CASE STUDY

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Increased Energy and Nutrient Intake During Training and Competition Improves Elite Triathletes' Endurance Performance

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Dietary habits were evaluated in 6 elite triathletes (4 male, 2 female). Analysis of 7-day diet records showed mean daily energy and carbohydrate intake to be insufficient to support estimated requirements. Mean intakes of vitamins and most minerals exceeded the Recommended Dietary Allowances (RDAs) except zinc and chromium, which did not meet 66% of recommended amounts. Individualized nutrition intervention using the Diabetic Food Exchange System to support performance during training and competition was provided. To improve dietary intake, subjects consumed fortified nutrition supplements (Reliv, Inc.) before and after daily training. Follow-up 7-day diet records showed that average energy intake and percentage of energy from carbohydrate increased, as did intakes of zinc and chromium. Triathletes' performance in a short course triathlon was improved compared to a similar competition completed prior to the nutrition intervention. Following the intervention, triathletes were able to meet recommended daily energy, macronutrient, and micronutrient intakes and improve endurance performance.

Key Words: triathletes, nutritional habits, carbohydrate, chromium

Nutrition is important for triathletes, not only to optimize performance during competition but also to support demanding daily training programs. The available data on energy and nutrient intake of triathletes suggest that they are aware of the role of nutrition in athletic performance (8, 11, 17). In general, these athletes consume more kilocalories per kilogram of body weight and exceed recommended levels of intake for most vitamins and minerals compared to the general population (11, 19). Additionally, triathletes report modifying carbohydrate (CHO) intake prior to and during athletic competition to enhance exercise time (8, 17).

The composition of triathletes' diets, however, is reported to be more similar to the recommended diet for the general population, with a CHO intake lower and a fat intake higher than recommended for endurance athletes (11, 20, 27). Walberg-Rankin (26) recently summarized the dietary CHO and energy intake of athletes involved in long-duration sports. The average energy intake from CHO was 56.7%.

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When expressed relative to body weight, average CHO consumption was 6.4 g/kg, substantially lower than the 9–10 g CHO/kg recommended for endurance athletes (13). Endurance athletes may not know about specific dietary recommendations to support performance or may not know how to achieve the desired intake (19).

The purpose of the present study was to evaluate the dietary habits of top-level triathletes and observe the effect of dietary intervention on subsequent endurance performance.

Methods

Six elite triathletes (4 male, 2 female) gave written consent to participate in the study. All subjects were actively training and competing at the time of the study. All subjects were considered trained, top-level performers, as they were repeat competitors in the Hawaiian Ironman Triathlon. Subject characteristics are presented in Table 1.

Triathletes completed a diet history that included a 7-day dietary record, which required subjects to record the type and amount of food and drink consumed as well as the specific time of day. The average kilocalorie, CHO, fat, and protein as well as vitamin and mineral contents were calculated from the Nutritionist IV software program (First Data Bank, San Bruno, CA). Additionally, Diabetic Food Exchange lists (1) were generated that indicated both actual number of servings of exchange groups consumed and recommended number of servings to consume based on recommended energy and nutrient needs to support endurance performance.

While maintaining current dietary practices, subjects competed in a short course triathlon (T1) consisting of a 1.3-km swim, 40-km bicycling course, and 10-km run. Subjects' precompetition dietary practices and fluid intakes during competition were recorded.

Following T1, triathletes met individually with the primary author to discuss their dietary analyses. Dietary recommendations to support endurance training were presented. Specifically, triathletes were presented with their typical eating patterns expressed in Diabetic Food Exchange servings and a revised Diabetic Food Exchange listing based on recommended numbers of servings from the food groups to meet

Table 1 Physical Characteristics of Subjects (Mean ± *SD*) Before and After Nutrition Intervention

	Before		After	
Characteristics	*M*	*SD*	*M*	*SD*
Age (years)	31	3	31	3
Height (cm)	152	4	152	4
Weight (kg)	69	3	70	2
Body fat (%)	8.0	1	8.1	2
Weekly training (hr/week)	11	2	11	2

the triathletes' energy and macronutrient needs. Once triathletes understood food types and serving sizes within the food groups, they were asked how they could modify their current intake to meet the recommended number of servings from the respective groups, and sample daily menus were generated. As all of the triathletes reported working full time and eating three meals per day plus a before- and after-training snack, food recommendations were organized according to these eating events.

To supplement dietary energy, CHO, and chromium intake, subjects were instructed to consume one serving (8 oz) of Innergize, a liquid sports drink, and one Ultra Bar (40 g) (Reliv, Inc., Chesterfield, MO) along with their daily before- and after-training snacks (Table 2). The supplements provided an additional 480 kcal, 88 g CHO, and 200 µg chromium per day.

Subjects complied with the dietary recommendations for 4 weeks. They kept records of the number of food group exchanges consumed each day. These were checked weekly by the primary author during training time. At this time subjects also received a weekly supply of Innergize and Ultra Bars.

At the end of the 4 weeks, subjects again completed body composition measurements and a 7-day diet record prior to participating in another short-course triathlon (T2). T2 consisted of the same swimming, cycling, and running distances as T1, along similar terrain. Subjects' precompetition dietary intakes were the same as T1. During the T2 race, however, subjects consumed an equal volume of Innergize (Reliv, Inc.), containing 200 µg chromium, instead of their regular carbohydrate drink to evaluate the palatability of the beverage during competition.

Data were analyzed by the Statistical Analysis System (SAS) (Cary, NC). Dependent *t* tests were performed to distinguish differences in dietary intake and competition time before and after nutrition intervention. The alpha level of significance was chosen as .05. All values are reported as mean ± standard deviation (±*SD*).

Results

Mean energy and nutrient intakes and numbers of Food Group Exchanges consumed are shown in Table 3. No significant differences were found when intakes were normalized for body weight; thus, data for males and females were combined for all analyses.

Table 2 Composition of Nutritional Supplements

	Innergize[a]	Ultrabar[a]
Serving size	8 oz	40 g
Kilocalories/serving	70	170
Carbohydrate/serving (g)	17	27
Chromium/serving (µg)	50	50
Protein/serving (g)	—	3
Fat/serving (g)	—	6

[a]Reliv, Inc., Chesterfield, MO.

Table 3 Triathletes' Dietary Intake (Mean ± *SD*) Before and After Nutrition Intervention

	Before		After	
	M	*SD*	*M*	*SD*
Energy (kcal)	2,318	150	3,992	425*
% kcal CHO	59	5	65	4*
% kcal fat	18	11	16	9
% kcal protein	15	4	17	6
% kcal alcohol	4	2	2	4
Carbohydrate (g)	344	156	650	118*
g/kg	4	2	8	2*
Fat (g)	57	7	79	8*
Protein (g)	90	25	166	32*
Alcohol (g)	14	6	11	4
Vitamin C (mg)	97	28	114	45
Thiamin (mg)	2	0.8	4	0.6
Riboflavin (mg)	3	0.7	5	2
Niacin (mg)	36	14	60	21*
Calcium (mg)	876	214	1,996	374*
Iron (mg)	21	3	33	6*
Zinc (mg)	7[a]	4	38	6*
Diet			14	5
Supplement			24	1
Chromium (μg)	18[a]	4	238	9*
Diet			38	10
Supplement			200	2
Food group servings				
Milk	1.3	1.1	4.1	2.4*
Vegetable	1.9	1.2	9.5	2.1*
Fruit	7.3	3.0	11.6	4.4*
Bread/cereal	10.9	4.6	23.3	7.4*
Meat	6.6	3.2	5.6	2.6
Fat	8.6	2.6	11.3	4.3

[a]Below 66% of the RDA, ESADDI. *Significant difference ($p < .05$).

Prior to nutrition intervention, subjects consumed too few kilocalories to support estimated daily energy expenditures (2,318 ± 150 kcal/day vs. 4,000 ± 250 kcal/day, $p < .05$). The energy derived from CHO, fat, protein, and alcohol, respectively, averaged 59 ± 5%, 18 ± 11%, 15 ± 4%, and 4 ± 2% of total energy intake. CHO intake, expressed in grams per kilogram of body weight, was significantly lower than recommended to support daily needs (4 ± 2 g/kg/day vs. 9–10 g/kg/day, $p < .05$). Mean intakes for vitamins and minerals studied were above the Recommended Dietary Allowance (RDA) (16) except for zinc and chromium. Mean zinc intake was 7 ± 4 mg/day, in contrast to the RDA for zinc for males and females, 15 and 12 mg/day, respectively (15). Subjects consumed an average of 18 ± 4 µg chromium/day, whereas a chromium intake of between 50 and 200 µg/day is recommended for adults (16). The average adult chromium intake from self-selected diets containing 2,300 kcal is 33 µg/day, so it is not unusual that the athletes consumed below the Estimated Safe and Adequate Daily Dietary Intake (ESADDI) (16). Subjects' CHO intake was derived mainly from the bread/cereal group and fruit group. Mean intake of the milk and vegetable group was less than the minimum daily servings recommended for a healthy diet: 2–4 servings of milk and 3–5 servings of vegetables.

Following nutrition intervention, subjects reported consuming sufficient kilocalories per day to meet energy requirements (3,992 ± 425 kcal/day) without experiencing change in body weight or body composition (Table 1). The energy derived from CHO, fat, protein, and alcohol was 65 ± 4%, 15 ± 9%, 17 ± 6%, and 2 ± 2%, respectively. Mean CHO intake (g/kg) was not significantly different from amounts recommended (8 ± 2 g/kg). Subjects' energy and macronutrient intakes were increased by increasing daily servings from the bread/cereal, fruit, vegetable, and milk groups ($p < .05$) as well as use of the nutritional supplements. Subjects were able to exceed two-thirds of the RDA for zinc through increased food consumption. Subjects met 76% of the minimum ESADDI for chromium (50 µg) through increased food consumption. After use of the fortified nutritional supplements, subjects' mean zinc intake was 38 ± 6 mg/day and their mean chromium intake was 238 ± 9 µg/day (Table 3).

Table 4 displays the total kilocalorie intake and the amount (in grams) of each macronutrient consumed during each eating period before and after nutrition intervention. Before intervention, triathletes consumed 89% of caloric intake from meals and 11% from pre–post training snacks. Breakfast kilocalories were 75 ± 4% CHO compared to lunch and dinner, which were 50 ± 6% and 50 ± 4%, respectively. Protein intake was similar during all meals: breakfast 20 ± 2%, lunch 19 ± 2%, supper 18 ± 3%. The pre- and posttraining snacks contributed exclusively CHO kilocalories due to consumption of sports drinks and/or fruit.

Following nutrition intervention, subjects significantly increased kilocalorie intake at breakfast and pre–post training snacks (Table 4). Breakfast still contained the most CHO (77 ± 3%) compared to the other meals (lunch 54 ± 6%, supper 42 ± 6%). The significant increase in energy and CHO intake at pre–post training snacks was derived mainly from easily digestible CHO drinks and energy bars and the nutritional supplements.

The triathletes' exercise training regimen prior to T2 was the same as T1, and the triathletes consumed the same precompetition meal (Table 5). Three hours prior to T1 and T2, triathletes consumed 16 oz of a sport nutrition supplement containing 360 kcal, 58 g CHO, 16 g protein, and 7 g fat per 8 oz (GatorPro, The Quaker Oats Co., Barrington, IL). Triathletes consumed 32 oz of a carbohydrate beverage during T1 (Gatorade Thirst Quencher, The Quaker Oats Co., Barrington, IL). During T2, however, triathletes consumed 32 oz of Innergize, which provided similar energy and CHO content as the T1 beverage but additionally provided 200 µg chromium during the competition (Reliv, Inc., Chesterfield, MO). Triathletes completed T2 in less time than T1 ($p < .05$) (Table 5).

Table 4 Food Intake Patterns of Triathletes (Mean ± *SD*) Before and After Nutrition Intervention

	Breakfast		Lunch		Snack[a]		Snack[b]		Supper	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Before										
Energy (kcal)	357	55	644	34	100	26	140	31	948	74
Protein (g)	18	4	31	3	—	—	—	—	40	2
% kcal	20	2	19	2	—	—	—	—	18	3
CHO (g)	62	6	81	17	25	2	35	3	119	18
% kcal	75	4	50	6	100	6	100	4	50	4
Fat (g)	4	3	22	10	—	—	—	—	28	16
% kcal	10	4	31	11	—	—	—	—	30	12
After										
Energy (kcal)	625	142*	725	116	620	40*	892	35*	1,130	320*
Protein (g)	27	11	38	6	6	2*	6	2*	87	11*
% kcal	17	6	21	4	4	2*	3	1*	31	6*
CHO (g)	120	35*	98	25	122	3*	190	2*	120	54
% kcal	77	3	54	6	79	2	85	3	42	6
Fat (g)	4	4	20	4	10	2*	12	4*	29	11
% kcal	6	3	25	6	17	2*	12	2*	38	4

[a]Pretraining. [b]Posttraining. *Significant difference ($p < .05$).

Table 5 Competition Dietary Practices (Mean ± *SD*) and Performance Times of Triathletes

	Triathlon 1		Triathlon 2	
	M	*SD*	*M*	*SD*
Precompetition meal				
Energy (kcal)	720	10	720	12
CHO (g)	116	2	116	2
Protein (g)	32	3	32	4
Fat (g)	14	1	14	1
Competition				
Energy (kcal)	220	20	280	12*
CHO (g)	56	6	68	6*
Chromium (μg)	—	—	200	3*
Time to completion (hr:min)	5:25	0.10	5:00	0.15*

*Significant difference ($p < .05$).

Discussion

The triathletes in this study devoted approximately 11 hr/week to training, often with two workouts per day, reflecting a serious commitment to the sport. Their ability to qualify successive years for the Hawaiian Ironman Triathlon further indicates their trained status and desire to maintain a high level of competitiveness. Because dietary intake affects performance, dietary patterns and nutrition issues relating to training, performance, and competition are of interest to triathletes as well as researchers studying such athletes. This study is unique in that the effect of nutrition intervention, including the use of nutritional supplements, in a select group of triathletes was evaluated and related to performance in field conditions.

The triathletes' mean 7-day baseline dietary record analysis showed an energy intake similar to some male and female triathletes (27) but lower than others (11, 20) (Table 6). The number of days of food intake records required to estimate true mean intakes for groups of individuals ranges from 3 to 6 days for energy, protein, and carbohydrate intake, and longer for vitamin and mineral intake (9). We believe our data to be estimates of true average dietary intake due to the primary author's daily contact with the triathletes as well as the lifestyles of the triathletes. They were all adult professionals who reported having limited time to train and eat during the day. Further, it was due to 1 triathlete's illness during training that nutrition intervention was initiated. When he was questioned about his diet prior to becoming ill, he indicated that he consumed only approximately 1,875 kcal/day, with an estimated energy output of 4,250 kcal/day during the previous week. On average, each triathlete needed to increase energy intake by approximately 1,000 kcal. Thus, we were not surprised to see that, although triathletes reported understanding the importance of diet to support performance, they were unable to achieve dietary intakes to meet daily energy requirements.

The triathletes consumed an average of 59% of energy from CHO per day, which is similar to the percentage of kilocalories from CHO consumed by other triathletes (11, 20, 27) but below the recommendations for endurance athletes. Costill (13) advocated a diet with 65–70% of the energy coming from CHO to support endurance performance. For triathletes who require a high daily energy

Table 6 Comparison of Studies of Energy and Macronutrient Intakes of Triathletes

Study	Energy (kcal)	CHO (g/kg)	% Energy CHO	% Energy Protein	% Energy Fat	Recording days
Current						
Baseline	2,318	4.2	59	15	22	7
Intervention	3,992	8.3	65	17	18	7
Burke & Read (11)	4,095	9.1	60	13	27	7
Khoo et al. (20)	3,623	7.2	56	14	30	3
Worme et al. (27)						
Men	2,829	5.1	53	14	30	3
Women	2,216	4.7	52	15	30	3

intake, the recommendation may be more appropriately based on body weight than expressed as a percentage of dietary energy (26). Costill (13) recommended consuming carbohydrate at 9–10 g/kg daily to provide adequate CHO for complete muscle glycogen replenishment within 24 hr after exhaustive exercise. The triathletes consumed an average of 4 ± 2 g/kg/day, an amount similar to the triathletes studied by Worme et al. (27) (4.9 g/kg and 5.1 g/kg for women and men, respectively) but much less than the triathletes studied by Burke and Read (11) (9.1 g/kg) and Khoo et al. (20) (7.2 g/kg), who reported consuming higher daily energy intakes. Studies by Costill (13) and Costill and Miller (14) and others (10, 23) showed that when a low-CHO diet is consumed during successive strenuous daily exercise periods, there is a progressive decrease in muscle glycogen and diminished endurance.

The triathletes' mean protein intake of 1.3 g/kg/day was above the RDA (1) but was considered appropriate for endurance athletes who participate in daily heavy exercise. Tarnopolsky et al. (25) and Lemon et al. (21) recommended that endurance athletes consume between 1.2 and 1.8 g/kg of protein per day to minimize use of protein as a fuel source.

Mean intakes of most vitamins and minerals were above the RDA through food consumption alone. This finding is consistent with other reports on triathletes (11, 20, 27). Triathletes' mean dietary intakes of zinc and chromium, however, were below 33% of the RDA and ESADDI, respectively. Worme et al. (27) also reported a low dietary zinc intake in triathletes who were consuming insufficient kilocalories. Triathletes' intake of dietary chromium has not been reported (11, 20, 22, 27).

The primary purpose of the nutrition intervention program was to increase triathletes' daily energy and CHO intakes in a manner that would be compatible with their work and training schedules. Additionally, due to suboptimal dietary intakes of zinc and chromium, and the utilization of these minerals during exercise, we focused on improving the dietary status of these minerals through food and nutritional supplementation.

The nutrition intervention was successful in increasing triathletes' daily energy and CHO intakes without increasing body weight or body fat composition. Unlike other triathletes who report eating and drinking frequently throughout the day (11, 22), the triathletes studied here reported eating only three times a day and having a snack before and after their heaviest training session in the late afternoon. Thus, instead of adding additional eating events throughout the day, we sought to improve the quantity and quality of the triathletes' diets using their current eating schedules. Dietary modification involved increasing CHO intake through increased servings of breads/cereals, fruits, vegetables, and dairy products. The Diabetic Food Exchange System was useful in helping athletes track the number of servings from the food groups they were to consume during mealtime.

In addition to improving the quality of meals, the triathletes needed to significantly increase energy and CHO content of the pre- and posttraining snacks by approximately 1,000 kcal. The additional kilocalories were divided between the two snacks to support training performance without causing discomfort, to facilitate glycogen replenishment following training, and to allow sufficient kilocalories to be consumed at supper to meet total daily energy needs.

To comfortably derive energy from primarily CHO 2 hr before and immediately following training, the triathletes consumed easily digestible CHO (juice, fruit, bagels) and nutritional supplements including Innergize and Ultra Bars (Reliv, Inc., Chesterfield, MO). While other commercial sports drinks and energy bars would have adequately met triathletes' energy and carbohydrate needs, the Reliv, Inc., products were selected because of their fortification with chromium and zinc.

Evidence suggests that endurance activity negatively influences chromium status. Anderson et al. (7) observed that mean urinary chromium concentration increased fivefold 2 hr after endurance exercise. They further reported that 24-hr urinary excretion of chromium was significantly higher on an exercise versus a nonexercise day. Anderson et al. (5) also observed that while basal urinary chromium excretion and excretion of chromium following exercise were less in aerobically trained males compared to untrained males, following sessions of exercise at 90% VO_2max, changes in chromium levels were significant for trained but not untrained subjects. Urinary chromium losses following strenuous exercise may be enhanced due to the complexing of chromium with lactate, which is increased during strenuous exercise (2, 12). Additionally, chromium losses increase in response to an increase in plasma cortisol that is known to occur during strenuous exercise (3).

The triathletes' initial low chromium intake is similar to the average intake reported for the general population: one half of the minimum suggested (4). Dietary chromium intake was increased following nutrition intervention. However, the mean intake was still toward the minimum end of the ESADDI. With use of the Reliv, Inc., products, subjects exceeded the upper level of the ESADDI. Chromium status, including measures of glucose tolerance and insulin sensitivity (6), was not determined. It is unknown as to whether chromium, independent of additional energy and CHO intake, enhanced training performance or affected rate of glycogen resynthesis following training.

The triathletes' initially low dietary zinc intake was probably due in part to the triathletes' low energy intake as well as to the limited intake of animal products (15). Due to the significant increase in energy intake, triathletes were able to exceed two-thirds the RDA for zinc for men and women, respectively. With the use of the Reliv, Inc., products, mean zinc intake was approximately 300% of the RDA. Triathletes were cautioned that bioavailability of zinc from nutritional supplements fortified with zinc may not be the same as from consumption of oysters, beef, and dark meat from turkey and chicken. Iron intake also affects zinc bioavailability. Ratios on nonheme iron to zinc of 2:1 and 3:1 have been shown to inhibit zinc absorption. Thus, supplemental nonheme may also contribute to a suboptimal zinc status (24). None of the athletes studied reported consuming iron supplements. Zinc nutriture will continue to be an issue of concern for endurance athletes due to the effect of exercise-stimulated zinc losses and suboptimal dietary intake on body functions including decreased immune response, anorexia, and slow wound healing (24). Additionally, excesses of zinc are deleterious. High zinc intakes impair copper retention and decrease superoxide dismutase activity, an indicator of impaired copper status (24). An association between high levels of zinc and lower levels of high density lipoprotein cholesterol has also been reported (18).

The triathletes showed an improvement in competitive performance during T2 compared to T1, despite the increase in race day temperature (T1 = 82 °F, T2 = 92 °F). The triathletes all indicated they felt stronger during T2 versus T1, despite the heat. It is speculated that the triathletes' increased energy, macronutrient, and micronutrient intakes during daily training prevented the progressive decrease in muscle glycogen that occurs in response to successive strenuous daily exercise periods. Additionally, triathletes maintained their high-energy, high-CHO intake during the tapering phase prior to competition. This may have served as a type of glycogen overloading regimen (13). Thus, due to improved dietary intake during training, the triathletes may have been in a position to maintain a higher intensity of exercise for a longer time during T2 versus T1, thereby improving race time (13).

In addition to improving their dietary intake during training, subjects consumed Innergize instead of Gatorade, in equal volume amounts, during T2, so we could evaluate the palatability of Innergize as a competition beverage. Since subjects consumed equal amounts of Gatorade and Innergize during T1 and T2, absolute amounts of carbohydrate and chromium consumed did not vary. Thus, the extent to which chromium alone influenced performance time cannot be statistically discerned.

This study shows that improved dietary intake, consonant with current recommendations to support endurance training, improved triathletes' performance. Further study directed at evaluating the role of chromium in influencing training and competition performance is warranted.

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