COMITÉ OLÍMPICO ESPAÑOL

COMISIÓN MÉDICA

X

JORNADAS SOBRE MEDICINA Y DEPORTE DE ALTO NIVEL

6ª CONFERENCIA:

"Nuevas estrategias nutricionales en deportes individuales"

PONENTE:

Trent Stellingwerff

DR. TRENT STELLINGWERFF
Senior Research Scientist in Sport Nutrition,
Energy and Performance
Nestlé Research Center

EMPLOYEMENT & CONSULTING

Nestlé Research Center, Lausanne, Switzerland **Sept. '06 - present**

- Department of Nutrition and Health, Group of Physical Performance and Mobility

Athletics Canada- Governing body for athletics in Canada **May. '07 – present**

- Serve as nutrition and physiology expert consultant for Olympic caliber Canadian track and field athletes

EDUCATION

University of Maastricht, Department of Movement Sciences, Maastricht, the Netherlands.

- Post-Doctorate Fellowship in the area of Human Exercise and Skeletal Muscle Physiology (2005-2006)

University of Guelph, Department of Human Biology and Nutritional Sciences, Guelph, Canada

- PhD Degree in the area of Human Exercise and Skeletal Muscle Physiology, Sept. 2005

Cornell University, College of Human Ecology- Division of Nutritional Sciences, Ithaca, NY, U.S.A.

- Honors Bachelor of Science in Nutrition, with a minor in Exercise Science, May 2000

ACADEMICS

RESEARCH EXPERIENCE:

Post-Doctorate Fellowship- University of Maastricht **Sept. '05 – Sept. '06**

- Post-doctorate fellowship in skeletal muscle physiology and specifically in post-exercise recovery research.

PhD- University of Guelph **Sept. '00 – Sept. '05**

- PhD degree in the area of carbohydrate and fat interactions in resting and exercising human skeletal muscle,

Honours Student Research Assistant- Cornell University **Jan. '99 - May '00**

- Vitamin E metabolism and bioavailability in human liver cell culture models

PUBLICATIONS:

Articles published in peer-reviewed journals

- Pelsers, Maurice MA, Trent Stellingwerff, and Luc J.C. van Loon. The role of membrane fatty-acid transporters in regulating skeletal muscle substrate use during exercise. Sports Medicine- 38(5): 387-399, 2008.

- Stellingwerff, Trent, Mike K. Boit and Peter T. Res. Nutritional strategies to optimize training and racing in middle-distance athletes. Journal of Sports Sciences- 25(S1): S17-S28, 2007.

- Koopman, Rene, Milou Beelen, Trent Stellingwerff, Bart Pennings, Wim H. Saris, Arie K. Kies, Harm Kuipers and Luc J.C. van Loon. Co-ingestion of carbohydrate with protein does not further augment post-exercise protein synthesis. American Journal of Physiology: Endocrinology and Metabolism- 293(3): E833-E842, 2007.

- Stellingwerff, Trent, Hanneke Boon, Anemie P. Gijsen, Jos H. Stegen, Harm Kuipers and Luc J. van Loon. Carbohydrate supplementation during prolonged cycling exercise spares muscle glycogen but does not affect intramyocellular lipid use. Pflugers Archive- European Journal of Physiology- 454(4): 635-647, 2007.

- Stellingwerff, Trent, Hanneke Boon, Richard A. Jonkers, Joan M. Senden, Lawrence L. Spriet, René Koopman and Luc J. van Loon. Significant intramyocellular use during prolonged cycling in endurance-trained males as assessed by three difference methodologies. American Journal of Physiology: Endocrinology and Metabolism- 292(6): E1715-E1723, 2007.

- Stellingwerff, Trent, George J.F. Heigenhauser and Lawrence L. Spriet. Reply to letter "Pyruvate metabolism in working human skeletal muscle" by Henderson et al. American Journal of Physiology: Endocrinology and Metabolism- 292(4): E1238-E1239, 2007.

- Stellingwerff, Trent, Paul J. LeBlanc, Melanie G. Hollidge, George J.F. Heigenhauser and Lawrence

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- Stellingwerff, Trent, Lawrence L. Spriet, Matthew J. Watt, Nicholas E. Kimber, Mark Hargreaves, John A. Hawley and Louise M. Burke. Decreased PDH activation and glycogenolysis during exercise following fat adaptation with carbohydrate restoration. American Journal of Physiology: Endocrinology and Metabolism- 290(2): E380-E388, 2006.

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- Glazier, Lee, Trent Stellingwerff and Lawrence L. Spriet. Effects of microhydrin supplementation on

  endurance performance and metabolism in well-trained cyclists. International Journal of Sport Nutrition and Exercise Metabolism. 14(5): 560-573, 2004.

- Watt, Matthew J., Trent Stellingwerff, George J. F. Heigenhauser and Lawrence L. Spriet. Effects of plasma adrenaline on hormone-sensitive lipase at rest and during moderate exercise in human skeletal muscle. Journal of Physiology. 550(1): 325-332, 2003.

- Stellingwerff, Trent, Matthew J. Watt, George J.F. Heigenhauser and Lawrence L. Spriet. Effects of reduced free fatty acid availability on skeletal muscle PDH activation during aerobic exercise. American Journal of Physiology: Endocrinology and Metabolism- 284(3):E589-E596, 2003.

- Watt, Matthew J, George J.F. Heigenhauser, Trent Stellingwerff, Mark Hargreaves and Lawrence L. Spriet. Carbohydrate ingestion reduces skeletal muscle acetylcarnitine availability but has no effect on substrate phosphorylation at the onset of exercise in man. Journal of Physiology. 544(3): 949-956, 2002.

Major Presentations:

- Sport Nutrition as a Recovery Tool- Optimizing post-exercise protein synthesis. – keynote speaker at Athletics Canada Technical Congress, November, 2007.

- Carbohydrate supplementation during prolonged cycling exercise spares muscle glycogen. – slide presentation at the 2007 American College of Sports Medicine (ACSM) Conference- New Orleans, LA. May, 2007.

- Nutritional strategies to optimize training and racing in middle-distance athletes. – keynote speaker at the 2007International Association of Athletics Federations (IAAF) Consensus Congress on Nutrition in Athletics- Monaco, April 2007.

- Optimizing nutrition before and after an event. – keynote speaker at Sports Nutrition for Endurance Athletes Symposium- Lausanne, Switzerland, April, 2007.

- Greater leg lactate efflux versus pyruvate efflux during steady-state cycling.– slide presentation at the 2006 European College of Sports Science (ECSS) Conference- Lausanne, Switzerland, July, 2006.

- Hyperoxia decreases muscle glycogenolysis, pyruvate and lactate production during exercise. – slide presentation at the 2006 American College of Sports Medicine (ACSM) Conference- Denver, CO. May, 2006.

- Decreased PDH activation and glycogenolysis during exercise following fat adaptation with carbohydraterestoration. – slide presentation at the 2005 American College of Sports Medicine (ACSM) Conference- Nashville. TN. May, 2005.

- Nutrition for the Elite Endurance Athlete - Athletics Canada Endurance Camp- hosted by Guelph National Endurance Centr - 1hr. educational presentation, April 2005.

- Effects of hyperoxia on skeletal muscle carbohydrate metabolism. – slide presentation at the University of Guelph College of Biological Sciences Graduate Student Symposium. January, 2005.

- Effects of hyperoxia on skeletal muscle carbohydrate metabolism during transient and steady-state exercise.–poster presentation at the 2004 Scandinavian Physiological Society Meeting-Lundsbrunn, Sweden. May, 2004.

- Skeletal muscle metabolism during transient and steady state aerobic exercise at two levels of hyperoxia.-poster presentation at the 2003 Experimental Biology (FASEB) Conference- San Diego, CA. April, 2003.

- Effects of reduced free fatty acid availability on skeletal muscle PDH activation during aerobic exercise. –slide presentation at the 2003 American College of Sports Medicine (ACSM) Conference-San Francisco. May, 2003.

- Nutrition and Hydration 2003 Speaking Series for Gatorade Canada on Nutrition and Hydration including: Vancouver Marathon, Ottawa Marathon, Ontario Hockey League Trainer's Meeting, Ironman Canada, Victoria Marathon.- 2003

- Nutrition and hydration concerns for the Ironman Triathlete. – presentation for Gatorade Canada (Second Dimension Int.) at Ironman Canada, Penticton, B.C.- August, 2002.

- Gatorade Education- Physiology of hydration and carbohydrate supplementation. – 3 hr educational presentation for Quaker-Tropicana-Gatorade, Toronto- August, 2002.

- Basic physiology during distance running and application in racing and training. Athletics Canada National Coaching Certificate Program- Level II Distance Running:–3hr. educational presentation, May 2002.

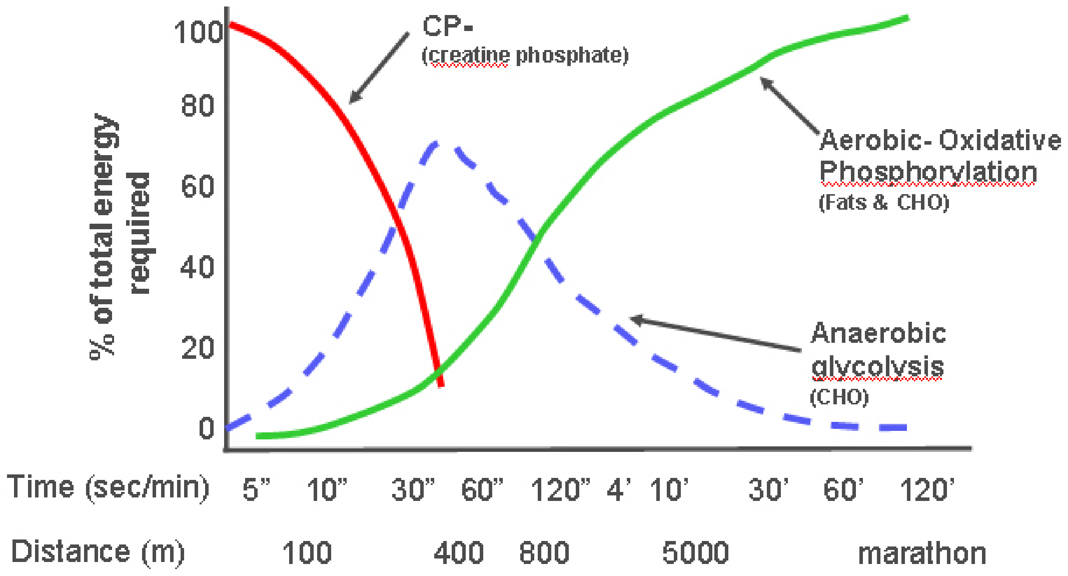
NUTRITIONAL RECOMMENDATIONS

FOR INDIVIDUAL SPORTS.

Dr. Trent Stellingwerff, PhD, Nestlé Research Center, Switzerland

Individual sports such as swimming, athletics, gymnastics and cycling all have varied requirement for energy (ATP, adenosine triphosphate) production. And, these energy producing pathways vary significantly according to the intensity and duration of the specific activity, and thus the types of endogenous and exogenous fuels that are used to produce the required energy also vary dramatically (Fig. 1).

Figure 1: ATP energy provision across different durations of activity.



Adapted from: (Martin & Coe, 1991).

For example, some sports such as gymnastics (explosive power for under 30 sec) and sprint/power based events in swimming (50 to 100m events) and athletics (100m to 400m running, jumping and throwing events) utilize nearly exclusively anaerobic based ATP production, which relies on creatine phosphate (CP) and carbohydrate (CHO) derived energy provision.

This CP and CHO fuel provision is used during quick explosive movements, and intense activities of up to ~1 min. Sports and events lasting from ~1min to 8min (eg. 800m to 3000m of running, 200m to 800m of swimming, or Individual Pursuit in cycling) rely heavily on anaerobic glycolysis to provide the required ATP. However this comes at a cost, as there are also large amounts of lactate and hydrogen ion (H^+) also produced. This H^+ induces acidosis, and eventually, fatigue in the athlete.

Conversely, oxidative phosphorylation provides the bulk of ATP provision, primarily utilising fat as a fuel, during low to moderate intensity training found during longer duration (>30min) running and cycling events. Fat can be provided in both endogenous muscle stores (intramuscular triacylglyceride; IMTG) and as fat stored in peripheral adipocytes and released as plasma free fatty acids (FFA). During low intensity exercise, primarily Type I slow twitch oxidative fibres are recruited, which have a high oxidative capacity to utilise primarily fat (Fig 1).

Therefore, due to this incredible diversity of energy provision between aerobic and anaerobic sources, different types of athletes implement different types of training volume, duration and intensity throughout their training year, which utilizes all energy producing pathways (CHO; fat) and muscle fibre types (slow; fast). Furthermore, most athletes also perform extensive resistance and plyometric exercises to develop strength, explosiveness and stimulate central nervous system and neuromuscular adaptations. Accordingly, a fundamental appreciation of the different fuels (CHO, fat) used during training and competition, coupled with the important need for protein (PRO) for repair and recovery of muscle, needs to provide the basis for all acute and seasonal nutritional recommendations.

Dr. Louise Burke has identified that across all individual sports common nutritional related issues can be broken up into three main categories of: 1) Physique issues, 2) Training Issues and 3) Competition Issues (Burke, 2007). Table 1 below outlines the common nutritional related issues across the sports of athletics, cycling, gymnastics and swimming. The major issues across all these sports, and what is going to be covered in this article and symposium, are highlighted in yellow.

Table 1. Most prevalent nutritional issues faced by athletes in athletics, cycling, gymnastics and swimming.

Ath	Cyc	Gym	Swim	Physique Issues
√	√	√	√	• Desire to reduce body fat and body mass to enhance performance via enhanced power-to-mass relationship
√	√	√	√	• Risk of dietary extremes, disordered eating, and inadequate nutrition attributable to overemphasis on low body mass and body fat level
		√	√	• Changes in physique during maturation and adolescence
		√		• Negative effects of chronic energy restriction and long-term growth during maturation

Ath	Cyc	Gym	Swim	Training Issues
√	√		√	• High energy and CHO requirements to meet heavy training load
	√		√	• Practical difficulties in consuming sufficient energy and CHO intake in a busy day
√	√	√	√	• Optimal recovery between multiple daily training sessions
√	√		√	• Adequate fuel and fluid intakes during prolonged training sessions
√	√	√		• Risk of low iron status, especially in female and vegetarian athletes
√	√	√		• Risk of menstrual disturbances in female athletes, female athlete triad, low bone mineral density
√	√	√	√	• Periodizing nutrition to meeting periodized training
	√			• High level of interest in supplements
√				• Compromise in achieving fuel requirements and adequate protein and micronutrient intakes when trying to achieve body weight and body fat goals
			√	• Consideration of creatine loading to enhance resistance training response
		√		• Mismatch between training energy expenditure and low energy intake to try and achieve very low body fat
√	√	√	√	• Adequate protein intake to promote muscle mass gain during resistance training and to repair damaged muscle for recovery

Ath	Cyc	Gym	Swim	Competition
√	√	√	√	• Having adequate fuel stores for race day: CHO loading before long events
	√			• Minimizing gastrointestinal issues before and during competition
√	√		√	• Consideration of caffeine to enhance performance
√	√			• Fuel and fluid intake during competition
√	√	√	√	• Aggressive short-term recovery strategies needed
√	√	√	√	• Travel-- live on the road and circuit
√			√	• For anaerobic events, the possible use of sodium bicarbonate for enhanced buffering
			√	• Adjusting energy intake during taper to prevent excessive weight and fat gain

Ath, Athletics; Cyc, Cycling; Gym, Gymnastics; Swim, Swimming

Table adapted from: (Burke, 2007)

General Nutritional Recommendations

Table 2 at the end of this article, displays the average data collected in over 100 studies analyzing daily dietary macronutrient intakes of male and female cyclists, distance runners, swimmers and gymnasts. The absolute values for energy and macronutrient intake vary radically across sports and gender. However, even the relative weight corrected values for energy and macronutrient intakes also exhibit some interesting differences and trends. For example, regardless of sport, females consistent have a lower energy intake per kg than males, with all females reporting less than 200 MJ/kg of energy consumption per day, and nearly all males reporting greater than 200 MJ/kg. Female gymnasts report only ~160MJ/day (~1700 kcals) of energy intake per day.

It is generally recommended that hard training athletes (especially endurance athletes) consume >60% of energy (E) as CHO, or on a relative weight basis ~7 to 10g/kg/day. However, table 1 clearly illustrates that most athletes fail to reach these recommendations. Hence, a greater emphasis needs to be made to help athletes, and especially females, meet their recommended CHO and energy intake needs. It is also vital during situations of high CHO intakes that athletes do not neglect the other important macro-and micro-nutrients. Therefore, to maintain immune function, recover glycogen storage, and reduce over-reaching and over-training symptoms, a habitually high CHO diet (7-10g CHO•kg BW^{-1}•day^{-1}) is recommended.

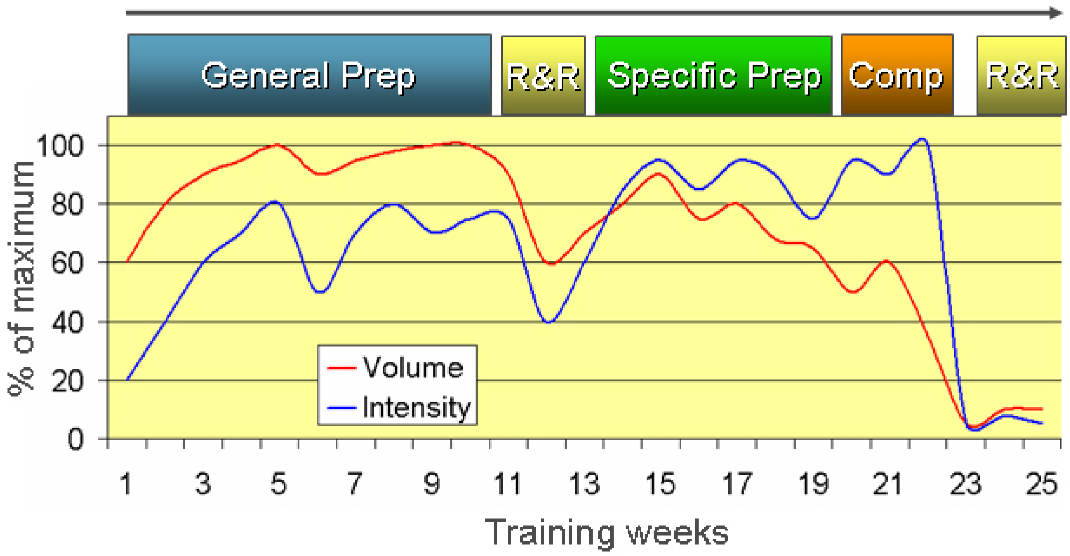
Since protein intake in excess of 1.7g PRO•kg BW^{-1}•day^{-1} has been shown to be oxidized, recommendations have been made that any athlete, regardless of whether an endurance athlete or a power athlete, who is undertaking a large and intense training load should ideally aim for between 1.5-1.7g PRO•kg BW^{-1}•day^{-1}. There continues to be considerable scientific discussion regarding the optimum daily protein intake for athletes, but this appears irrelevant. Dietary studies in athletes from Western countries (Table 1) have consistently shown that athletes generally consume more protein than any elevated dietary recommendation anyways.

Periodized nutrition for periodized training

Regardless of the sport, most elite athletes and coaches tend to structure, or 'periodize', their training throughout the yearly training calendar into specific training phases, with each phase having unique physiological emphasis. Depending on the individual sport, these different physiological emphases throughout the year, leading towards a championship seasonal peak, can include: aerobic and endurance development, anaerobic improvement and tolerance, explosive strength development, body composition optimization, technical and neurological optimization, competition phase and rest and recovery.

As an example of a given individual athlete, the stark differences in training volume and intensity between these phases for a middle-distance athlete can be remarkable and are displayed in Figure 2. A given middle-distance athlete may undertake training during the aerobic development (General Prep) phase that rivals a marathon runners' volume, but during the competition tapering phase (Comp), training will nearly mimic a long-sprinters' intensity, speed and volume. Consequently, the training load and intensity, coupled with the required energy expenditure and fuel selection (CHO vs. FAT) throughout each training phase varies significantly throughout the year. Thus, at the centre of this periodized training regime, should be a well-planned and periodized nutritional approach that takes into account acute and seasonal nutritional needs induced by specific training stimuli.

Figure 2: An example overview of the major training phases for elite middle-distance athletes highlighting the large differences in training intensity and volume.



Peaking at the exact time of a major championship is one of the most difficult endeavours to achieve. But, realizing the important and integrated role of nutrition in this quest will bring the athlete one step closer to their goals.

Individualized recovery nutrition recommendations

Optimizing recovery via individualized nutritional recommendations and protocols can have a large impact in training load, quality and ultimately performance for a given athlete. Hard training is catabolic in nature. It is only during recovery, of which nutrition is one of the cornerstones, that the benefits of the hard-work are realized through the recovery of muscle energy stores (primarily glycogen) and the synthesis of new proteins. All athletes across different sports utilize an incredible diverse and varied exercise stimulus. Therefore, depending on the previous exercise mode, intensity and duration, the acute recovery nutritional recommendations will also vary. Table 3 below gives general recovery nutrition recommendations based on the type, intensity and volume of training that can be applied to any individual sport.

Table 3: Summary of acute post-exercise dietary recommendations in respect to specific type of training.

Type of Training	Examples of Training Sessions	Fuels Utilized	Acute Nutrition Recommendations
Aerobic capacity & power- oxidative & glycolytic enzymes / VO2max / AT	1) >2hrs cycling 2) >75min running 3) >75min swimming	Mainly FATS	***during aerobic training:*** CHO: ~1-1.4 g•kg^{-1}•hr^{-1} sports drink *exp: ~800 to 1000ml sports drink per hr*
Anaerobic capacity & power- glycolytic enzymes / CHO metabolism / muscular strength / running economy	(Note: all of the described training sessions below could be applied to cycling, swimming and running) 1) 30sec reps on 1min recov. 2) 10x1min on 2min recov. 3) hill runs of 15-30sec 4) 90sec reps on 5min recov.	FATS/CHO	***short term (<4hrs) recov:*** in small repeated doses over first 2hrs post-exerc CHO: 1.2-1.5 g•kg^{-1}•hr^{-1} *exp: ~800 to 1200ml sports drink per hr*
		CHO	***longer term (>20hrs) recov:*** over first 2hrs post-exerc CHO: ~1g•kg^{-1}•hr^{-1} total PRO: ~0.3 g•kg^{-1}•hr^{-1} FAT: ~0.1 g•kg^{-1}•hr^{-1} *exp: 1) whole-wheat bagel + peanut butter* *2) 750ml sports drink + protein bar* *3) 2 cups cereal + milk + banana* *4) tuna on whole wheat + 500ml juice* *5) chocolate milk + low-fat fruit yogurt*
Explosive training and technical work- maximal contraction ability / muscular hypertrophy / technique & economy	1) weight training 2) plyometric jump training 3) sprint & speed drills 4) hill sprints	CHO & ATP/CP	***during and 2hrs post-resistance exerc:*** CHO: ~0.5 g•kg^{-1}•hr^{-1} total PRO: ~0.3 g•kg^{-1}•hr^{-1} EAA: ~0.1 g•kg^{-1}•hr^{-1} *exp: 1) 500ml sports drink + protein bar* *2) 250ml of milk + piece of fruit*

AT, anaerobic or lactate threshold; CHO, carbohydrate; CP, creatine phosphate; EAA, essential amino acids; exerc, exercise; exp, example; PRO, protein; recov, recovery.
Nutrition recommendations adapted from (Tarnopolsky, 1999; Jentjens & Jeukendrup, 2003; Burke *et al.*, 2004; Tipton & Wolfe, 2004).

When the athlete is faced with a short time period for recovery CHO must be immediately supplied to maximize glycogen re-synthesis rates. Contemporary studies suggest utilizing frequent smaller doses (i.e. 20-30 g CHO every 20 to 30min) for an overall intake rate of 1.2 to 1.5 $g \cdot kg\ BW^{-1} \cdot hr^{-1}$ for the first several hours of recovery (Jentjens & Jeukendrup, 2003). This CHO intake protocol is specifically important when an athlete is faced with a short recovery period (<4 hrs), such as between rounds of races or between hard training sessions on the same day. During these situations, fat should also be avoided, as it can slow gastric emptying.

During longer-term recovery (24 hrs^{+}) and/or recovery from resistance exercise, PRO intake in conjunction with CHO is vital to maximize muscle glycogen re-synthesis, protein synthesis rates and the repair of damaged muscle tissues (Table 3). However, it remains to be clarified what is the most ideal macronutrient blend, feeding pattern, type of CHO and/or protein (whole intact proteins vs. hydrolyzed) and the intake timing to optimize recovery and adaptation after different types of exercise stimuli.

Optimizing body composition

All sports have an ideal height, weight and body composition which are dictated by individual dietary and exercise habits, but also to a large degree by genetics. However, beyond this 'ideal' or normal height, weight and body composition there are always athletes that excel who do not exactly fit within this mold.

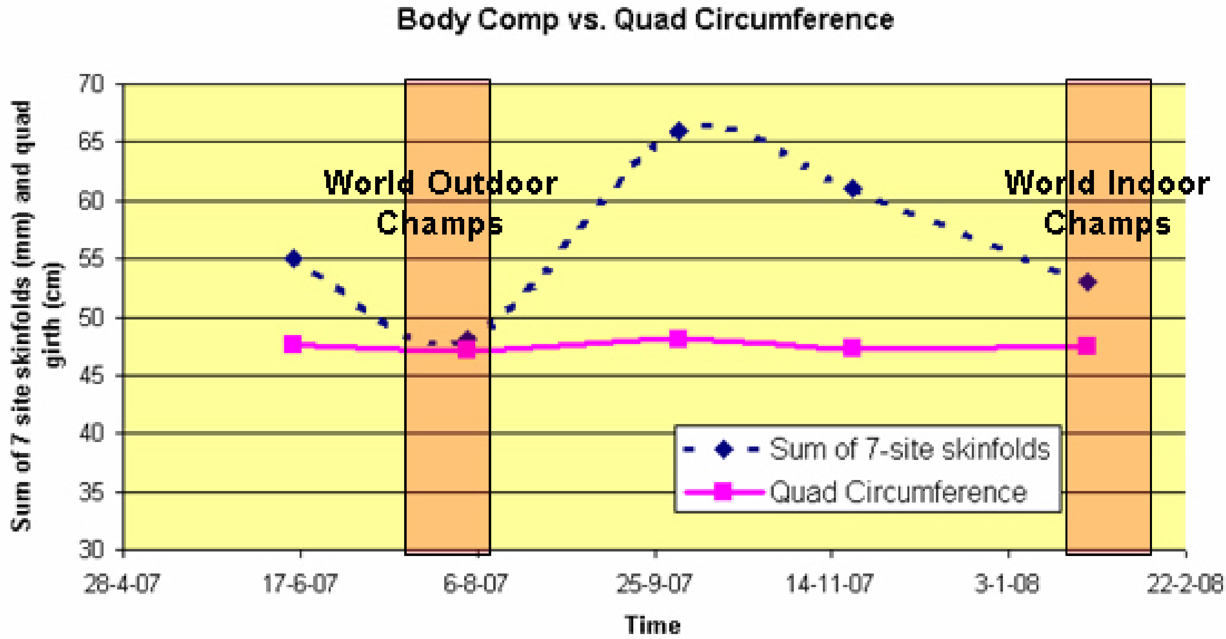
A number of athletes (primarily female) are over-mindful of the benefit that low body weight brings to performance, and many believe that post-exercise protein consumption may bring unwanted gains in muscle mass, ultimately leading to weight gain. However, recent evidence has suggested that the specific exercise stimulus (resistance vs. endurance), rather than the nutrition intervention, plays a more dominant role in the divergent signalling pathways and the types of proteins that are synthesised after exercise, which explains the adaptive response and divergent phenotypes. Thus, protein intake should not be avoided on the premise that it might lead to unwanted muscle mass, and weight.

In line with this, several recent studies have shown that higher-protein intakes spare muscle protein and enhance fat loss during periods of energy restriction (Phillips, 2006).

Given this, it might be advantageous for athletes looking to loose weight, while maintaining muscle mass, to slightly increase protein intake up to ~35% E, as this may result in a metabolic advantage in changing body composition during situations of energy restriction

In already lean athletes, and/or young athletes who are looking to loose further weight, it is also wise to only undertake reducing body fat and weight via negative energy balance under the supervision of an expert dietician/physiologist. In many circumstances, further weight loss in already lean athletes actually can cause a loss of muscular power and strength, an increased risk for stress fractures and a decreased immune function, all leading to a decrease in performance. For example, for an already very lean runner or cyclist it would not be performance enhancing to loose another 3% of body weight and fat, but at the same time loose significant leg muscle mass (quad girth). Instead, it is much better to loose body fat from the core, while maintain leg muscle mass to drive performance (Fig 3). By measuring and assessing this over time, one can truly see if they are making ideal periodized changes in their body weight, body fat percentage and in their muscle girths. Like training and nutrition, body composition should also be periodized over time and athletes should only aspire to be truly at competition 'performance weight' for short periods of time throughout the year (Fig. 3). In the end, optimizing body composition can also involved a high degree of emotional and psychological body image stress, which needs to be properly and positively addressed by a nutritional expert, along with the coach and family, to ensure no disordered eating arises.

Figure 3: Body composition measurements made of a weight-dependant track and field athlete throughout a training year.



When to seek expert nutritional advice

From developing to elite athletes, as long as individuals adhere to a healthy and well-balanced diet and obtain ideal rest and recovery from training, then the vast majority of athletes will not need highly specialized nutritional advice. Nearly all of the dietary recommendations that most athletes need can be found in respected contemporary applied sports nutrition books. However, there are unique and specific situations that may arise with a small percentage of athletes that will need to be properly addressed by a qualified and experienced sports nutrition professional. Table 4 below highlights some of these situations that you as a practitioner, coach or athlete may have experienced, and in these situations, expert opinion should be sought after.

Table 4. When to seek nutritional advice from a medical professional and/or sports nutrition expert.
• Are you consistently very fatigued every single day during a hard training phase?
• Do you continually get run-down and sick? (decreased immune function?)
• Do you tend to run out of fuel in workouts or afternoon runs, and feel like light headed or feel like you have no energy?
• Do you have wild fluctuations in body weight throughout the training year (greater than a 5% gain or loss in body weight)?
• Do you have a very hard time trying to maintain a lean and competitive physique in a healthy manner?
• Have you had problems with iron-deficiency anemia on several occasions?
• As a female athlete, have you experienced amenorrhea (no menstral cycle) for greater than a continuous 3 or 4 month length of time?
• After a hard work-out or race, do you have severe muscle soreness for several days on end?

For further reading please see selected books and reviews on these topics and individual sports:

BURKE, L. (2007). *Practical Sports Nutrition*, vol. 1. Human Kinetics, Champaign, IL.

BURKE, L. M. (2001). Nutritional practices of male and female endurance cyclists. *Sports medicine* **31,** 521-532.

BURKE, L. M., COX, G. R., CULMMINGS, N. K. & DESBROW, B. (2001). Guidelines for daily carbohydrate intake: do athletes achieve them? *Sports medicine* **31,** 267-299.

BURKE, L. M., KIENS, B. & IVY, J. L. (2004). Carbohydrates and fat for training and recovery. *Journal of sports sciences* **22,** 15-30.

CAINE, D., LEWIS, R., O'CONNOR, P., HOWE, W. & BASS, S. (2001). Does gymnastics training inhibit growth of females? *Clin J Sport Med* **11,** 260-270.

HAWLEY, J. A., TIPTON, K. D. & MILLARD-STAFFORD, M. L. (2006). Promoting training adaptations through nutritional interventions. *Journal of sports sciences* **24,** 709-721.

HOUTKOOPER, L., ABBOT, J. M. & NIMMO, M. (2007). Nutrition for throwers, jumpers, and comined events athletes. *Journal of sports sciences* **25,** S39-S47.

JENTJENS, R. & JEUKENDRUP, A. (2003). Determinants of post-exercise glycogen synthesis during short-term recovery. *Sports medicine* **33,** 117-144.

JEUKENDRUP, A. & GLEESON, M. (2004). *Sport Nutrition: An Introduction to Energy Production and Performance*, vol. 1. Human Kinetics, Champaign, IL.

JEUKENDRUP, A. E., JENTJENS, R. L. & MOSELEY, L. (2005). Nutritional considerations in triathlon. *Sports medicine* **35,** 163-181.

MARTIN, D. E. & COE, P. N. (1991). *Training Distance Runners*. Leisure Press, Champaign, IL.

O'CONNOR, P. J., LEWIS, R. D. & BOYD, A. (1996). Health concerns of artistic women gymnasts. *Sports medicine* **21,** 321-325.

PHILLIPS, S. M. (2006). Dietary protein for athletes: from requirements to metabolic advantage. *Appl Physiol Nutr Metab* **31,** 647-654.

STELLINGWERFF, T., BOIT, M. K. & RES, P. (2007). Nutritional strategies to optimize training and racing in middle-distance athletes. *Journal of sports sciences* **25,** S17-S28.

TARNOPOLSKY, M. (2004). Protein requirements for endurance athletes. *Nutrition* **20,** 662-668.

TARNOPOLSKY, M. A. (1999). Protein metabolism in strength and endurance activities. In *Perspectives in Exercise Science and Sports Medicine: The Metabolic Basis of Performance in Exercise and Sport*, vol. 12. ed. LAMB, D. R. & MURRAY, R., pp. 125-164. Cooper Publishing Group, Carmel, IN.

TIPTON, K., JEUKENDRUP, A. & HESPEL, P. (2007). Nutrition for the sprinter. *Journal of sports sciences* **25,** S5-S15.

TIPTON, K. D. & WOLFE, R. R. (2004). Protein and amino acids for athletes. *Journal of sports sciences* **22,** 65-79.

Table 2. Overview of major daily macronutrient and energy dietary intake data across different genders and sports.

Gender/Sport	Age	BM	ENERGY			CHO			PRO			FAT		
			MJ	MJ/kg	~kcals	g	g/kg	%E	g	g/kg	%E	g	g/kg	%E
Male cyclists (n=139; 11 studies)	24±4	71±2	17.8±3.5	251±48	4250	547±130	7.8±1.9	51±7	143±23	2.0±0.3	14±2	153±41	2.2±0.6	33±7
Female cyclists (n=51; 4 studies)	24±1	63±5	12.4±1.2	193±26	2970	426±71	7.3±1.6	56±6	114±30	2.0±0.6	16±4	90±27	1.5±0.4	27±9
Male cyclists racing (n=36; 5 studies)	26±3	70±2	22.5±2.2	276±140	5380	818±69	11.8±1.0	61±1	194±26	2.8±0.4	14±1	148±12	2.1±0.2	25±1
Male distance runners (n=311; 21 studies)	26±5	64±5	14.1±2.1	223±31	3370	453±89	7.3±1.8	53±7	127±26	2.0±0.4	15±2	114±34	1.8±0.5	30±6
Female distance runners (n=220; 16 studies)	23±5	53±3	9.1±1.8	173±31	2169	292±45	5.8±0.8	54±6	78±15	1.5±0.4	15±1	79±24	1.5±0.5	31±5
Male swimmers (n=135; 10 studies)	19±3	75±3	17.5±3.2	237±46	4180	529±75	7.2±1.1	51±7	163±55	2.3±0.8	15±3	168±61	2.2±0.8	34±6
Female swimmers (n=175; 15 studies)	19±2	63±2	11.2±2.9	174±47	2669	355±65	5.7±1.1	54±9	99±39	1.5±0.6	15±4	97±53	1.5±0.8	31±8
Male power athletes (n=311; 18 studies)	25±4	88±10	16.8±5.1	181±57	4000	448±137	5.2±1.6	46±9	203±58	2.5±0.7	20±5	164±77	1.9±0.9	35±8
Female gymnasts (n=278; 13 studies)	15±3	46±9	7.3±1.0	162±36	1730	223±29	5.3±1.1	51±6	68±12	1.6±0.4	15±1	65±20	1.4±0.4	33±6

Data complied from: (Burke, 2007). And taken from reviews: (Tarnopolsky, 1999; Burke *et al.*, 2001; Burke *et al.*, 2004; Tipton & Wolfe, 2004)
Age in years; BM, body mass in kg; MJ, mega-joules; %E, percent contribution towards total energy