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Case Study

Case study: long-term low carbohydrate, high fat diet impairs performance and subjective wellbeing in a world-class vegetarian long-distance triathlete

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ABSTRACT

The aim of this case study was to report on the performance outcomes and subjective assessments of long-term low carbohydrate, high fat (LCHF) diet in a world-class long-distance triathlete who had been suffering from GI distress in Ironman competition. The lacto-ovo vegetarian athlete (age 39 y; height 179 cm; usual racing body mass 75 kg, sum of 7 skinfolds 36 mm) changed his usual high CHO availability (HCHO) diet to a LCHF diet for 32 weeks (~95% compliance). He participated in 3 professional races while on the LCHF diet, but acutely restored CHO availability by consuming CHO in the pre-event meals and during the race as advised. The athlete had his worst ever half-Ironman performance after 21 wk on the LCHF diet (18th). After 24 wk on LCHF, he had his second worst ever Ironman performance (14th), and suffered his usual GI symptoms. He did not finish his third race after 32 wk on LCHF. He regained his usual performance level within 5 wk back on a HCHO, finishing 2nd and 4th in two Ironman events separated by just 3 wk. Subjective psychological wellbeing was very negative while on the LCHF diet, with feelings of depression, irritability and bad mood. In conclusion, this long-term (32 wk) LCHF intervention did not solve the GI problems that the athlete had been experiencing, it was associated with negative performance outcomes in both half-Ironman and Ironman competition, and it had a negative impact on the athlete's subjective wellbeing.

Key words: ketogenic diet, ultra-endurance, gastrointestinal distress

INTRODUCTION

Elite male professional triathletes complete half-Ironman (1.9 km swim, 90 km cycle, 21.1 km run) and Ironman (3.8 km, 180 km, 42.2 km) events in ~3 h 45 min and ~8 h, respectively. The long durations and relatively high intensities of races [83 ± 4 % and 77 ± 5 % of peak heart rate during the cycle and run, respectively (Laursen et al., 2005)] represent significant physiological challenges, particularly in terms of energy expenditure and provision. Indeed, half-Ironman and Ironman energy expenditures for well-trained male athletes are approximately 17.5 (Gillum et al., 2006) and 37.2-42.0 MJ (Kimber et al., 2002; Cuddy et al., 2010), respectively. In terms of energy provision, there is a major reliance on oxidation of both endogenous glycogen and exogenous carbohydrate (CHO) (Kimber et al., 2002; Cuddy et al., 2010), particularly in the half-Ironman distance (Gillum et al., 2006). Moreover, high CHO intake rates correlate with faster Ironman finishing times (Pfeiffer et al., 2012). However, muscle and liver glycogen stores are limited, and exogenous CHO ingestion may not be sufficient to match energy requirements. Furthermore, high rates of CHO intake may induce gastrointestinal (GI) distress during long-distance races (Jeukendrup, 2015; Pfeiffer et al., 2012).

Given these potential limitations, it has been suggested that strategies that enhance fat oxidation could be beneficial for performance in ultra-endurance events (Volek et al., 2015, Maffetone & Laursen 2017). It has been reported that fat oxidation contributed ~35% to the total energy expenditure during an Ironman event (Cuddy et al., 2010) and maximal fat oxidation rate has been associated with faster Ironman performance (Frandsen et al., 2017). Although trained endurance athletes exhibit an enhanced capacity for fat mobilization, transport and oxidation, it can be further upregulated by short-term (~5 d) exposure to a low CHO, high fat diet (LCHF, <20% energy from CHO, >60% energy from fat), even after acute restauration of high CHO availability inducing glycogen super-compensation and CHO intake during exercise. Such strategies, however, failed to enhance ultra-endurance performance in well-trained athletes (Carey et al., 2001). A longer (3 wk) LCHF diet markedly increased whole-body fat oxidation rates in elite race walkers, but it impaired exercise economy and negated the performance benefit of intensified training (Burke et al. 2017). On the other hand, adaptation to a LCHF diet over several months was reported to alleviate GI distress and benefit Ironman performance in a professional female triathlete (Maffetone & Laursen 2017).

The aim of this case study was to report on the performance outcomes and subjective assessments of long-term (32 weeks) LCHF diet in a world-class, lacto-ovo vegetarian long-distance triathlete who had been suffering from GI problems in Ironman competition (e.g. malabsorption of exogenous CHO, bloating).

METHODS

Athlete

The featured athlete (age 39 y; height 179 cm; usual racing body mass 75 kg, sum of 7 skinfolds 36 mm) started his triathlon career at the age of 16 y. He raced Olympic distance triathlon (~2 h) between 1992 and 2004, competing in Sydney 2000 (23rd place) and Athens 2004 (20th place), and winning silver at the European Championships in 2004. He was X-terra triathlon (i.e. cross-country triathlon) World champion in 2003, 2004 and 2009. Between 2005 and 2016 he completed 28 professional Ironman (average placing 5th; 6 victories; 11 top-3, and 7 top-8 placings) and 36 half-Ironman (average placing 2nd; 26 victories; 5 top-3, and 5 top-8 placings) distance races. The triathlete gave written informed consent for publication of the data reported here.

Dietary intervention

For 23 y the athlete had been following a lacto-ovo vegetarian diet, with an emphasis on high CHO availability (HCHO) both in training and competition. Over the three seasons prior to the LCHF dietary intervention, the athlete often suffered from severe GI distress (e.g. exogenous CHO and fluid malabsorption, stomach bloating and cramping, side-stitch) in Ironman competition, but not in training nor in half-Ironman racing, and most often after 10-15 km into the 42.2 km run. After trying several unsuccessful dietary interventions prior to and during Ironman racing to minimize GI side-effects (e.g. increasing CHO and fluid ingestion in training, manipulating the amount and composition of CHO and fluid ingested during the cycle and run legs of the event), the athlete decided to try a long-term LCHF adaptation, while maintaining his vegetarian eating pattern. This nutritional intervention, which was done under the guidance and supervision of a sports physiologist with extensive prior experience in LCHF interventions with elite ultra-endurance athletes, was started mid-October 2016 and strictly maintained for 32 weeks until the end of May 2017. Breath ketone (acetone) levels were repeatedly measured and recorded by the athlete throughout the LCHF dietary intervention period (Ketonix AB, Varberg, Sweden). For races, the athlete was advised to acutely restore CHO availability by consuming CHO in the pre-event meals (125, 150, 175 g of CHO per day in the three days prior to half-Ironman racing; 200, 250 g of CHO per day in the two days prior to Ironman racing) and during the race (60 g of CHO per hour, largely in the form of slow release high-molecular-weight hydrothermally modified waxy maize starch, Ucan Superstarch, Generation Ucan, Woodbridge, CT, U.S.A., and Gu Energy gels, Berkeley, CA, U.S.A.). The same strategy was used in training prior to some high intensity and race simulation sessions. The athlete estimated his compliance with the prescribed diet at ~95%. See Table 1 for summary of typical energy, macronutrient and micronutrient intake on the HCHO and LCHF diets, based on the acceptably valid and reliable 7-day weighed food record method (Braakhuis et al. 2003, Burke 2015, Capling et al. 2017) and analyzed by registered dietitians.

Training and competition

The athlete's training volumes, relative dedication to swimming, cycling, running and strength training, and training intensity distributions were similar when he followed HCHO and LCHF diets (Table 2). He took part in three professional races in 2017 during the LCHF dietary intervention: half-Ironman Buenos Aires (March 12, after 21 wk on LCHF); Ironman South Africa (April 2; 24 wk on LCHF), and Ironman Brazil (May 27th; 32 wk on LCHF).

RESULTS

Competition performance and gastrointestinal symptoms

His performance was well below his usual level in all three events on the LCHF diet: 18th in Buenos Aires (his worst ever result in a half-Ironman event); 14th in South Africa (his second worst ever result in an Ironman event, after a 27th place at Ironman Hawaii the previous year, suffering from severe stomach cramps); and DNF in Brazil (he withdrew from the race after approximately 100 km on the bike). After Ironman South Africa, the athlete reported the same GI problems he had been suffering from in previous Ironman events. The athlete's micronutrient intake was similar on the HCHO and LCHF diets (Table 1), and hematological and biochemical values did not show any differences of clinical significance (Table 3).

Following these unsuccessful performances, the athlete decided to get back to his usual lacto-ovo vegetarian HCHO diet, while continuing his usual training routines. His next two professional races were Ironman Austria (July 1st; 5 wk off LCHF) and Ironman France (July 23rd; 8 wk off LCHF), in which he finished 2nd and 4th, respectively. Full performances and athlete assessments can be found in Table 4.

Subjective wellbeing

The athlete reported that the months on the LCHF diet were mentally very tough: he had many psychic slumps and feelings of depression sometimes. He considered that the LCHF intervention affected him negatively in his personal relationships, he felt irritable, was often in a bad mood and overall considered the LCHF intervention a very uncomfortable experience for his everyday life (personal communication).

DISCUSSION

To the best of the author's knowledge, this is the first peer-reviewed case report on the performance consequences of a long-term (32 weeks) LCHF diet on a world-class lacto-ovo vegetarian ultra-endurance athlete. In contrast with the cessation of GI symptoms, marked improvement in a variety of health functions and positive performance outcomes previously reported (Maffetone and Laursen 2017), and also in contrast with the athlete's own expectations, this long-term LCHF intervention did not solve the GI problems he had been experiencing, it was associated with negative performance outcomes in both half-Ironman and Ironman competition, and it had a negative impact on the athlete's subjective wellbeing. Indeed, the athlete had publicly expressed his hopes that LCHF could solve the GI problems he had been experiencing and contribute to his competition performance. Though a positive placebo effect from the LCHF could have been expected, the negative performance outcomes were in keeping with previous findings on elite race walkers who followed a 3-wk LCHF diet, in which capacity for higher intensity performance was impaired (Burke et al., 2017).

The athlete's mean daily macronutrient intakes per kg of body mass prior to and during LCHF training were similar to those recently prescribed by Burke et al. (2017) to elite race walkers for high CHO availability or LCHF, respectively. Short-duration (5 d to 3 wk) LCHF dietary interventions have been shown to upregulate whole-body fat oxidation in well-trained and elite endurance athletes, and although actual measurements were not performed, such a metabolic effect probably took place in the present case, as suggested by his constantly elevated breath acetone levels. In view of the growing contribution of fat metabolism to overall power production associated with event duration, a positive contribution of LCHF could have been expected in half-Ironman and most especially in Ironman competition. Moderately trained endurance athletes were shown to increase their fat oxidation in a 100-km cycling time trial after 12 weeks of keto-adaptation and exercise training (McSwiney et al. 2018), and a previous study reported an association between individual rates of maximal fat oxidation and Ironman racing performance (Frandsen et al., 2017), but the association was rather week ($r^2 = 0.12$) and the athletes involved were on average 2 h 45 min slower than the athlete in this case report. Furthermore, the relationship between individual maximal rates of CHO oxidation and performance was not reported, and it is possible that they were also related to performance with a reverse causation explanation: faster performance times require higher rates of overall energy production. In the case of the presently studied athlete, it is likely that the higher relative racing intensity increased even further the well-known reliance on CHO for power production in both half-Ironman (Gillum et al.,2006) and Ironman competition (Kimber et al., 2002; Cuddy et al., 2010).

It is interesting to note that the apparently unsuccessful race nutrition strategy incorporated acute restoration of CHO availability (pre-race CHO intake and exogenous CHO intake during racing at 60 g/h). Such fat adaptation-CHO restoration protocols are known to induce remarkable reductions in muscle glycogen use during exercise even when it is available (Burke, 2015). While this phenomenon was first considered to be evidence of favorable CHO "sparing", later work showed it to reflect an impairment of CHO oxidation pathways, via a reduction in glycogenolysis and downregulation of the activity of the pyruvate dehydrogenase complex (Stellingwerff et al., 2006). Importantly, this impairment was shown to reduce the performance of higher intensity segments of an ultra-endurance cycling protocol, which is consistent with the anecdotes from the present athlete of a loss of ability to work at a faster race pace (see Table 3). In this respect, it is worth noting that the CHO restoration protocol prescribed for the athlete represented only 1.7 to 2.3 g of CHO per kg of body mass over three days prior to half-Ironman racing, and 2.6 to 3.3 g of CHO per kg of body mass over two days prior to half-Ironman racing. Although the ingestion of a low-glycemic slow release high-molecular-weight hydrothermally modified waxy maize starch before cycling exercise can blunt the spike in serum glucose and insulin, and increase fat breakdown (Roberts et al. 2011), its ingestion during exercise can increase GI distress and be a major mechanistic determinant of performance impairment (Baur et al. 2016). Prior to the athlete's third race on LCHF (Ironman Brazil), he was advised not to perform a CHO restoration protocol. As indicated in the results section, the athlete did not finish the race and felt extremely weak from the beginning of the race (personal communication). Such negative performance outcomes did not seem to be related with an altered health status of the athlete, as his hematological and biochemical values were similar on his usual HCHO diet and on the LCHF diet, and also similar to values previously reported for this athlete 5-8 days after finishing first or second in six Ironman events over 4 years (Mujika et al. 2017).

In addition to his failure to enhance competition performance, the athlete reported that the LCHF intervention was associated with higher heart rate values at rest (~48-50 vs. ~40 bpm) and at submaximal training intensities (~7-8 bpm higher). In addition, the athlete's body mass dropped down to 71.6 kg within two weeks on the LCHF diet, then progressively increased to his usual training mass of ~76 kg over the following 7 weeks, to remain stable thereafter. Weeks after the LCHF dietary intervention and the two Ironman races back on his usual high CHO diet, the athlete still felt the need to compensate for the consequences of training on the LCHF diet by doing more lactate threshold intensity and strength training, as he felt he had lost strength and power (personal communication).

An obvious limitation of the present report is that the evaluation of the LCHF intervention relies mostly on competition outcomes and the athlete's subjective assessments, and the potential impact of other factors which could affect competition performance cannot be assessed from the available data. While there is no denying this limitation, it is worth indicating that this particular athlete has been the subject of a prior case report highlighting his remarkable competitive versatility, consistency and longevity (Mujika & Pyne, 2014), that no significant changes took place in his athletic of personal life during the follow-up period other than the LCHF intervention, and that his educated assessments on sports nutrition and training interventions have often served to guide his nutrition and training programs over the years. A previous case study on long-term LCHF diet in a non-vegetarian professional female triathlete reported beneficial health and performance outcomes (Maffetone & Laursen 2017), and the fact that the present athlete followed a lacto-ovo vegetarian diet was not considered a limitation when he was advised to undertake a LCHF diet. It has been reported that a well-formulated omnivorous LCHF diet can provide sufficient intake of all of the recommended micronutrients (Zinn et al. 2018), and no micronutrient deficit was observed in the present case while on the lacto-ovo vegetarian LCHF diet. Whether his vegetarianism, his age and/or being accustomed to a HCHO diet over his entire triathlon career affected to some degree the potential effects of LCHF on his ultra-endurance performance and subjective wellbeing remains to be elucidated.

In conclusion, a 32-week LCHF dietary intervention did not solve the GI problems that the athlete had been experiencing, it was associated with negative performance outcomes in both half-Ironman and Ironman competition, and it had a negative impact on the athlete's subjective wellbeing. Until carefully controlled trials investigating the effects of LCHF on the performance of elite endurance and ultra-endurance athletes become available, the careful testimonials of athletes such as the world class triathlete currently described can add to our knowledge of such dietary strategies

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Table 1. Typical weekly dietary intake of the elite triathlete in the general preparation phase, on his usual diet providing high carbohydrate availability (HCHO), and during the low carbohydrate, high fat (LCHF) dietary intervention. Based on 7-day weighed food records and analyzed by registered dietitians.

Nutrient	**HCOH**	**LCHF**
Energy (MJ)	16.59 ± 2.40	16.67 ± 1.56
Protein (g)	138 ± 25	153 ± 28
(%TE)	14 ± 2	15 ± 2
Carbohydrate (g)	638 ± 56	52 ± 9
(%TE)	65 ± 8	5 ± 1
Fat (g)	98 ± 42	354 ± 37
(%TE)	21 ± 7	79 ± 2
Saturated Fat (g)	14 ± 8	123 ± 14
Monounsaturated Fat (g)	29 ± 12	141 ± 17
Polyunsaturated Fat (g)	9 ± 3	59 ± 8
Cholesterol (mg)	178 ± 240	995 ± 264
Fiber (g)	84 ± 34	39 ± 8
Calcium (mg)	1782 ± 357	1670 ± 535
Iron (mg)	34 ± 6	26 ± 5
Magnesium (mg)	812 ± 210	896 ± 165
Zinc (mg)	13 ± 5	20 ± 4
Sodium (mg)	1095 ± 372	3484 ± 849
Potassium (mg)	5537 ± 1478	4121 ± 460
Phosphorus (mg)	1510 ± 425	2703 ± 486
Iodine (μg)	139 ± 37	343 ± 109
Thiamin (mg)	3.6 ± 0.6	1.8 ± 0.4
Riboflavin (mg)	4.5 ± 1.0	4.6 ± 1.6
Niacin (mg)	43 ± 7	44 ± 10
Vitamin C (mg)	520 ± 136	49 ± 26
Vitamin A (μg)	1008 ± 643	1516 ± 547
Vitamin D (μg)	4.5 ± 2.7	7.6 ± 2.3
Vitamin E (mg)	18 ± 11	31 ± 6
Vitamin B_6 (mg)	5.4 ± 0.7	4.1 ± 1.5
Vitamin B_{12} (μg)	4.5 ± 2.4	8.0 ± 2.5
Folic Acid (μg)	862 ± 257	433 ± 65

Table 2. Typical training program of the elite triathlete in the 7 weeks prior to an Ironman race while on his usual diet providing high carbohydrate availability (HCHO); during the low carbohydrate, high fat (LCHF) dietary intervention; and in the 4 weeks back on HCHO after LCHF.

Diet	Weekly Training (h/wk)	Swim		Cycle		Run		Strength	
		Time (h)	%	Time (h)	%	Time (h)	%	Time (h)	%
HCHO (7 wk)	17.6	26.5	21.5	62.3	50.5	27.0	21.9	7.5	6.1
LCHF (7 wk)	16.1	20.3	18.0	61.0	54.2	27.7	24.6	3.5	3.1
HCHO (4 wk)	16.6	11.3	17.0	38.6	58.1	16.5	24.8	0	0

Table 3. Selected hematological and biochemical parameters of the elite triathlete while on his usual diet (February 2016) providing high carbohydrate availability (HCHO), and after 29 weeks (May 2017) on the low carbohydrate, high fat (LCHF) diet.

	HCOH	**LCHF**
Erythrocytes (10^{12}/L)	5.49	5.66
Hemoglobin (g/dL)	15.8	16.2
Hematocrit (%)	46.4	49.0
Mean Corpuscular Volume (fL)	84.5	86.6
Mean Corpuscular Hemoglobin (pg)	28.8	28.6
Mean Corpuscular Hemoglobin Concentration (g/dL)	34.1	33.1
Red Cell Distribution Width (%)	12.8	13.2
Leukocytes (10^{9}/L)	4.85	5.74
Platelets (10^{9}/L)	199	214
Serum Iron (µg/dL)	89	48
Transferrin (mg/dL)	225	218
Saturation Index (%)	32.16	17.9
Ferritin (ng/mL)	29	41
Glucose (mg/dL)	88	91
Urea (mg/dL)	30	39
Creatinine (mg/dL)	0.89	0.86
Uric Acid (mg/dL)	4.50	4.50
Cholesterol (mg/dL)	149	194
Triglycerides (mg/dL)	45	99
High-Density Lipoprotein Cholesterol (mg/dL)	76.1	70.2
Low-Density Lipoprotein Cholesterol (mg/dL)	64	104
Total Protein (g/dL)	7.17	7.24
Aspartate Aminotransferase (IU/L)	37	36
Alanine Aminotransferase (IU/L)	29	28
Lactate dehydrogenase (IU/L)	463	435
CK (IU/L)	342	211
Cortisol (ng/mL)	134.5	171.7
Total Testosterone (ng/mL)	5.53	6.14

Table 4. Professional competition performances and subjective assessment of the elite triathlete during the low carbohydrate, high fat (LCHF) dietary intervention, and in the 8 weeks back on his usual diet providing high carbohydrate availability (HCHO) after LCHF. Athlete's subjective assessments are based on his comments on social media and personal communication with the author. W: average power output.

Diet	Competition	Placing	Nutrition	Total (h:min:s)	Swim (h:min:s) (s/100 m)	T1 (h:min:s)	Cycle (h:min:s) (km/h) (W)	T2 (h:min:s)	Run (h:min:s) (min/km)	Athlete's subjective assessment
LCHF	Half-Ironman Buenos Aires (March 12, 2017)	18	Pre-race CHO loading Race 70-80 g CHO/h	3:59:02	0:25:36 79	0:01:44	2:12:31 40.8 286	0:01:51	1:17:20 3:40	Finisher and happy with that, given that I thought about quitting the race many times. There was no "juice" in my legs today, at least not enough to be up front. Very stuck in slow rhythm, beyond which I struggle to go lately. Bad body sensations. Riding at that power output should have been easy but I struggled all day. I could not push in the run either. I want to think that although it was a negative outcome today it may be good to face Ironman South Africa in three weeks, and that the "Ironman pace" that I have learnt will be useful in the longer distances.
LCHF	Ironman South Africa (April 2, 2017)	14	Pre-race CHO loading Race 70-80 g CHO/h	8:34:15	0:49:19 76	0:02:16	4:28:31 40.3 262	0:02:25	3:11:44 4:32	Another struggle to finish. 14th in the end. I felt fairly well on the bike, but not comfortable and I felt I was missing "a gear". Few points for Kona ranking, and the worst part is that I still could not run a proper marathon. It looks like there is a wall against which I keep hitting head-on, but I have a big and hard head and I will tear that wall down.
LCHF	Ironman Brazil (May 27, 2017)	DNF	No CHO loading Race 70-80 g CHO/h		0:47:40 74	03:04				I will not add another finished Ironman to my record; neither my body nor my mind were strong today. I could not even lift my arms in the swim. A forgettable start to season.
HCHO	Ironman Austria (July 1, 2017)	2	Pre-race CHO loading Race 70-80 g CHO/h	8:12:43	0:50:37 78	0:03:14	4:28:48 40.2 270	0:02:02	2:47:52 3:58	I stopped LCHF after Brazil. I went back to Carbohydrates, trying different things. It worked quite well today, but not 100%.
HCHO	Ironman France (July 23, 2017)	4	Pre-race CHO loading Race 70-80 g CHO/h	8:40:54	0:50:44 78	0:02:47	4:48:00 37.6 254	0:03:03	2:56:20 4:10	What a day of torture; it all looked good when I reached second place in the marathon, but that was the end of it. After the half marathon it was pure survival to reach the finish line. I felt "decent", but quite tired after Austria just 3 weeks ago.