 66.15 kg
- Post exercise body mass: 66.80 kg

Example #3

Calculate the athlete's % change in hydration status after exercise

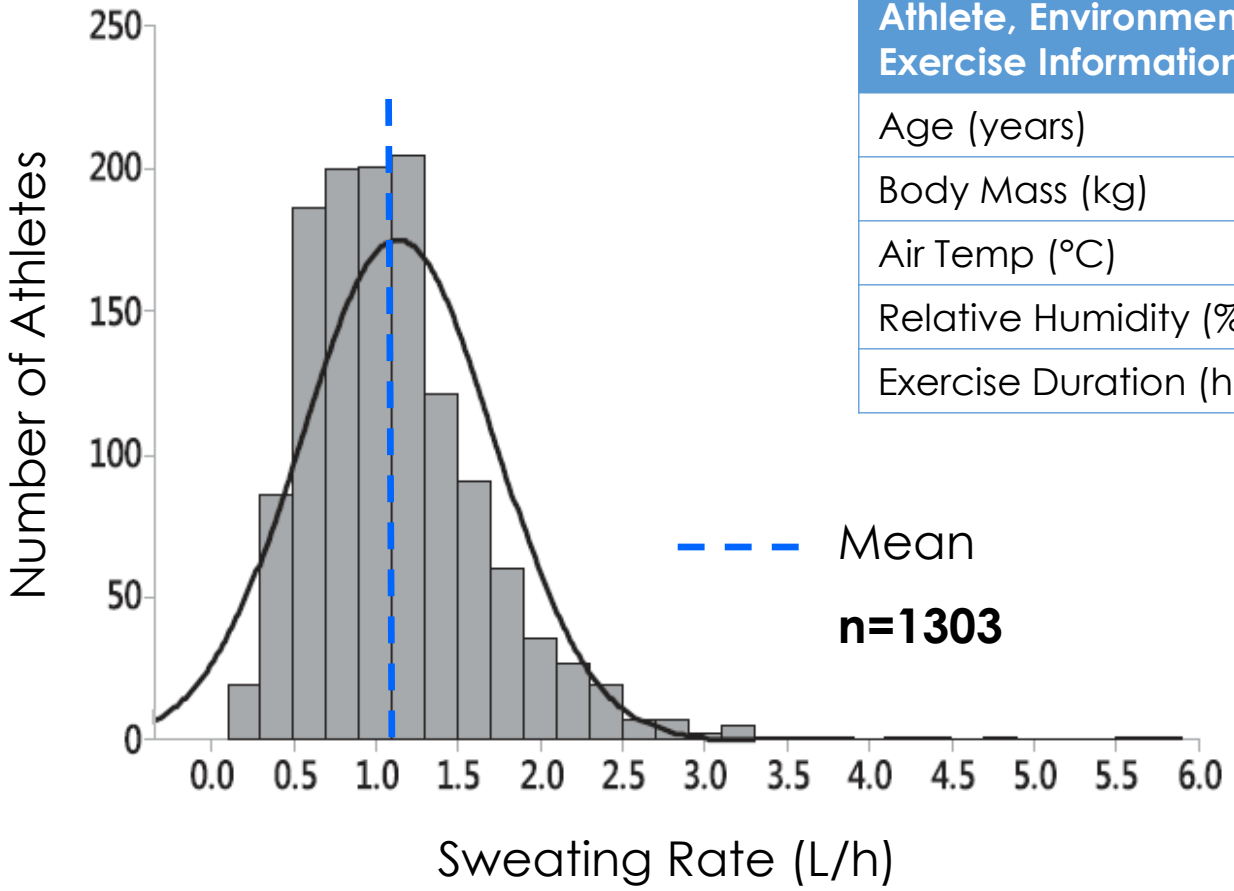
Body mass increased from 66.15 kg to 67.00 kg, so Δ body mass = +0.65 kg

Hydration status = [(Δ body mass) / baseline body mass]*100

(0.65 kg / 66.15 kg) *100

+1.0% change in body mass

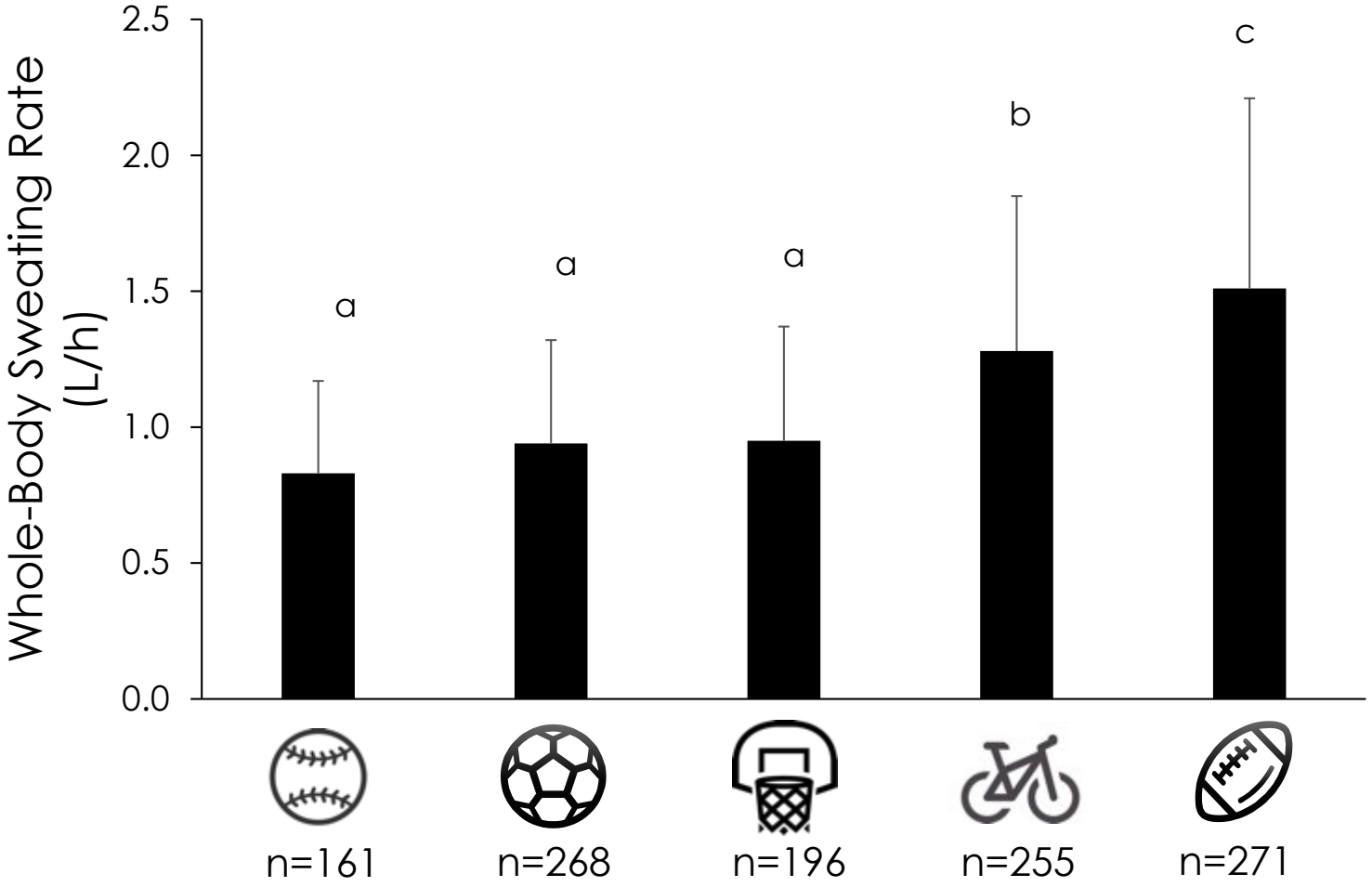
Sweating Rate – Normative Data in Athletes



Athlete, Environment, and Exercise Information	Mean ± SD (Range)
Age (years)	24 ± 9 (9-70)
Body Mass (kg)	84 ± 24 (23-178)
Air Temp (°C)	26 ± 5 (11-50)
Relative Humidity (%)	55 ± 17 (13-95)
Exercise Duration (h)	1.7 ± 0.7 (0.5-5.4)

Barnes KA, Anderson ML, Stofan JR, et. al. *J Sports Sci.* 2019;37(20):2356-2366

Sweating Rate – Normative Data by Sport



Sports sharing same letter are not different ($p>0.05$)

Barnes KA, Anderson ML, Stofan JR, et. al. *J Sports Sci.* 2019;37(20):2356-2366

Factors impacting the variability in sweating rate

Exercise intensity
Body size
Environmental conditions
(temperature, humidity, solar load, wind)
Heat acclimatization
Fitness
Clothing/equipment worn
Body composition
Hydration status
Age (maturation)
Genetics
Methodology

Sweat Loss Calculations

Mass loss

Sweat
Urine
Respiration
(fuel oxidation, water vapor)

Mass gain

Drinking
Eating

Sweat Loss = [Pre-Ex Body Mass – (Post-Ex Body Mass – Fluid & Food + Urine & Resp)]

Respiratory losses = 0.2 g/kcal of energy expended during exercise. Because of the relatively small contribution of respiratory losses to total body mass loss and because energy expenditure is difficult to measure, this part of the equation is usually dropped for acute bouts of exercise.

Sweat Loss = [Pre-Ex Body Mass – (Post-Ex Body Mass – Fluid & Food + Urine)]

Sawka MN, Burke LM, Eichner ER, et. al. *Med Sci Sports Exerc.* 2007;39(2):377-390
Cheuvront and Montain. *Exp Physiol.* 2017;102:1047-1053
Cheuvront and Kenefick. *J Appl Physiol.* 2017;123(3):632-636

Data Collection – Sweat Rate

SSE #161

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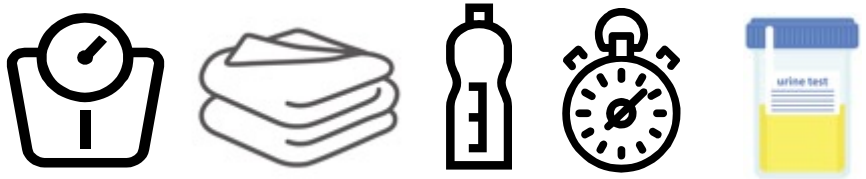
Supplies needed

- ✓ Digital platform body weight scale with precision of 0.10 kg or better
- ✓ Towels
- ✓ Clock or Stopwatch
- ✓ Drink Bottles
- ✓ Small digital scale
- ✓ Urine cup



Instructions

Before Exercise

- ✓ Ask athlete to use the restroom, void bladder and bowels
- ✓ Weigh athlete while he/she is wearing minimal clothing (e.g., compression shorts, sports bra)
- ✓ Weigh drink bottles and food (bars, gels, etc), if applicable

During Exercise

- ✓ Collect urine loss in cup and weigh, if applicable

After Exercise

- ✓ Ask athlete to towel dry thoroughly
- ✓ Weigh athlete while wearing the same minimal clothing as before exercise
- ✓ Weigh drink bottles and food, if applicable

Example #1

Data

- Baseline body mass: 104.55 kg
- Practice duration: 2.5 h
- Fluid consumed: 1.25 kg
- Food consumed: two 50-g energy bars
- Urine loss = N/A
- Post exercise body mass: 101.00 kg

Example #1

Calculate the athlete's sweat rate

Sweat Loss = [Pre-Ex Body Mass – (Post-Ex Body Mass – Fluid & Food + Urine)]

104.55 kg - (101.00 kg -1.35 kg + 0 kg)

4.90 kg (or L) of sweat lost in 2.5 h

Sweat Rate = 4.90 L / 2.5 h **= 1.96 L/h**

Example #2

Data

- Baseline body mass: 56.35 kg
- Match duration: 1.5 h
- Fluid consumed: 0.85 kg
- Urine loss: N/A
- Post exercise body mass: 55.45 kg

Example #2

Calculate the athlete's sweat rate

Sweat Loss = [Pre-Ex Body Mass – (Post-Ex Body Mass – Fluid & Food + Urine)]

56.35 kg - (55.45 kg - 0.85 kg + 0 kg)

1.75 kg (or L) of sweat lost in 1.5 h

Sweat Rate = 1.75 L / 1.5 h **= 1.17 L/h**

Example #3

Data

- Baseline body mass: 66.15 kg
- Exercise duration: 2 h 20 min
- Fluid consumed: 2.05 kg
- Urine loss: 0.20 kg
- Post exercise body mass: 66.80 kg

Example #3

Calculate the athlete's sweat rate

Sweat Loss = [Pre-Ex Body Mass – (Post-Ex Body Mass – Fluid & Food + Urine)]

66.15 kg - (66.80 kg -2.05 kg + 0.20 kg)

1.20 kg (or L) of sweat lost in 2.33 h

Sweat Rate = 1.20 L / 2.33 h **= 0.52 L/h**

Planned Drinking vs Drinking to Thirst

SSE #182

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Drink to Thirst

Short duration activities < 60 to 90 min
Cooler conditions
Lower intensity

Planned Drinking

Longer duration activities > 90 min
Particularly in the heat
High intensity
High sweat rates
When performance is a concern
When carbohydrate intake of 1 g/min

Electrolyte Balance

Sweat composition

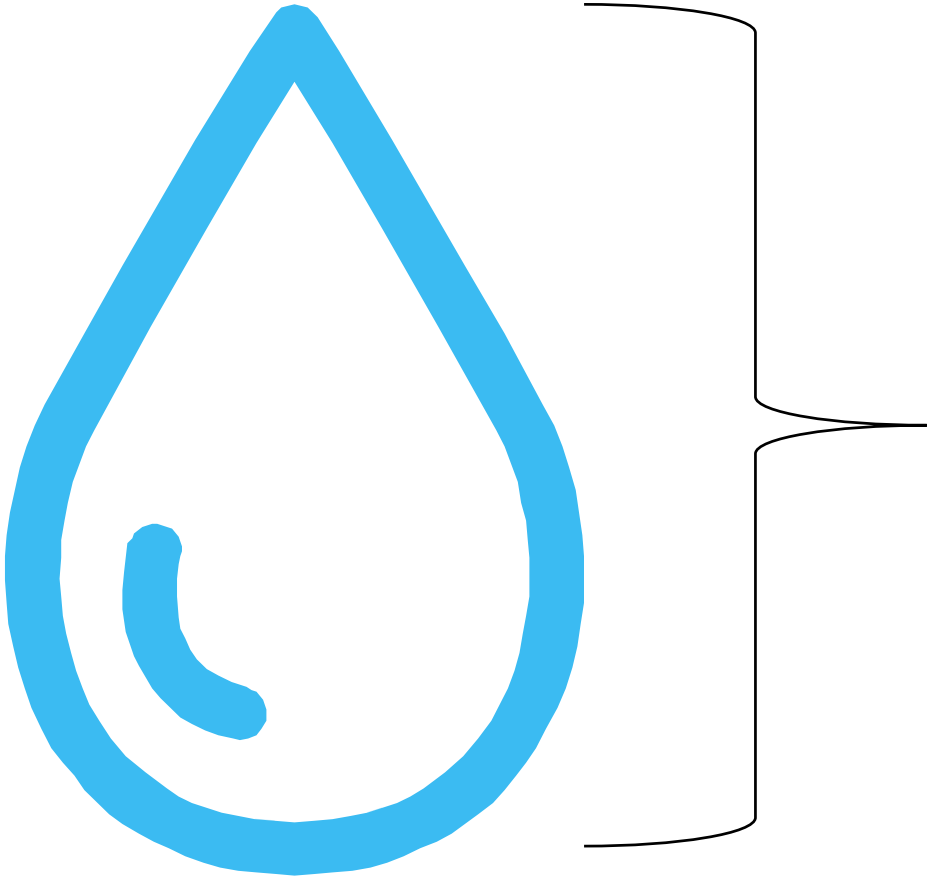
Sweat sodium concentration

Sweat sodium loss

Data collection

Example calculations

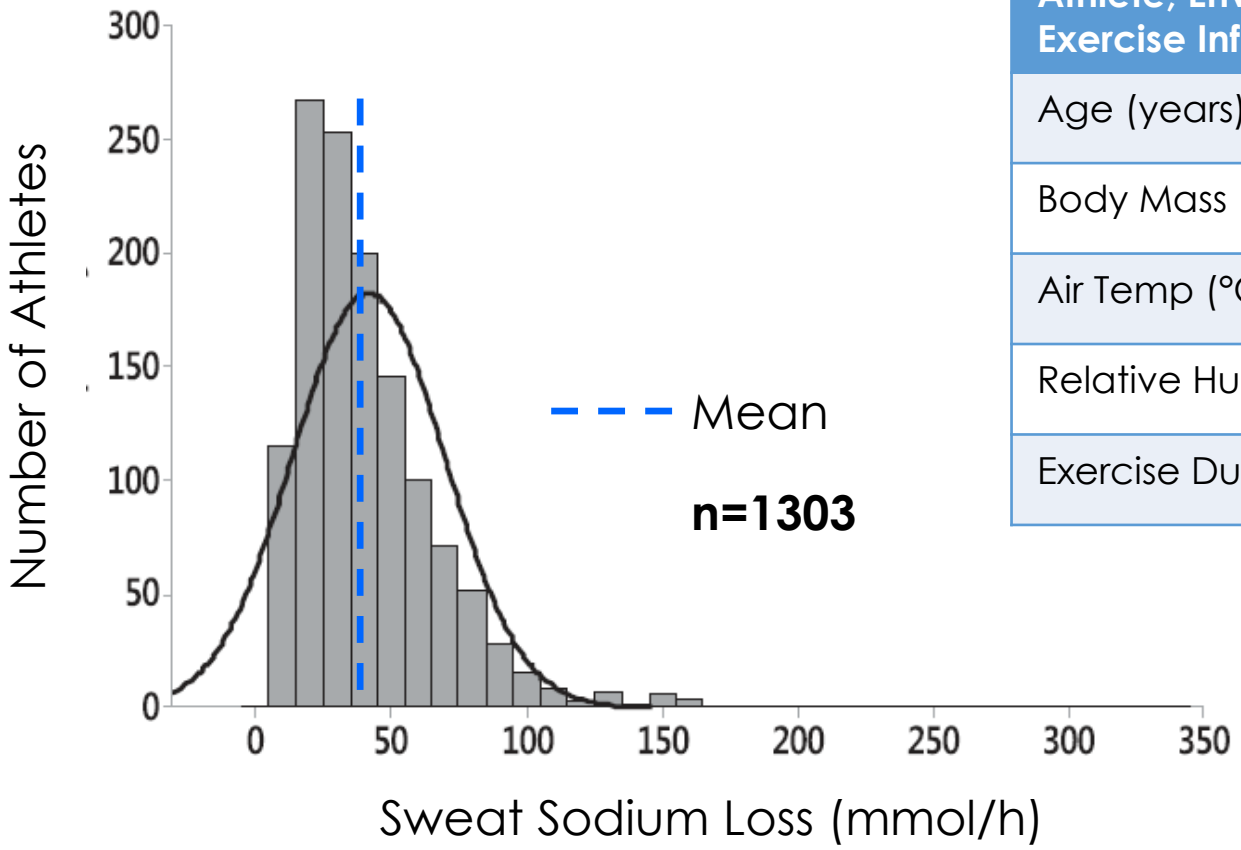
Sweat Composition



	Concentration
Sodium	10-90 mmol/L
Chloride	10-90 mmol/L
Lactate	5-40 mmol/L
Urea	4-12 mmol/L
Potassium	2-8 mmol/L
Ammonia	1-8 mmol/L
Others (e.g., bicarbonate, calcium, magnesium, glucose, amino acids, iron, copper, zinc)	< 1 mmol/L each

Baker and Wolfe. *Eur J Appl Physiol.* 2019;120:719-752

Sweat Sodium Loss – Athlete Normative Data



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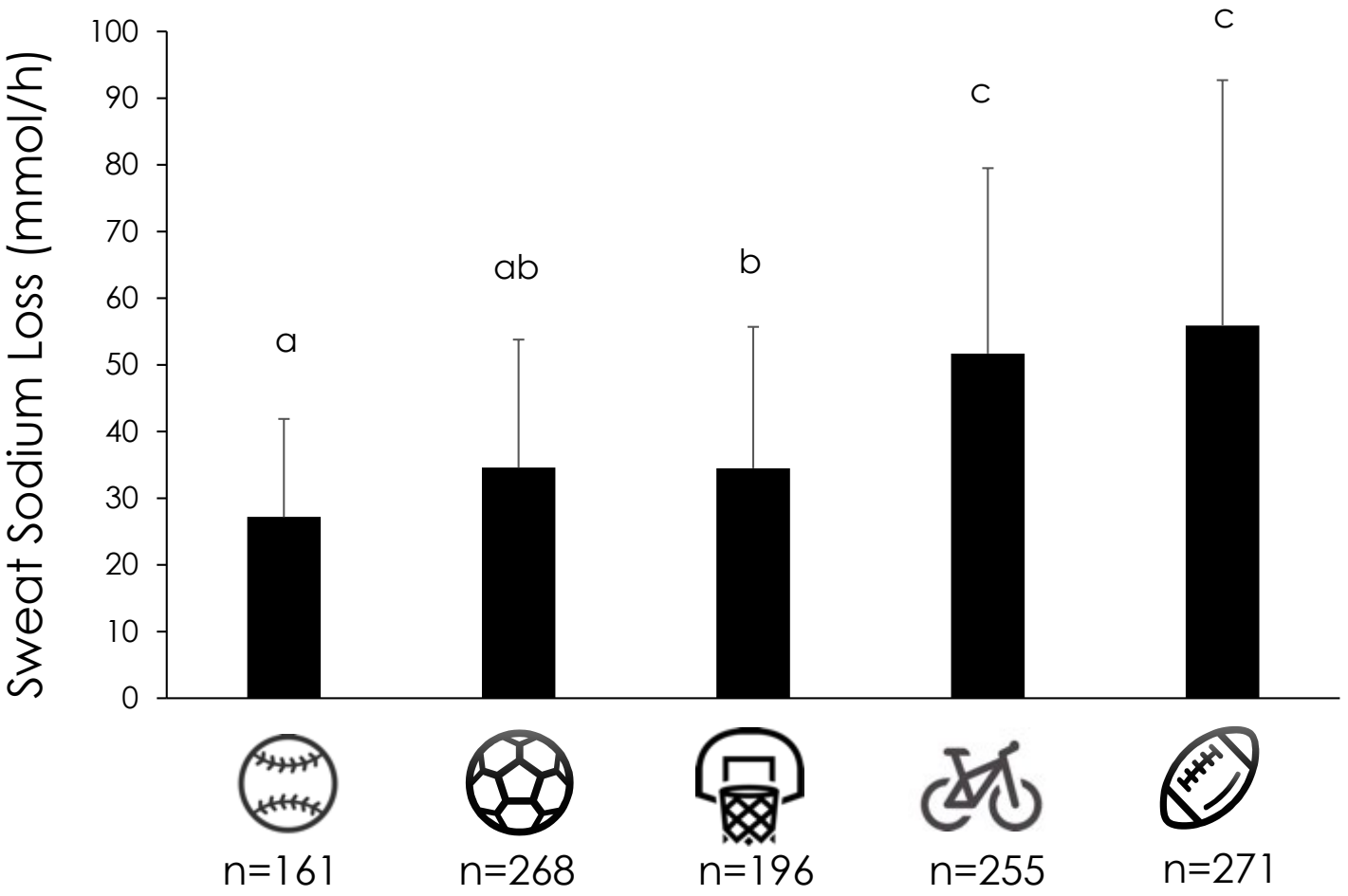
Sweat Sodium Loss – Normative Data by Sport



Sports sharing same letter are not different ($p>0.05$)

Barnes KA, Anderson ML, Stofan JR, et. al. *J Sports Sci.* 2019;37(20):2356-2366

Data Collection – Sweat Sodium Concentration

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Supplies needed

- ✓ Absorbent sweat patch
- ✓ Forceps
- ✓ Alcohol wipes and/or deionized water
- ✓ Gauze or paper towels
- ✓ Gloves
- ✓ Storage tube
- ✓ Analytical device

Instructions

Before Exercise

- ✓ Clean the athlete's forearm with alcohol and/or deionized water, wipe dry
- ✓ Apply patch to mid-forearm

During/After Exercise

- ✓ Monitor patch via visual inspection
- ✓ Use gloved hands and clean forceps to remove patch upon moderate saturation
- ✓ Place absorbent pad into storage tube

Storage/Anlaysis

- ✓ If analysis is not done immediately, seal tube and store refrigerated for up to 1 week
- ✓ Measure sodium concentration using ion chromatography or ion selective electrode
- ✓ Use published regression equations to predict whole body sweat sodium concentration

Example #1

Data

- Forearm sweat sodium concentration: 80 mmol/L
- Practice duration: 2.5 h
- Sweat loss: 4.90 L

Example #1

Calculate the athlete's total sweat sodium loss

Whole Body Sweat [Na^+] = 0.57(80 mmol/L) +11.05 = 56.65 mmol/L

Whole Body Sweat Sodium Loss = 56.65 mmol/L * 4.90 L = 277.59 mmol

= 277.59 mmol * 22.99 mg/mmol

= **6382 mg sodium**

Example #2

Data

- Forearm sweat sodium concentration: 62 mmol/L
- Match duration: 1.5 h
- Sweat loss: 1.75 L

Example #2

Calculate the athlete's total sweat sodium loss

Whole Body Sweat [Na^+] = 0.57(62 mmol/L) +11.05 = 46.39 mmol/L

Whole Body Sweat Sodium Loss = 46.39 mmol/L * 1.75 L = 81.18 mmol

= 81.18 mmol * 22.99 mg/mmol

= **1866 mg sodium**

Example #3

Data

- Forearm sweat sodium concentration: 38 mmol/L
- Exercise duration: 2 h 20 min
- Sweat loss: 1.20 L

Example #3

Calculate the athlete's total sweat sodium loss

Whole Body Sweat [Na^+] = 0.57(38 mmol/L) +11.05 = 32.71 mmol/L

Whole Body Sweat Sodium Loss = 32.71 mmol/L * 1.20 L = 39.25 mmol

= 39.25 mmol * 22.99 mg/mmol

= **902 mg sodium**

Recommendations

- ✓ Begin exercise properly hydrated
- ✓ Use a personalized fluid intake strategy based on sweat test results, exercise duration, and environmental conditions
- ✓ Drink enough fluid to prevent >2% dehydration, especially in warm weather
- ✓ Do not overconsume fluids during exercise
- ✓ Consume sodium with fluids if exercise is >2 h in hot weather and/or if sweat electrolyte losses are very high (> 3 g)

McDermott BP, Anderson SA, Armstrong LE, et. al. *J Athl Train.* 2017;52(7):687-696
Thomas DT, Erdman KA, Burke LM. *Med Sci Sports Exerc.* 2016;48(3): 543-568
Racinais S, Alonso JM, Coutts AJ, et. al. *Scand J Med Sci Sports.* 2015;25(1):6-19
Sawka MN, Burke LM, Eichner ER, et. al. *Med Sci Sports Exerc.* 2007;39(2):377-390

Link to Summary Video