NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Lacy's Dry Run: How the Body Maintains Water Balance

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Objectives

Upon completion of this case, students should be able to:

- Describe the major sources of water input and output in the human body.
- Describe the mechanisms of water loss from the human body.
- Describe the reabsorption of water and sodium ions in the nephron.
- Describe the effects of caffeine on nephron function.
- Explain some of the consequences of an imbalance of body water.
- Describe the relationship between body fluid and blood pressure.
- Outline the mechanisms by which water is absorbed in the small intestine.

Part I – Inputs and Outputs

Lacy was a 15-year-old girl with the reputation of being a talented star athlete. She was scheduled to compete in six track events at her school track and field day. The sports meet was held on an unusually warm Saturday at the end of a cool winter, with ambient temperature of 98°F. In addition, there were dry, hot westerly winds blowing, and low humidity.

Questions

1. List the major avenues of water input and water output contributing to daily water balance in the human body.

2. Describe how the environmental conditions are likely to affect Lacy's water balance.

Part II – The Nephron

Lacy was up late the night before the track meet watching movies. Consequently, she slept through her alarm the following morning. When Lacy did not come downstairs for breakfast at the usual time, her mom woke her up, and she then quickly drank two cups of coffee to get herself moving. Lacy did not have time for breakfast at home and so they picked up some hash browns at the drive-thru on the way to the meet. During the morning Lacy drank four "energy drinks" (each containing 80 mg of caffeine per 250 mL) as she believed they would increase her stamina, speed and jumping ability. Lacy noted that she needed to use the toilet many times between her morning events and voided more urine than usual. As she did not have time to pack lunch, she ate two bags of cheesy Doritos in between events; one at around 11:00 a.m. and another for lunch (12.30 p.m.).

Lacy's afternoon schedule of events was very busy, and she did not have time to consume any other food or drink. When she went to the toilet prior to the 800 m race at 2:00 p.m. she noticed her urine was dark yellow in colour (similar to what it is like when she first gets out of bed in the morning). Lacy tried extra hard in the race but could not quite perform at her usual standard.

Questions

3. On the diagram of the nephron provided (next page), indicate where water (H_2O) is reabsorbed, and where it is reabsorbed under hormonal influence. Label these sections of the nephron.
4. Indicate on your nephron drawing where sodium ions (Na^+) are reabsorbed, and where they are reabsorbed under hormonal influence. Label these sections of the nephron.
5. Diuresis is increased urinary excretion. Using the information below, explain the physiological effect of the excess caffeine with respect to diuresis and glomerular filtration rate (GFR). Describe the effects of excess caffeine on Lacy's hydration status.

   "The concentration of caffeine reached in plasma and brain after two or three cups of strong coffee—about 100 μmol/l—is sufficient to produce appreciable adenosine receptor block, and a small degree of phosphodiesterase inhibition. The diuretic effect probably results from vasodilation of the afferent glomerular arteriole causing an increased glomerular filtration rate" (Rang *et al.*, 2016; p. 594). There is also evidence that caffeine has a natriuretic effect in the nephron, reducing Na^+ reabsorption both proximally and distally (Shirley *et al.*, 2002).

6. Would Lacy have an increased or decreased plasma osmolarity? Explain your answer. What specialised receptors would detect this change?

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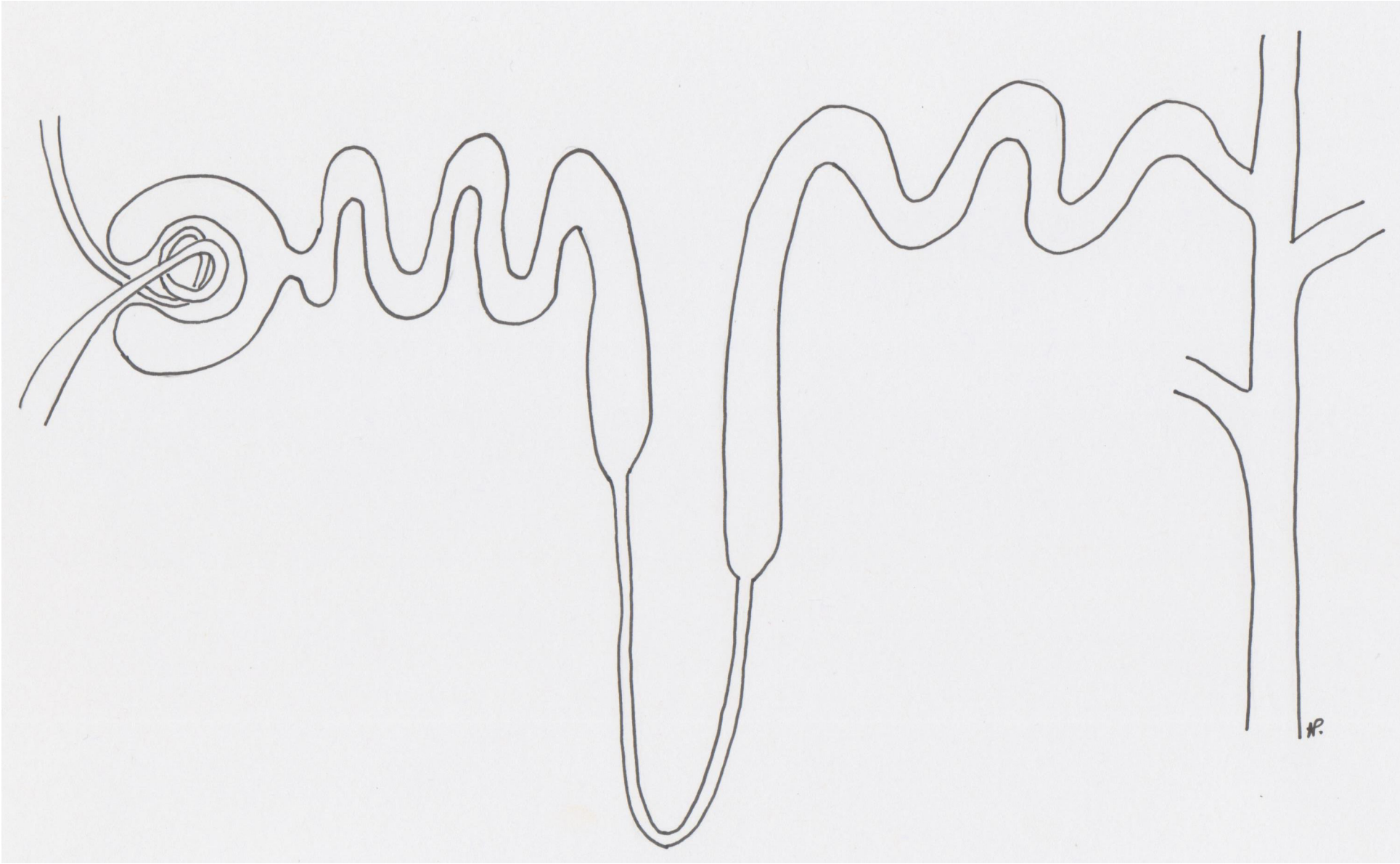

Part III – Dehydration

By 3:00 p.m. Lacy had competed in a few more events, and was now feeling unwell. She told her coach that she felt dizzy, tired, weak and had a headache and dry mouth. Her coach noticed that Lacy's skin was pale, dry and her eyeballs appeared sunken. The coach asked Lacy about her food and beverage consumption and came to suspect that Lacy was dehydrated.

Questions

7. Draw a flow diagram to illustrate the homeostatic mechanisms Lacy's body would employ to counteract the water deficit. Indicate on your diagram of the nephron the specific actions in the kidney.

8. Would Lacy expect to have changes in blood pressure? Explain your answer.

Part IV – Rehydration

Lacy's coach decided to get her to the nearby hospital for assessment. He asked one of the nearby parents to call for an ambulance. While waiting for the ambulance one parent suggested getting Lacy to drink water while a second parent suggested that they get Lacy to drink a sports-electrolyte drink (containing both Na^+ and glucose). Before they could come to a decision the ambulance arrived.

Question

9. Explain which solution—water or the sports drink—would be more efficient for starting to rehydrate Lacy.

References

Rang, H.P., J.M. Dale, R.J. Flower, and G. Henderson. 2016. *Pharmacology,* 8th ed. Elsevier Churchill Livingston: UK.

Shirley D.G., S.J. Walter, and F.H. Noormohamed. 2002. Natriuretic effect of caffeine: assessment of segmental sodium. *Clinical Science* 103: 461–6.