<u>Case study:</u> 2008 Olympic 50km race-walker

Practical applications of science to optimize endurance performance

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In most circumstances, it is impossible to identify a single factor that causes fatigue and limits performance during endurance events lasting longer then 90min (3). Causes of exhaustion during prolonged high-intensity exercise can potentially include central nervous system fatigue, thermal stress, dehydration, and most certainly involves mismanaged energy intake compared to expenditure. During prolonged exercise, nearly the entire energy provision comes from aerobic metabolism, which utilizes a combination of both fat and carbohydrate (CHO) energy (Table 1). Fat is the primary fuel utilized during low intensity exercise. However, since these athletes are working at greater than 70% VO2peak, carbohydrate, and especially stored muscle glycogen, is the predominate fuel. Yet, unlike whole-body fat stores, muscle glycogen stores are rather limited. Some argue that these glycogen stores are the major limiting factor to endurance performance and, along with hypoglycaemia, are the cause of the dreaded "bonk" (running out of muscle glycogen and lower blood glucose, resulting in a shift toward fat oxidation and the obligatory and significant drop in power output). Finally, athletes want to ensure they have some muscle glycogen remaining to ensure a fast final burst to the finish line. Taken together, one can postulate that the longer the exercise challenge, the greater the potential for sensible nutritional and physiological interventions to have positive impact.

Table 1. *Comparison of energy source provision, estimated energy expenditure (EE) and theoretically maximal energy intake (EI) across different 2008 Olympic male endurance events.*

Event	2008 Olympic Gold Medalist	Distance	Time	Speed	% Energy Contribution			Estimated EE (total kcals)	Theoretical EI range
					CP	Anaerobic	Aerobic		
Triathlon	Jan Frodeno (Germany)	1.5km swim 40km bike 10km run	18:14 59:01 30:46	~80m/min ~40km/hr ~20km/hr	<1	<1	99	~300 kcals ~1150 kcals ~650 kcals **~2100 kcals**	0 200-400 kcals 50-200 kcals **~250-600 kcals**
Marathon	Sanuel Wanjiru (Kenya)	42.2km	2:06:32	~20km/hr	<1	<1	99	**~2800 kcals**	**~200-600 kcals**
50k Walk	Alex Schwazer (Italy)	50km	3:37:09	~13.8km/hr	<1	<1	99	**~3600 kcals**	**~350-1050 kcals**
Road Cycling	Samuel Sanchez (Spain)	245km	6:23:49	~38km/hr	<1	<1	99	**~7100 kcals**	**~1300-2600 kcals**

CP - creatine phosphate energy provision; EE - energy expenditure; EI - Energy intake

Contrary to popular belief, the 50km race-walk is one of the most metabolically and energetically challenging events on the Olympic program (Table 1). The total estimated energy expenditure (EE) is ~3600 kcals during the ~4hr race. This estimated EE is actually significantly greater than for either the triathlon or the marathon events, and is only lower than the road cycling event (Table 1). However, unlike road cycling where sports drink bottles can be easily carried throughout the race allowing for great EI opportunities, race-walking is limited to EI only once every 2km resulting in a greater relative energy imbalance (ratio of EE to EI). In this case study article, several key science-based physiological and nutritional interventions will be highlighted that were tested and implemented with an Olympic 50km race-walker prior to and during the 2008 Beijing Olympic Games. However, all of the nutritional and physiological interventions presented could be considered, individually tested and utilized across all endurance events lasting longer than 90min.

Maximizing fat metabolism during training

Current nutritional recommendations contend that endurance athletes should always consume adequate CHO during prolonged exercise training and consume CHO immediately after exercise to ensure subsequent training bouts are conducted in a glycogen-replete state. However, anecdotal reports from professional cyclists and East African distance runners indicate that some of these athletes intentionally undertake select training sessions in a glycogen-depleted state, or without exogenous CHO, in an attempt to promote further training adaptations. Accordingly, a recent training study reported increased adaptation and performance when 50% of endurance training was undertaken in a glycogen-depleted state (training twice per day, so the second training bout was glycogen depleted)(5). However, subsequent studies have only found increased markers of aerobic training status with no further enhancement of training induced performance as compared to a group that always trained with high muscle glycogen (for reviews see: (1,6)). Furthermore, prolonged fat-adaptation studies (>5-days on a high fat diet, or continual low muscle glycogen while training), actually show a down-regulation of CHO metabolism and a decrease in sprint performance (2). Thus "glycogen cycling", or training part of the time on high muscle glycogen and part of the time on low muscle glycogen, appears to be to allow for muscular adaptations without the compromised sprint performance. However, whether periodic low-glycogen training results in enhanced performance benefits beyond normal training remains to be seen.

It has been proposed that fasted-training with water may also enhance training induced enhancements in fat oxidation. Accordingly, another recent training study examined the effects of fat-metabolism and aerobic muscle markers by having athletes train 3 times per week, for 1 to 2 hrs over 6 wks while either consuming CHO or water during training after an overnight fast. Interestingly, after 6 wks the fasted trained group had an increase in the proteins involved with fat oxidation, but no performance measures were made. In line with some of these novel interventions, this 50km race-walker purposely undertook periodic training bouts first thing in the morning, while overnight fasted, during his endurance training phase in an effort to maximize training induced fat adaptation in the 6-months prior to the Olympic Games.

These scientific results have caused a degree of uncertainty among scientists that athletes should *always* strive to endurance train with ample exogenous and endogenous CHO availability. Despite the fact that these types of training are both physiologically and psychologically challenging, perhaps athletes may need to periodically cycle glycogen stores and undertake fasted training to maximize the full benefits of their training. In conclusion, both scientific evidence and anecdotal reports suggest that there may be unique nutritional and training periodization to optimize training adaptations, which may be different than the nutritional intakes that an athlete would implement during competition. However, currently, this concept of nutritional and physiological periodization throughout the year is a research area that is very underdeveloped and ripe for scientific examination (for review see: (11)).

Acclimation camp: Tracking hydration status and individualizing fluid intake and pacing targets

Training acclimation camp rationale

Given the potential of having daily temperature highs of 31°C with humidity approaching 75% (which would feel like 43°C; see humidex, Table 1) in Beijing in August, it was imperative to find similar environmental conditions for a pre-Olympic training camp (Table 1). Singapore proved to be an ideal site which allowed athletes many of the comforts of their normal Western culture, a similar time-zone to Beijing, and the required 10 to 14 days needed to allow for optimal physiological heat and jet-lag acclimation (8). This ~2 wk period of acclimation allows for an ideal balance between optimizing the relatively acute performance enhancing thermal adaptations versus having a overly prolonged daily heat strain negatively effecting final training quality leading into the Games.

Table 2. *Historical average versus actual weather conditions for prepatory acclimation camp in Singapore and the Beijing Olympic 50km walk final on Aug. 22nd, 2008*

Parameter	Temp (°C)	Humidity (%)	Humidex*
Singapore Average: 24hr-daily	27°C	75%	36
Singapore Average: Daily Highs	31°C	78%	45
Beijing Average: 24hr-daily	25°C	77%	33
Beijing Average: Daily Highs	31°C	75%	43
Actual: 8AM race day	22°C	98%	31
Actual: 10AM race day	29°C	55%	36

* Humidex - Meteorological calculation which combines both temperature and humidity into one number to reflect the perceived temperature. Since it takes into account the two most important factors affecting summer comfort, it can be a better relative measure of potential thermal strain then either temperature or humidity alone.

Tracking hydration and weight status throughout the camp
Since athletes were immersed in another culture, which featured different foods, another time zone and differing weather conditions than they normally faced, it was strongly suggested that they volunteer for daily weigh-in and hydration tracking throughout the camp (Figure 1). This allowed for individual athlete tracking so if any drastic changes or problems were presented, they could be immediately addressed and circumvented before they became a significant concern.

Figure 1. *Body weight and urine specific gravity tracking throughout a 10 day pre-Olympic acclimation training camp for an Olympic 50km race-walker.*

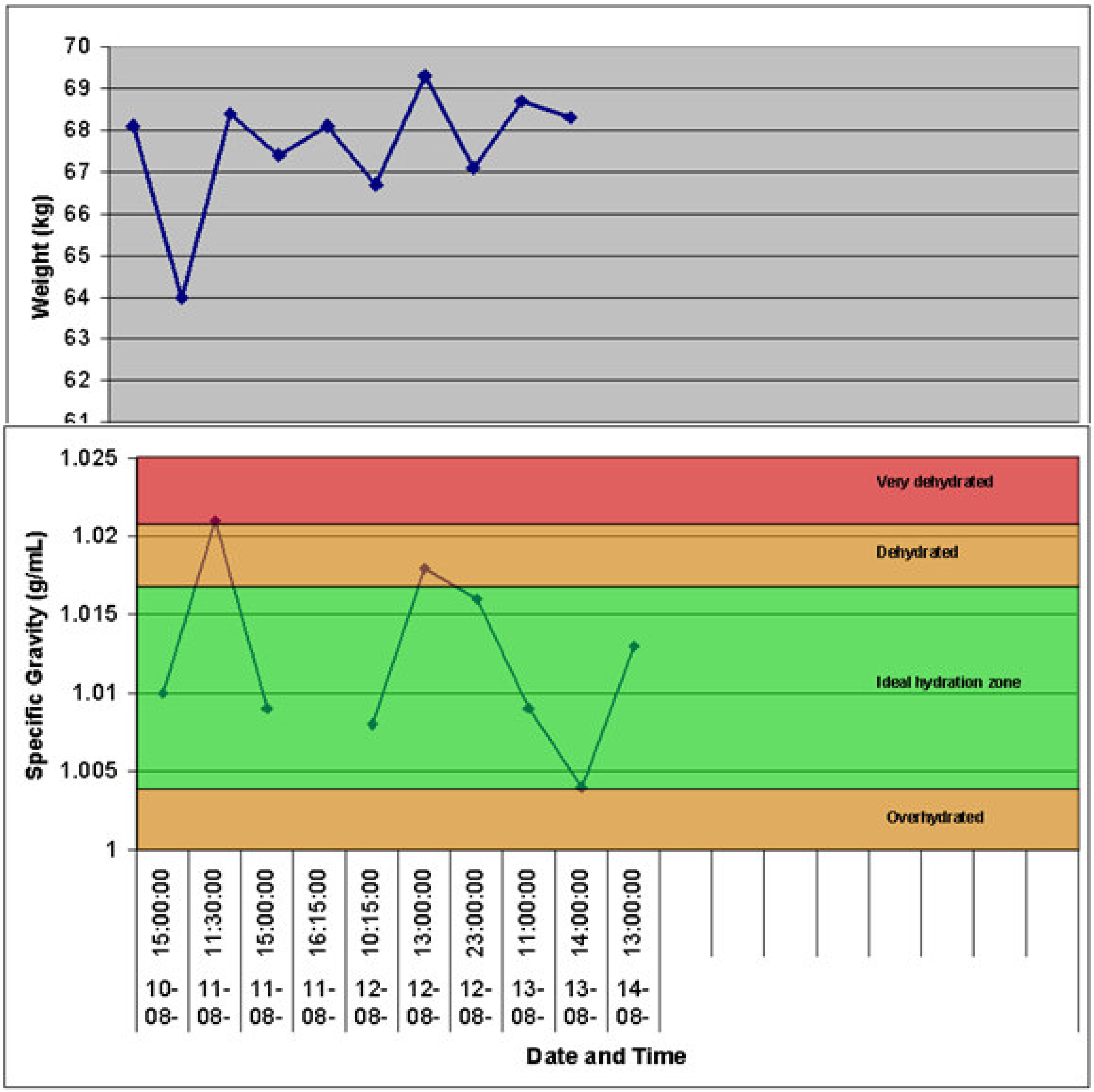

Figure 1 illustrates weight and hydration tracking data for a 50km race-walker. Hydration was tracked via measurements of urine specific gravity (USG) using a hand refractometer. To highlight, there was one workout on August 10th (Figure 1, Table 3), in which this athlete inadvertently under-consumed fluid in relation to the extreme weather conditions (his water bottle got stolen). This substantial under-consumption of fluids over only a 90min period quickly resulted in nearly a 6% decrease in body weight (BW), and a large increase in USG, indicating a very dehydrated state.

The 2007 American College of Sports Medicine Position Stand on fluid intake illustrates the need for making individualized fluid intake recommendations according to individual sweat rate (10). Given that this pre-Olympic camp featured very similar environmental conditions that this athlete would likely face at the

Olympics, it provided ideal conditions to assess individual sweat rate in several different conditions (Table 3). Between two workouts on Aug. 10th and 12th, with slightly different environmental conditions, we were able to calculate an individual sweat rate of between 1.7 to 2L/hr. Since greater than a 2 to 3% BW loss can lead to endurance performance decreases, we could estimate for a certain weather condition the amount of fluid intake per hour needed to prevent a greater than 3% loss in BW (Table 3).

***Table 3.**. Calculated sweat and fluid intake rates during acclimation camp and Beijing Olympic Final*

Parameters	Singapore Training Camp		Beijing Olympic Final
	Workout #1 Aug. 10th	Workout #2 Aug. 12th	Aug. 22nd
Weather Temp (°C)	30°C	29°C	29°C
Humidity (%)	78%	65%	55%
Humidex	43	38	36
Pre-weight (kg)	68.1 kg	68.1 kg	67.7 kg
Post-weight (kg)	64.1 kg	66.7 kg	65.9 kg
(% BW loss)	(5.9%)	(2.1%)	(2.6%)
Weight change	4.0 kg	1.4 kg	1.8 kg
	+	+	+
Total fluids consumed (L)	1.9 L	2.4 L	4.7 L
Total fluid turnover (L or kg)	5.9 L	3.8 L	6.5 L
	/	/	/
Exercise time (hr)	3 hrs	2.25 hrs	4.1 hrs
Sweat Rate (ml/hr) *	~2000 ml/hr	~1700 ml/hr	~1600 ml/hr
Actual Fluid Intake Rate (ml/hr)	~630ml/hr	~1070ml/hr	1140ml/hr
Calculated fluid intake rate to prevent >3% BW loss	~1270ml/hr	~760ml/hr	~1020ml/hr

* Urine losses not accounted for in sweat rate; 1 L water = 1 kg; BW - body weight; Temp - Temperature;

Pre-cooling techniques to improve performance

Prior to every major training session during the pre-Olympic camp in Singapore the 50km race-walker also utilized and mimicked pre and during exercise cooling techniques. There is strong scientific evidence that pre-cooling the body prior to exercise will have a significant performance benefit during endurance events in hot and humid conditions (9). The primary methods to keep thermal strain low features shortening warm-up routines and utilizing ice-vests to keep the core body temperature increase during warm-up and pre-event as low as possible. Interestingly, along with external cooling, new techniques also involve the consumption of cold liquids to enhance internal cooing mechanisms as well. Both external and internal cooling has been suggested to lead to an increase in heat storage capacity, which will allow the given athlete to complete a greater amount of work before a high critical body temperature is reached, with this resultant thermal strain leading to premature fatigue (9). Recently, several papers have also shown positive performance effects from external cooling during prolonged exercise in hot and humid conditions. This can include fixing ice packs to the inside of a hat and extracting heat through the hands by carrying ice.

Pre and during event cooling during training was piloted prior to race day to characterize the athlete's rate of perceived exertion (RPE) and pace. It is established that most athletes learn optimal pacing strategies in training, and that for prolonged endurance events (unlike middle-distance events) an even paced race generally leads to the best performance (4). Conversely, it is possible that pre and during event cooling techniques could affect an athlete's RPE, possibly giving the athlete the impression that they are feeling better than they might actually be early in a race – which could lead to disaster late in the race. Therefore, it was important to mimic these potential confounding effects in several targeted training sessions, so the athlete could better judge the potential for artificially lowered RPE with the resultant pace.

Race day hydration, energy and supplementation

Beyond training and genetic status, the largest single determinant of ensuring optimal performance during prolonged endurance events in the heat is through the consumption of a CHO-based sports drink providing CHO energy, fluids and electrolytes. Recent data from several different labs has consistently shown that a CHO drink blend of glucose (GLU) and fructose (FRU) results in a ~30 to 50% higher oxidation rate as compared to GLU intake alone – the mechanism being that there are separate and distinct GI transporters for each GLU and FRU. In turn, several different labs have now confirmed that these GLU+FRU mixtures can lead to ~8% improvement in endurance performance. However, to achieve these high oxidation rates, large amounts of GLU and FRU need to be consumed (>1g/min), and this has recently been recommended to athletes when competing in endurance events >2hrs (7). There is also sound evidence that caffeine intake enhances endurance performance in a small, but worthwhile amount. Current caffeine intake recommendations for athletes are ~3 to 6mg caffeine/kg BW consumed ~90 min prior to exercise. However, some recent studies have shown worthwhile performance benefits in caffeine doses as low as 1 to 3 mg/kg BW. To ensure peak plasma caffeine levels throughout the 4 hr race, ~1.5mg/kg BW were dosed (~100mg) 90min prior to exercise, and then again in the second, third and fourth hours, respectively.

Numerous anecdotal reports support the idea that an individual's gastro-intestinal (GI) tract can be trained and adapted to handle the intake of large amounts of CHO and fluid during exercise – providing more rationale on the need for periodizing different nutritional interventions between training and racing situations. In accordance, recent published data has suggested that the GI tolerance of large amounts of CHO intake can be optimized and adapted, although the ultimate amount appears to be very individual (7). Therefore, during the preceding competitions and in the immediate months prior to the Games, this athlete became very accustomed and comfortable with the CHO-based sports drink as outlined in Table 4. Impressively, this athlete adapted himself to being able to handle the intake of ~75g/hr of CHO (2:1 ratio of GLU+FRU) in conjunction ~1.2 L/hr of fluids (6% CHO solution) while walking 50km in just over 4hrs.

Table 4. *Fluid, macronutrient and supplement intake for a 67kg male athlete during the 50km Olympic walk*

Drink characteristics	1st hour	2nd hour	3rd hour	4th hour	Average/hr	Targets
CHO (g):	75.6	70.8	64.8	85.4	**74 g/hr**	~60-90 g/hr
PRO (g):	11.34	10.62	9.72	9.06	**10 g/hr**	
Na+ (mg):	1190.7	1115.1	1020.6	1151.3	**1119 mg/hr**	~1 to 1.5g/hr
K+ (mg):	66.15	61.95	56.7	71.85	**64 mg/hg**	
Mg+ (mg):	113.4	106.2	97.2	90.6	**102 mg/hr**	
CAF pill (mg):	100	100	100	100	**100 mg/hr**	~6mg/kg over 4hrs
Total Fluids:	1245	1185	1110	1205	**1200 ml/hr**	~1 to 1.2L/hr

This individualized drink was the product of practical experiences drawn from a ~20-yr international race-walking career combined with the most recent scientific evidence and recommended targets as outlined above. A commercially available recovery beverage provided the CHO base (2:1 ratio of GLU+FRU) of this individualized drink, which was augmented with extra electrolytes (Na+, K+, Mg+), caffeine and fluids to reach recommended and individualized targets. Taking scientific evidence in conjunction with experience, individual tolerances and flavour preferences resulted in a drink profile that this athlete had much experience and confidence with, and allowed for all his CHO, fluid, electrolyte and caffeine targets to be met with minimal GI side-effects and only a 2.6% BW loss on race day (Tables 3&4).

Summary

For elite athletes, nutrition and training interactions need to be carefully planned and monitored between coach, athlete and nutrition expert, and this comprehensive long-term approach needs to be considered for every physiological factors. Emerging nutrition and training methods, such as low-glycogen or fasted training, do not negate the importance of nutrition around training. Instead, it places more emphasis on the intelligent timing and differential application of altered macronutrient provisions specific to the training bout and desired physiological outcome. Testing and mimicking as many of the planned interventions as possible prior to the championship event (logistics, environment, nutrition etc), and considering and anticipating all possible scenarios, results in an athlete having the full psychological confidence in their unique and individualized approach. Ideally, this supports the athlete in realizing their best possible performance for their targeted championship event.

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