Exercise and Hydration: Individualizing Fluid Replacement Guidelines

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SUMMARY

WHEN DEVELOPING FLUID REPLACEMENT GUIDELINES FOR EXERCISING INDIVIDUALS, A VARIETY OF FACTORS SHOULD BE TAKEN INTO CONSIDERATION. THE ENVIRONMENTAL CONDITIONS, INTENSITY LEVEL, DURATION OF EXERCISE, VARIABILITY IN SWEAT RATE, AND LEVEL OF HEAT ACCLIMATIZATION ARE AMONG THOSE FACTORS. DETERMINING INDIVIDUAL SWEAT RATES AND ASSESSING HYDRATION STATUS SHOULD HELP GUIDE SPECIFIC RECOMMENDATIONS. THE TYPE OF EXERCISE TOGETHER WITH THE SPECIFIC NEEDS OF THE INDIVIDUAL WILL HELP DETERMINE THE FLUID REPLACEMENT BEVERAGE THAT WOULD BE MOST BENEFICIAL. EDUCATING INDIVIDUALS ABOUT THEIR OWN FLUID NEEDS WILL ENSURE THAT THEY EXERCISE SAFELY AND PERFORM WELL.

INTRODUCTION

Fluid replacement for exercising individuals is a topic of much debate both in the clinical and research arenas. Coaches and health care professionals who may have the responsibility of determining their athletes' fluid needs should consider a variety of factors before developing a hydration plan. Any given exercise bout may vary in the environmental conditions, intensity level, duration, rest periods, the amount of clothing worn, and the goal of the session, practice, or competitive event. Similarly, individuals may also vary substantially with regard to sweat rate, hydration status, physical fitness, level of heat acclimatization, and their overall physiological response to exercise. As a result of these variations, it is difficult to either recommend general fluid requirements or recommend that all exercising individuals simply drink according to their thirst. In the past, various organizations have produced general guidelines for fluid replacement; however, research and clinical experiences have demonstrated that hydration should be individualized.

Variability between individuals and even among the same person in different situations demonstrates the need for individualization of fluid replacement guidelines (25,40). It is imperative that clinicians use the latest research together with the knowledge of their athletes to ensure the best, evidence-based clinical practice when it comes to hydration for athletes.

EFFECTS OF HYDRATION STATUS ON PHYSIOLOGICAL FUNCTION AND EXERCISE PERFORMANCE

It is not uncommon for exercising individuals to experience a fluid deficit if sweat losses are not replaced during an exercise bout (25). The extent that this fluid deficit can affect physiological function and performance has also been a topic of debate. Decades of laboratory studies have demonstrated that exercising in a hypohydrated state can result in increases in heart rate and core body temperature (10,13,21,30,39,41). On the other hand, others (14,32,33) have demonstrated that fluid deficits during in vivo situations (where intensity was not controlled) may not be as detrimental as that seen in controlled laboratory studies. More recently, several controlled field studies (8,22) found that when intensity was controlled in a field setting and fluid deficits were present during exercise, core body temperature and heart rate were significantly elevated in a similar fashion as has been seen in the laboratory setting. Interestingly, in cases where individuals were hypohydrated and heart rate during exercise was controlled, heart rate was significantly elevated after exercise compared with a hydrated control, resulting in a slower recovery rate (8). Similarly, a study examining the effects of dehydration on resistance exercise found that 3% body mass losses resulted in higher preset heart rates and also hindered heart rate recovery (20).

These same disparities between field studies and laboratory studies have been seen in regard to the effect of hydration on exercise performance. The American College of Sports Medicine's position stand on exercise and fluid replacement (40) recommends preventing body mass

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losses greater than 2% to prevent decrements in performance, whereas a recent meta-analysis concluded that body mass losses may have actually improved cycling time trials (15). However, it is important to note that these cycling time trials occurred under mild environmental conditions (26°C) (15). The recommendation to prevent body mass deficits of 2% or more is supported by several researchers (25,43,44), particularly when these fluid deficits occur while exercising in the heat (8,17,22,45). In 2 recent field studies, trail runners running at the same exercise intensity ran significantly slower and had higher heart rates compared with hydrated control trials (8,22).

In a recent editorial, these inconsistencies in the literature were attributed to differences between controlled exercise bouts to volitional exhaustion in laboratory studies and real-life competitive events, where individuals exercise "as fast as possible" rather than "as long as possible"(31). Furthermore, the notion that individuals can self-pace in real-life competition compared with the fixed-intensity exercise often seen in laboratory studies is important to note. Self-paced exercise becomes extremely important in hot conditions where individuals may be experiencing considerable heat strain combined with a fluid deficit; most individuals will naturally decrease their intensity to accommodate to these circumstances, often resulting in slower run times and decrements in performance. Ask any runner who has run a marathon in warmer than usual temperatures, and they will be quick to mention, perhaps even before they begin the race, that it is not going to be a personal best race time.

Although research on the impact of hydration on anaerobic activity is not as prevalent, some studies have found decrements in anaerobic performance with fluid deficits ranging from 1 to more than 3% of body mass losses (3,4,11,16,19,20,27). In some studies, fluid deficit resulted in decrements in skill performance during basketball and soccer activities (4,27). Strength and power have also been negatively affected by dehydration (16,19,20). Hayes and Morse (16) found that dehydration had no effect on vertical jumping or isokinetic leg extensions at 120° per second; however, dehydration impaired isometric and isokinetic leg extensions at 30° per second. Jones et al. (19) found that approximately 3% body mass losses negatively affected the ability to generate both upper and lower extremity anaerobic power, whereas Kraft et al. (20) found that the same body mass losses significantly impaired resistance exercise, increased heart rate during exercise, increased perceived exertion, and decreased repetitions. Some of these performance deficits may also be attributed to mood disturbances and/or impaired cognitive abilities. Studies have revealed mood disturbances (2,12), decreased attention (3), and impaired cognitive performance (12) associated with various levels of dehydration. Therefore, perhaps the combined effects of the physiological and psychological impairments due to dehydration result in decreased performance.

FLUID REPLACEMENT BEFORE, DURING, AND AFTER EXERCISE

Recent studies have demonstrated the importance of beginning an exercise bout in a euhydrated state (8,22). Beginning an exercise bout in a hypohydrated state has been shown to decrease performance and impair physiological function by increasing heart rate and core body temperature (8,22,38). Unfortunately, several studies have shown that athletes, including younger adolescent athletes, are often hypohydrated at the start of practice or even competitive events (6,26,36,46–50). Therefore, ensuring that these individuals are educated about their fluid needs, particularly at the start of exercise, is essential.

Recommendations on how much fluid individuals need during exercise have been extensively debated in sports fields, medical tents, conferences, and in the literature (31). The reasons for the debate are well warranted and 2-fold: (a) to prevent injury or death from drinking inappropriate amounts of fluid, and (b) to prevent decrements in athletic performance. However, it seems impractical to continue to argue that there is one best method of replacing fluids for all exercising individuals. An individual's fluid needs are dictated by several factors and may vary accordingly. The same fluid recommendations would not be given to a runner participating in a marathon in cool weather as to an American football offensive lineman practicing in full pads, in 2-a-day practices and in a hot, humid environment. Similarly, an individual's fluid needs in the winter may vary from his/her own fluid needs in the hot, summer months.

Some fluid replacement guidelines recommend that athletes drink when thirsty (33). The basis behind this recommendation is that the thirst response mechanism is triggered to ensure plasma osmolality is maintained between 280 and 295 mOsm/kg H_2O (33). Although this may be used successfully for some experienced runners in cooler environments, drinking to thirst has often resulted in significant fluid losses (24) that may have negative effects physiologically or in performance (40), particularly when exercising in hot, humid environments.

Drinking to thirst may not always be practical in all settings. For instance, in some situations, exercising individuals may have barriers to hydration, such as limited access to fluids because of the nature of the sport or the location of the exercise bout, and they may not be able to solely rely on thirst (35). Similarly, when individuals are not knowledgeable about appropriate hydration strategies or are unaware of their own fluid needs, this may result in dehydration or even hyperhydration or overhydration (24), which may lead to hyponatremia and possibly death. Therefore, exercising individuals should be made aware of their sweat rates so that they are neither in a state of hyperhydration nor lose so much fluid that it begins to impair their performance or physiological responses to exercise.

Replacing fluids after exercise can be extremely important as well, particularly for those individuals participating in numerous events in 1 day or throughout the course of several days. In sports requiring multiple practices in 1 day, such as 2-a-days of football in the hot summer months, postexercise hydration is crucial. Chronic dehydration, which occurs when someone is in a hypohydrated state over the course of several days, can result in athletes already being in a hypohydrated state before participating in their next exercise bout. This may impair the ability to continue exercise, particularly in hot environments, and can also have deleterious effects on exercise performance and the health of those athletes. Therefore, those individuals making decisions on fluid replacement should be able to determine what their athletes' postexercise fluid needs are and help them meet those needs to ensure their safety and to better prepare them for their next event.

WATER OR SPORTS DRINK?

Aside from determining the quantity of fluids needed for exercising individuals, the type of beverage consumed can also be very important when making fluid replacement recommendations. The duration and intensity of exercise as well as the environmental conditions may dictate what type of drink exercising individuals should choose to replace fluid losses. If a person is exercising constantly for more than 90 minutes, they need to consume a "sports drink" if performance is a concern. Individual variability, such as sweat sodium losses, level of heat acclimatization, hydration status, and other nutritional considerations may play a role.

The general recommendations are that shorter duration exercise bouts (<1 hour) may only require that athletes replace fluid losses with water, whereas longer, endurance-type activities may require a carbohydrate-electrolyte beverage (40). High-intensity events lasting longer than 1 hour or lower-intensity events lasting several hours would warrant the use of carbohydrates in addition to simply replacing fluid losses (40). The ACSM position stand recommends the use of approximately 30 to 60 g/h (0.5–1 g/min) of carbohydrates to maintain blood glucose levels and exercise performance during these higher-intensity exercise bouts of >1 hour or long-lasting endurance events (40). However, it has recently been suggested that in higher-intensity, long-duration events, a high-carbohydrate intake of up to 90 g/h (1.5 g/min) may be needed if the energy expenditure is high enough (18,37).

Aside from simply replacing fluid losses and carbohydrates, athletes often need to also replace electrolytes lost through sweating. Ensuring enough sodium is replaced is particularly important for those who are "salty sweaters" to prevent muscle cramping (5). Salty sweaters can be identified by noticing salt residue on their skin and clothing after exercise (23,42). Frequent muscle crampers will benefit from simple diet modifications of consuming salty snacks (such as pretzels, chips, or canned soup) before exercising as well as adding a bit of sodium to a sports beverage. Some studies have looked at the gastric emptying rate of pickle juice as well as its effect on plasma electrolytes levels; however, these studies were not conducted on individuals who were experiencing muscle cramps (28,29).

Excessive water intake without sodium replacement may result in the dilution of plasma sodium levels and increase the risk of exercise-associated hyponatremia (40). This risk may be further increased in long-duration events, such as marathons and ultra-marathons, and in particular in slower runners. Lighter and slower runners have been shown to finish marathons with a positive fluid balance because of excessive fluid intake that does not match fluid losses (9). Therefore, in marathon or ultra-endurance events, where considerable amounts of both fluid and sodium will be lost, increasing salt intake and monitoring body weight changes would be beneficial.

For those individuals requiring increased sodium, the fluid replacement and nutrition plan should consist of not only adding sodium in the diet before exercise but also during and after exercise. Sodium can easily be added by eating salty snacks or by adding a quarter teaspoon of salt to a 32 oz carbohydrate-electrolyte beverage to increase salt intake while still ensuring the beverage is palatable (5). Sodium replacement after exercise is also extremely important in emergency cases of hyponatremia, where a 3% hypertonic saline is used to restore plasma sodium levels intravenously (34); however, this should only be used in extreme cases and only by qualified medical personnel when plasma sodium levels fall below 130 mmol/L (40).

PRACTICAL APPLICATION: DETERMINING INDIVIDUAL FLUID NEEDS

Some factors that play a role in a person's sweat rate and fluid needs may include level of heat acclimatization, individualized variations in sweat rate, physical fitness, duration, intensity and type of activity, environmental conditions, and equipment worn. When determining fluid needs for an athlete, it is important to perform a needs analysis, taking these factors into consideration. One of the simplest methods of determining an individual's fluid needs is by calculating their sweat rate (Table). Even when keeping all other factors the same (environmental conditions, intensity of exercise, and the like), there will be individual variability with sweat rate.

Two soccer players on the same team, even playing similar positions, may have different sweat rates, and therefore, different fluid needs. Similarly, the amount of clothing and equipment worn, such as helmet and shoulder pads in football or additional protective gear for goalkeepers in soccer or field hockey, will likely increase body temperatures and the amount of fluids lost through sweating. The duration and intensity of exercise should also be taken into consideration when determining an individual's fluid needs.

Table
How to calculate individualized sweat rates

A. Enter pre-exercise body weight in kilograms (To convert pounds to kilograms, divide pounds by 2.2)		Example: 70.0 kg
B. Enter postexercise body weight in kilograms		− 68.9 kg
C. Subtract B from A Pre-Post Difference in kilograms		1.1 kg
D. Convert your total in C to grams by multiplying by 1000	×1000	×1000
Total Body Mass Loss		1100 g
E. Enter the amount of fluid consumed during exercise in milliliters (To convert from ounces from milliliters, multiply ounces by 30)		500 mL
F. Add E to D Sweat Rate (mL/time)		1600 mL/h (or 1.6 L/h)

Therefore, a very simple method is to have athlete's weigh-in before and after practices or other events. If they have lost weight during practice, they should make a note to consume fluids; in particular, if they have lost more than 2% of their body mass during practice, they need to replace those lost fluids before the next practice or event. If they have gained weight during practice, they drank too much fluid and need to better assess their fluid needs. A more precise calculation of their individual sweat rate would help determine their fluid needs more accurately.

Sweat rate can be calculated a bit more accurately by having the individual weigh-in before and after the individual completes an activity lasting a specific amount of time (i.e., 30 minutes or 1 hour). Choose a particular activity, intensity, and the environment that will most closely mimic an event or activity (7). The duration can be altered a bit and adjusted afterward for the actual activity time (i.e., perform the activity for 30 minutes, multiply the sweat rate by 2, and that is the estimated hourly sweat rate).

Using the Table, the individual should first weigh either nude or with as little clothing as possible (such as shorts only for males and shorts and sports bra for females). Sweat-soaked clothing such as t-shirts and socks will be heavier after exercise and skew the results. Record the pre-exercise weight in kilograms in Box A of the Table. Have the individual perform the exercise bout and record any fluids (in mL) consumed during exercise (Box E). After exercise, have them towel dry and record a postexercise body weight (Box B) wearing the same exact clothing as the pre-exercise measure.

Continue to follow the steps in the Table, by subtracting the value in B from A (Box C), converting to grams (Box D), and finally adding the values in Boxes D and E. The result (Box F) will be a sweat rate per a given amount of exercise time.

If the individual needs to urinate at any time in between body weight measures, the urine would need to be collected, measured, and subtracted from the final number. Therefore, it is often best that the individual void their bladder before the exercise weigh-in and after the exercise weigh-in to avoid this step in the calculation. In the example given in the Table, the individual weighs 154 lb (154/2.2 = 70.0 kg) before exercising. He exercises for an hour, consumes 500 mL (just over 16 oz) of water during this time, and after exercise weighs 68.9 kg (a 1.1 kg body mass loss, equivalent to a 1.57% of his body mass). After adjusting for his fluid intake, the result is an estimated sweat rate of approximately 1.6 L (approximately 54 oz) per hour of exercise.

Another simple method of assessing hydration status on the field is via urine color or urine specific gravity. Although there are other more precise methods of assessing hydration in a laboratory setting (i.e., plasma or urine osmolality), urine color is a very simple way for an exercising individual to quickly

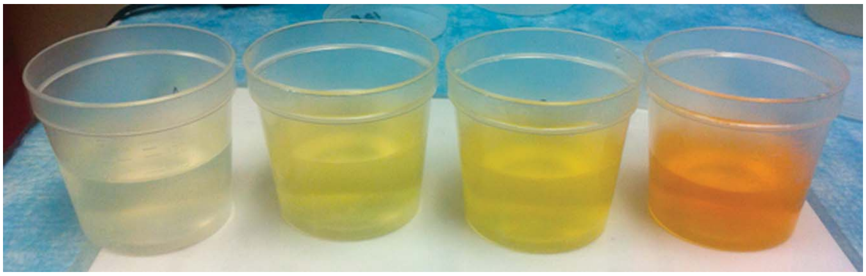

Figure 1. Using urine color to estimate hydration status.

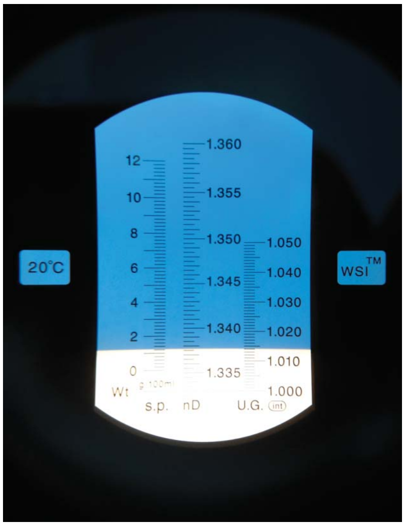

Figure 2. Example of a urine refractometer reading.

assess their hydration. Armstrong's urine color chart (1) consists of a spectrum of urine colors with numbers indicating that a more pale urine color indicates a person is euhydrated, whereas a darker, yellow-orange tone indicates the person is hypohydrated. Figure 1 is a sample of 4 different urine measures increasing in the level of dehydration from left to right.

Urine specific gravity is a measure of urine concentration and is measured with a urine refractometer, a handheld, inexpensive, and easy to use device. A urine specific gravity of ≤1.020 indicates euhydration (40). Figure 2 is an illustration of a reading of a urine sample using a urine refractometer. Using the measure to the far right (U.G.), the urine specific gravity for this sample is 1.014, indicating the individual is in a state of euhydration.

CONCLUSIONS

Education about hydration is paramount. The sources that athletes may rely on to gain information about best practices may not be reliable because they often look to other athletes for information about beverage choices and hydration (35). As a result, it is important for coaches and health care professionals to understand the importance of hydration for safety and performance and also be aware of the need for individualized hydration plans. By using sound research, clinical experiences, and the individual characteristics of our athletes, we can give more accurate fluid replacement recommendations, educate exercising individuals about their own fluid needs, and ensure that they exercise safely and perform well.

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