Workshop: Sweat Rate Measurement in Athletes

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Summary. Both laboratory and field tests for measuring sweat rate in athletes have been performed more and more often this past decade. This workshop gave the attendants a hands-on opportunity to test two volunteers who exercised on stationary bikes at a moderate intensity for 60 minutes. Some of the common mistakes when performing this type of tests were discussed and illustrated, and the final results calculated and discussed. This paper presents some theoretical background, describes the recommended standard protocol and recommended equipment, and discusses the practicality of sweat rate tests.

Introduction. When humans exercise, significant amounts of heat are produced. In order to dissipate that heat, several mechanisms are activated, including the production of sweat by the sweat glands. This places sweat on the skin for its evaporation; the evaporation of sweat allows for rapid heat transfer to the environment, but this mechanism results in fluid loss, unless fluids are replaced at a similar rate by drinking. Excessive fluid loss, particularly when exercising in the heat, can impair performance; avoiding dehydration during competition or training sessions is particularly important when physical exertion lasts more than an hour or so, and the only way to do it is to drink enough of the right fluids during the event or practice. It is difficult and ill-advised to recommend general hydration volumes, because sweat rates can be very different from one athlete to another. Figure 1 shows the range of dehydration achieved by professional football players during practice. Figure 2 shows individual data points for sweat loss and fluid intake for each player in a professional match. Because sweat rates can vary widely among athletes, it is important to know the approximate sweat rates for individual athletes (1, 2, 6, 8, 10).

Many athletes are not well equipped to avoid dehydration. Most athletes do not know their typical sweat rates, and hence rely on thirst alone to maintain fluid balance. There is a good amount of information showing that thirst is not a good enough indicator to maintain athletes euhydrated; as an example, several recently published studies show that fitness participants, amateur athletes, and even elite, professional athletes may show up to their training sessions or competitions in a state of hypohydration (1, 2, 9, 11, 12).

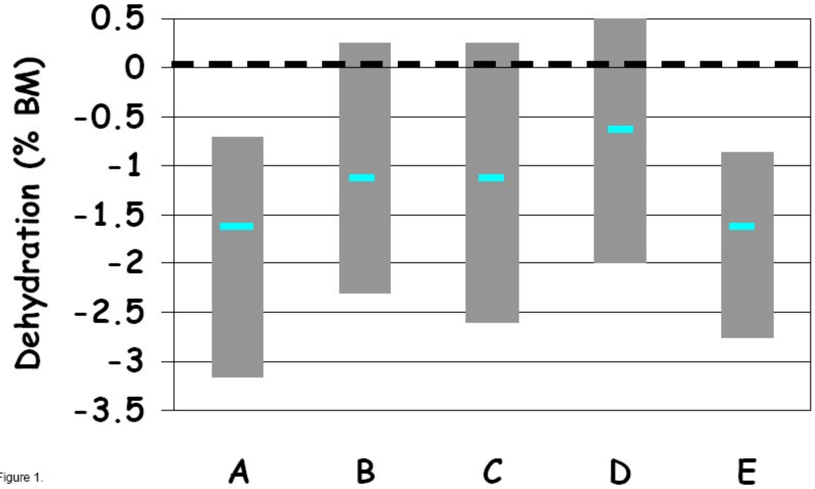

Figure 1.

Figure 1. *Dehydration during practice for five different professional football (soccer) teams from Europe and Latin America. The gray bars show the range of dehydration; the light blue lines show the average for each team, and the dotted bold line represents euhydration. Duration was between 90 and 120 minutes; environmental heat stress varied widely: Team A, 32°C, 20% rh; Team B, 28°C, 56% rh; Team C, 25°C, 60% rh; Team D, 26°C, 40% rh at altitude = 2300 m; Team E, 5°C, 81% rh.*

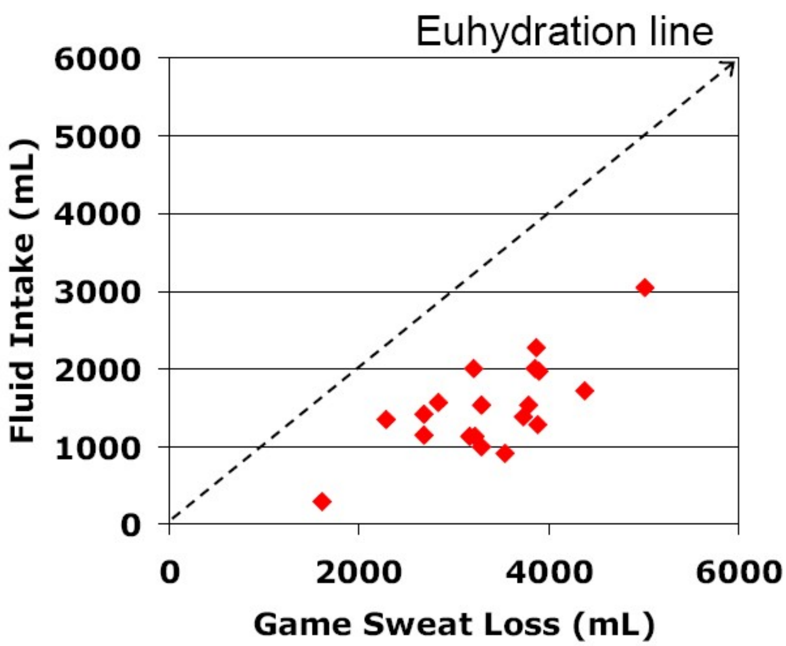

Figure 2.

Figure 2. *Individual sweat losses vs. fluid intake during a professional football (soccer) game in Costa Rica. n=18 (not all players starting the game agreed to participate). Average time: 2.5 hours, at an average heat stress index WBGT=26.8°C.*

The competitive athlete should try to meet two objectives with his/her dietary intake of fluids: maintaining proper hydration over time, and avoiding dehydration during competition or training sessions. To maintain proper hydration over time, it is necessary to drink enough of the appropriate fluids to recover after practice and/or competitions, but also to keep a regular fluid intake during travel and daily living to compensate for all fluid losses. Starting competition already in a state of dehydration has a deleterious effect on performance, as has been shown by Armstrong et al. in 1985, in track running tests of 1,500, 5,000 and 10,000 meters (3). To help them maintain euhydration, athletes are advised to monitor their first urine every morning; it should be abundant and clear, with a specific gravity of 1.020 or less (5). In addition, unnecessary fluid losses should be kept at a minimum by staying out of the sun and heat and avoiding non-sports related exertion in the heat.

The most widely accepted method for the assessment of individual sweat rates is based on the loss of body mass that occurs over a defined period of time. This method is based on the assumption that, under reasonably normal circumstances, approximately 99.5% of body mass loss comes from sweat loss. In the calculations, it is typically assumed that 100 g of mass lost represent 100 mL of sweat, considering that any correction for the true density of sweat, which is somewhat greater than 1.000 g_*mL^{-1}, is unnecessary and beyond the accuracy of the actual equipment used to measure body mass.

A recent paper by Maughan, Shirreffs, and Leiper (7) analyzes some of the pitfalls of the body mass change method to assess hydration status. While there are extreme conditions where the method could overestimate the dehydration occurring during a particular event, the method is still considered accurate and reliable and, most of all, a practical way to assess fluid losses in exercising individuals (4).

Materials and Methods. The procedure to monitor individual fluid needs of your athletes is relatively simple, but there are a few steps where things could go wrong, and therefore you need to be very careful.

This procedure is based on body weight changes. You will need a reliable, precise scale to weigh your athletes to an accuracy no less than 50 or 100 grams at the most. You will also need a smaller scale accurate to 1 gram to monitor fluid intake of each individual. It is desirable to have a refractometer with the capacity to measure urine specific gravity between 1.000 and 1.050, in order to assess initial hydration status, and a Wet Bulb Globe Temperature (WBGT) thermometer to measure the environmental conditions. There should also be one heart rate monitor for each participant, in order for the test administrator to control exercise intensity.

Other materials required are: exercise equipment, sport bottles, cool water or sports drinks, towels for each participant, latex gloves, a stopwatch for each participant, two sterile urine collection containers, small plastic pipettes, clipboards, workhouse paper towels for cleanup, and an appropriate area for measuring nude body mass.

Have individually marked bottles for each athlete. Everyone must drink only from their own bottle. Ideally, these bottles should contain the fluid normally ingested by athletes at a cool temperature.

Bottles are weighed to the nearest 1 gram before and after the exercise session.

Body weights must be obtained with the athlete nude and dry.

Every athlete must empty his/her bladder prior to weighing in (before practice).

Every athlete must empty his/her bladder into a container for measuring urine volume, prior to weighing out (at the end of practice or game/event). Alternatively, two post-exercise body weights should be obtained: one before (BB) and one after voiding (B). The difference in weight in g (BB-B) will be equivalent to urine volume in mL.

Athletes are free to drink all they want during the practice or game/event, but must stop drinking at the end until after weighing out.

The monitoring takes place during a regular workout or game/event, but it can also be designed to take place in the laboratory or another artificial situation.

To do your calculations, you will need:

Initial body mass (grams):	A________________
Final body mass (grams):	B________________
Fluid intake (milliliters, 1 g = 1 mL):	C________________
Urine elimination (milliliters):	D________________
Exercise time (minutes):	E________________
Sweat rate = [(A – B + C – D) / E] * 60	F_________mL/h__

If the objective of the test includes assessment of sweat composition for the athletes, then additional equipment will be needed. This type of testing is not easy for a coach or personal trainer to perform, unless he/she is specifically trained, and it requires sending the samples to a certified laboratory for analysis. It is recommended that you contact scientists who have experience with that type of testing, such as the staff from the Gatorade Sports Science Institute®. The additional equipment for such testing includes: 1 razor per participant, gauze pads (10 per player), distilled water, alcohol, ziploc bags, permanent marker pens, plastic tweezers, sterile patches for sweat collection (1 to 5 for each player, depending on the number of sites to be tested), tubes for sweat patch sample collection, and stickers or masking tape for labeling.

Results and Discussion. For this particular workshop, we had two participants, one male, and one female. They exercised on stationary bicycles for 60 minutes at a pre-determined exercise intensity, and they were free to drink *ad libitum*. Their results may be observed in the following table:

	Participant #1 (male)	Participant #2 (female)
Urine specific gravity	1.028	1.029
Initial body mass (grams)	64,318	60,180
Final body mass (grams)	63,773	60,318
Fluid intake (mL)	413	769
Urine elimination (mL)	42	45
Sweat rate ($mL{*}h^{-1}$)	916	586
Fluid balance (mL) B-A	-545	+138
Dehydration (%Body Mass)	-0.85%	+0.23%
Mean heart rate (beats/min)	123	127

Both participants arrived at the workshop in a hypohydrated state. They exercised at a moderate intensity, but the higher sweat rate and lower fluid intake of participant #1 resulted in a mild dehydration equivalent to -0.85% of body mass. Participant #2 drank slightly too much fluid for her needs, but because the exercise duration was only one hour, she did not overhydrate significantly.

The result you obtain for sweat rate (line F) will be anywhere between about 200 to 2500 mL/h, depending on the environmental conditions, exercise intensity, degree of acclimatization, and other individual characteristics of your participant. If you get a negative number here, there was a mistake in the calculations or the data collection.

IF (and only if) urine volume is small, this value F represents an approximate amount of fluid to be replaced every hour by this individual athlete, under similar conditions, in order to maintain euhydration. It may be appropriate to allow for up to 2% BM of dehydration, particularly if the sweat rate is high or if the particular sport rules or conditions make it difficult to drink regularly.

For a goal of euhydration, the calculation of B-A should be close to zero. If this number is negative, you may want to drink a little more during the game or practice. If it is positive, you need to drink less to avoid overdrinking and the potential complication of hyponatremia.

Conclusions. It is possible and reasonably practical to assess individual sweat rates in athletes during their practice sessions. It is also possible to set up a specific test where the exercise intensity and the environmental conditions are more under control. Either way, a careful protocol for measuring body weight before and after practice, while urine production and fluid intake are monitored, should be followed. An individualized hydration schedule can be developed by knowing each athlete’s typical sweat rate and practicing drinking during regular training sessions. This hydration schedule can then be used in competition, targeting the best balance between euhydration, comfort, and maximum performance. This workshop illustrated the procedure for measuring sweat rate, while allowing for questions and feedback from the audience.

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