Osmolarity

References below to Guyton and Hall, Textbook of Medical Physiology, 9th Edition, 1996 are denoted as *G&H*.

The osmolarity of body fluids is an important part of many physiological responses.

Water can move freely between the intracellular and extracellular spaces and between the plasma and interstitium. Thus, the osmolarities of plasma, interstitial fluid, and intracellular fluid are nearly identical. See G & H, chapter25. In this exercise this osmolarity will be called the osmolarity of body fluids.

The scenario is that Billy Bob is going hiking. It is a very hot day and Billy Bob forgot his water bottle. But he’s going ahead anyway.

We created Billy Bob by changing several relevant parameters – see Appendix. These conditions were then saved in an initial conditions file named BILLYBOB.ICS using the main menu File / Save Initial Conditions menu selection.

You can reload Billy Bob now using the main menu File / Load Initial Conditions menu selection, specifying the file named BILLYBOB.ICS.

There are three main objectives in this exercise.

1. Observe water loss from the body’s various compartments during exertion in heat. Look for changes in water distribution.
2. Observe sodium loss from the body during exertion in heat. Devise a strategy for replacing the lost sodium.
3. Observe osmolarity changes during exertion in heat. Calculate the resultant volume changes in a red blood cell in plasma. Calculate volume changes in a red blood cell as it travels into the renal medulla, where osmolarity is quite high.

A  in a table row below indicates that calculation is required.

# Water Loss During Exertion In Heat

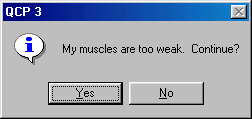
Exertion in heat raises the body temperature. This triggers sweating and the sweating moves water from the body to the environment. Sweating triggers thirst and we drink water to replace the lost amount. In this case, however, water intake has been restricted so we can specifically track water loss.

Click Restart to establish Billy Bob’s initial conditions. Use the Go main menu selection to advance time. Record volumes at control (0 hours) and at 1, 2 and 3 hours of hiking.

 - Panel shows volumes.

 Sweat – Panel shows sweating, FYI.

Note: Billy Bob will probably get worn out before 3 hours. He will stop exercising and the following page will be displayed.



What a wimp. Click Yes to continue on to 3 hours.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Control | 1 Hr | 2 Hrs | 3 Hrs |
| Total Body Water (L) |  |  |  |  |
|  Cumulative Water Loss In Sweat (L) |  |  |  |  |
| Plasma Volume (L) |  |  |  |  |
| Interstitial Volume (L) |  |  |  |  |
| Cell Water (L) |  |  |  |  |

\*\*\*The Cumulative water lost in sweat is not given in QCP, the numbers above are rates of evaporation given in mL/Min.

The compartment of body water that is the major source of the water for sweat is

The compartment of body water that is least changed by sweat is

Why?

# Sodium Loss During Exertion In Heat

Sweating not only moves water from the body to the environment, but sodium, potassium and chloride as well. Track sodium loss in this exercise.

Click Restart to again establish Billy Bob’s initial conditions. Use the Go main menu selection to advance time. Record data at control (0 hours) and at 1, 2 and 3 hours of hiking.

 Na+ - Panel shows extracellular Na+.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Control | 1 Hr | 2 Hrs | 3 Hrs |
| Extracellular Na+ Conc (mEq/L) |  |  |  |  |
| Extracellular Na+ Mass (mEq) |  |  |  |  |
|  Cumulative Na+ Loss (mEq) |  |  |  |  |
|  Cumulative NaCl Loss (G) |  |  |  |  |
|  Volume (mL) Of Normal Saline Needed To Replace NaCl Loss |  |  |  |  |

In Row 4 above, convert the Na+ loss in mEq to NaCl loss in G. The molecular weight of NaCl is 58.5 or 58.5 G/Mol.

In Row 5 above, calculate the volume of normal saline that must be given to replace the lost NaCl. Normal saline is 0.9% or 0.9 G/100 mL.

Is the volume of normal saline calculated above also sufficient to replace the water lost?

Why?

# Osmolarity And Cell Volume

Loss of both water and sodium can change the osmolarity of body fluids.

In this part, we’ll track changes in plasma osmolarity during exertion in the heat.

We will also look at osmolarity in the renal medulla. This osmolarity is normally high (see G&H, chapter 28) and it goes even higher when the kidney is creating concentrated urine.

Click Restart to establish Billy Bob’s initial conditions. Use the Go main menu selection to advance time. Record volumes at control (0 hours) and at 1, 2 and 3 hours of hiking.

In this part, we’ll be looking at some additional panels. Use the View main menu selection to put buttons on the toolbar for Organ Details and Nephron Details. Visible groups of toolbar buttons are checked on the View menu.

 …  - Organ Details buttons.

 – Nephron Details button.

 Osmolarity - Panel shows whole-body (plasma) osmolarity.

 Circulation – Panel shows renal blood flow.

 Medulla / Vasa Recta – Panel shows vasa recta blood flow and renal medullary osmolarity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Control | 1 Hr | 2 Hrs | 3 Hrs |
| Osmolarity, Plasma (mOsm/L) |  |  |  |  |
| Osmolarity, Renal Medulla (mOsm/L) |  |  |  |  |
|  Red Cell Volume,  Plasma (femtoL) | 90 |  |  |  |
|  Red Cell Volume,  Medulla (femtoL) |  |  |  |  |
| Renal Blood Flow (mL/Min) |  |  |  |  |
| Vasa Recta Blood Outflow (mL/Min) |  |  |  |  |

In Row 3 above, calculate the volume of a red cell in the plasma as osmolarity changes. Assume a red cell’s volume at normal plasma osmolarity is 90 femtoL. One femto liter is 10-15 L. In these calculations, assume the osmoles in the red cell remain constant.

In Row 4 above, calculate the volume of a red cell in the renal vasa recta as medullary osmolarity changes.

Identify the factors in this situation that will promote red cell sickling, particularly in the renal medulla.

# Appendix – Creating Billy Bob

Billy Bob was created as follows:

A hot day was created by increasing ambient temperature to 100 deg. F.



Physical exertion was created by setting the treadmill speed to 2 MPH. Treadmill exercise type was selected. Wind was set at 2 MPH.





Water restriction was created by setting water intake to fixed amount. Intake was then decreased to zero.

These setting were then save in the initial conditions file named BILLYBOB.ICS.