Bioenergetics: Open Access

ISSN: 2167-7662

Kreider, et al., Bioenergetics 2014, 3:3
DOI: 10.4172/2167-7662.1000119

Research Article Open Access

Effects of an Ultra-Endurance Event on Body Composition, Exercise Performance and Markers of Clinical Health: A Case Study

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Received date: June 16, 2014; **Accepted date:** September 08, 2014; **Published date:** September 15, 2014

Abstract

Objective of the study: The purpose of this case study was to observe the effects of a self-supported ultra-endurance mountain cycling event on body composition, lower and upper body muscular endurance, anaerobic capacity, aerobic capacity and markers of clinical health.

Materials and methods: A trained endurance cyclist competed in the self-supported ultra-endurance event known as the Tour Divide mountain bike race. The subject cycled the course route twice totaling approximately 8,835 total kilometers over the course of 44 days. Body composition, physical performance, and markers of clinical health were collected pre-race and up to 3-wk post-race.

Results: Average total energy intake increased by 1,541 kcals during the race compared to pre-race food consumption. We observed an increase in carbohydrate (113%) and fat (12.85%) intake with a marked decrease in protein consumption (-28%). The subject lost a total of 8.4 kg over the course of the 44-d trek and remained 11.0 kg below pre-race body mass 3-wk post-race. The subject lost fat (7.2 kg) and fat-free mass (1.9 kg.) over the race period, resulting in a 6.4% decrease in body fat. The subject experienced a decrease in absolute VO_2 peak, mean power, and peak power measured by a Wingate Anaerobic Capacity Test 96-hrs post-race. Upper and lower body muscular strength endurance performance decreased 96-hrs post-race -15-20 and -20%, respectively. Parameters of liver function, AST and ALT, were elevated immediately post-race (92 and 95%, respectively) and remained 46 and 58% above normative values 96-hrs post-race. Creatine kinase concentration also significantly increased 210% immediately following the race and remained elevated 24 (30%), 48 (46%) and 72-hrs (20%) post-race.

Conclusions: We conclude that completing a 44-d extreme ultra-endurance mountain biking race results in a decrease in fat and fat free mass. Additionally, prolonged ultra-endurance performance facilitates decreases in aerobic capacity, anaerobic power, muscular strength endurance as well as increases in markers of muscle damage.

Keywords: Ultra endurance; Body composition; Energy balance; energy intake; aerobic capacity; anaerobic power; cycling; mountain biking; Tour Divide

Introduction

As ultra-endurance events become increasingly popular, endurance athletes are determined to push the limits of human performance by competing in these ultra-endurance events. Typically, these events are defined as endurance competitions lasting longer than 6 hours [1,2]. Furthermore, several competitions consist of consecutive days or weeks of ultra-endurance distances as compared to single day events. For example, The Tour Divide race is a 4,418 kilometers bike race interspersed with climbs in elevation totaling approximately 60,960 meters following the U.S. and Canadian Continental Divide throughout Midwestern North America. Riders race for 16 or more hours per day through the Continental Divide with no external support. Typically, riders average ~161 kilometers per day and require approximately 22 days completing the race. Ultra-endurance events consist of varying distances and racing conditions, creating uncertainty on how to best prepare for such a competition. By better understanding the physiological demands of an event of this nature, athletes can better prepare themselves through proper training and nutritional practices.

Previous case reports have examined the effects of similar race events on energy balance and body composition but to the best of our knowledge no research has been conducted on the physiological effects of a race this long in duration [2-4]. Similar studies have reported substantial decreases in body mass, fat mass, fat-free mass, aerobic and anaerobic performance as well as an increase in markers of muscle damage following an ultra-endurance event [2, 5-10]. These changes are likely due to the high energy demands of extended performance leading to state of negative energy balance [3,4,11].

Objective of the Study

The objective of the study was to observe the effects of completing The Tour Divide race course twice on body composition, lower and upper body muscular endurance, anaerobic capacity, aerobic capacity and markers of clinical health. The subject rode from the finish line to the starting line of the event as part of an individual time-trial and then participated in the actual Tour Divide Race, ultimately completing the race course twice.

Materials and Methods

Experimental Design

Our single case study subject rode a mountain bike in the spring of 2013 from the finish line (Antelope Wells, NM, USA) to the starting line (Banff, Alberta, CA) and then participated in the actual Tour Divide race, which starts in Banff, CA and ends in Antelope Wells, USA. The subject completed baseline and post-race testing over the course of three separate days, one week prior and one week after the race, respectively. Baseline and post-race testing consisted of body composition, aerobic and anaerobic capacities, strength, and resting energy expenditure (REE). Resting heart rate, blood pressure and a blood chemistry panel were also assessed during this time. Additional aerobic and anaerobic capacity testing was conducted three weeks post-race when the subject was able to return to the lab. During the race, the subject biked approximately 8,835 total kilometers interspersed with climbs totaling nearly 121,920 meters over the course of 44 days. During the race the subject recorded daily mileage and food consumption.

Subject

An apparently healthy, endurance trained male participated in this study (34 yrs., 193 cm, 94.3 kg, 20.5% body fat, 46.3 ml/kg/min VO_2 peak, 240 km/week of training, ± 2 yrs. ultra-endurance training/ competition experience). The subject was informed of the requirements of the study and signed an informed consent statement in compliance with the Human Subjects Guidelines of Texas A&M University and the American College of Sports Medicine.

Testing Sessions

All exercise and body composition testing was completed in the Exercise and Sport Nutrition Lab and Applied Exercise Science Lab at Texas A&M University. The subject fasted for 8 hours and refrained from exercise for a 48 hr. period prior to testing. The subject recorded all food consumed for a 4-day period prior to testing. During the race, the subject also recorded food consumption. Upon arrival to the lab, a fasted venous blood sample, resting heart rate and blood pressure, height, body mass, and Resting Energy Expenditure (REE) were obtained. Total body water and body composition was assessed using a bioelectrical impedance analyzer (BIA) and a dual-energy x-ray absorptiometer (DEXA), respectively. On a separate day, the subject then completed a Wingate Anaerobic Capacity test on a cycle ergometer followed by a VO_2 peak test on the same cycle ergometer. On a third testing day, the subject completed two submaximal upper body tests, one employing a maximal pull-up protocol and the other implementing a submaximal bench press protocol. Lower body submaximal strength testing was performed on a leg press / hip sled machine. Following testing, the subject then completed the ultra-endurance event and returned to the lab for post-race testing. Throughout the race, environmental conditions were assessed using the Farmer's Almanac Weather History and the subject's mileage was recorded via the Tour Divide's website.

Dietary Analysis

Prior to the race, the subject completed a 4-day dietary food record which included 3 weekdays and 1 weekend day. During the race, the subject recorded food consumption by taking pictures of food items with a camera-phone. The subject also provided receipts of food purchased throughout the course of the race. Upon completion of the race, pictures and receipts were transcribed and analyzed for average energy and macronutrient intake using ESHA Food Processor (Version 9.1.0) Nutritional Analysis software (*ESHA Research Inc., Salem, OR*).

Resting Energy Expenditure, Heart Rate, and Blood Pressure

Resting Energy Expenditure (REE) was assessed using a Parvo Medics TrueMax 2400 Metabolic Measurement System (*ParvoMedics, Inc., Sandy, UT*). This test was a non-exertional test performed in a fasted state with the subject lying supine on an exam table while the subject remained motionless without falling asleep for approximately 20 minutes. Analysis was completed during the last five minutes of the 20 minute test. Previous studies from our lab have yielded test-retest correlations in the range of r = 0.315-0.901 (with a coefficient of variation ranging from 8.2%-12.0% [12]. Resting heart rate was determined by palpitation of the radial artery and blood pressure was assessed by auscultation of the brachial artery using a mercurial sphygmomanometer.

Blood Analysis

Upon arrival to the laboratory, the subject donated approximately 10 ml of blood at each sampling session (5 total samples: pre-race, 2h post-race, 24h post-race, 48h post-race, and 72h post-race) from the antecubital vein in the forearm using a 21-gauge needle, while the subject was in the seated position. A venous sample was collected in two serum separating tubes (*BD Vacutainer, Franklin Lakes, NJ*) and one EDTA tube (*BD Vacutainer, Franklin Lakes, NJ*) for whole blood analysis. The venous samples in the serum separating tubes sat at room temperature for 15 minutes before being centrifuged at 3,000 rpm for 15 minutes. The EDTA tube was stored at 4˚C until it was analyzed. Serum samples were then sent to Quest Diagnostics (Houston, TX) for a comprehensive metabolic and inflammatory panel and whole blood samples were analyzed using an Abbott Cell Dyn 1800 (Abbott Laboratories, Abbott Park, IL). Whole blood samples were analyzed for complete blood counts and platelet differentials.

Body Composition

Body composition (excluding cranium) was assessed using a Hologic Discovery W dual-energy X-ray absorptiometer (DEXA) (*Holigic Inc., Waltham, MA*) before and 48-hours after the ultra-endurance race. Height and body mass were recorded using a self-calibrating digital scale (*Cardinal Detecto Scale Model 8430, Webb City, Missouri*). Total body water and body composition was assessed using an ImpediMed DF50 bioelectrical impedance analyzer (*Impedimed, San Diego, CA*) before, 2-hours, 48-hours and 72 hours post. Bioelectrical impedance was used to assess immediate changes in body composition after the race as the finish line was a substantial

Citation: Jagim A, Levers K, Galvan E, Joubert D, Rasmussen C, et al. (2014) Effects of an Ultra-Endurance Event on Body Composition, Exercise Performance and Markers of Clinical Health: A Case Study. Bioenergetics 3: 119. doi:10.4172/2167-7662.1000119

distance from the laboratory and therefore DEXA analysis could not be completed.

Performance Tests

The subject spent several minutes adjusting the seat and handlebar height for optimal performance while pedaling at a self-selected cadence at 50 W. Following the warmup a Wingate Anaerobic Capacity test was then performed on a Lode Excalibur Sport 925900 cycle ergometer (*Lode BV, Groningen, The Netherlands*) at a work rate of 10 J/kg/rev to assess anaerobic capacity [13,14]. Twenty five minutes after the Wingate Anaerobic Capacity Test, the subject completed a graded exercise test to determine maximal aerobic capacity on the same cycle ergometer. The subject was outfitted with a Polar FT7 heart rate monitor (*Polar Electro Inc., Lake Success, NY*). Subject began with a 2-minute warm up at 150 W. Power output increased by 50 W every two minutes until the subject failed to maintain the specified cadence of 65 rpm (±3 rpm). This cadence was self-selected by the subject to mimic the riding cadence used throughout the Tour Divide Race. At volitional fatigue, the power output was reduced to 50 W and the subject was allowed to maintain a self-selected cadence for a 5-minute cool down period. Prior to the test, resting supine and upright heart rate, blood pressure, and rate of perceived exertion were determined. Heart rate, blood pressure and rate of perceived exertion were also determined during the last 30-seconds of each stage as well as during the cool down period (1-minute post, 3-minutes post, and 5-minutes post). Aerobic capacity was assessed using a ParvoMedics True One 2400 Metabolic System (*ParvoMedics, Sandy, Utah*). Previous research has indicated a mean intra-class correlation of 0.994 and a mean intra-class coefficient of variation of 4.7% when using the ParvoMedics True One 2400 Metabolic system [15]. Calibration procedures were completed prior to each testing session. On a different day, the subject completed a maximal neutral grip pull-up test and a standard isotonic Olympic bench press (*Nebula Fitness, Versailles, OH*) strength test for upper body muscular endurance. Additionally, a lower body submaximal strength test using a hip sled/leg press (*Nebula Fitness, Versailles, OH*) was completed. Regarding the neutral grip pull-up test, the subject was instructed to complete as many repetitions as possible until they were no longer able to complete a repetition with proper form and technique which was defined as the head above the handles in the "up" position and the arms fully extended with a slight bend in the elbows in the "down position." For the bench press test, the subjects self-selected a standardized load set at 61.2 kgs and completed as many repetitions as possible until volitional fatigue. A self-selected weight of 449 kgs was used during the lower body muscular endurance test. The subject was instructed to complete as many repetitions as possible until volitional fatigue while still maintains proper form and technique which consisted of a 90° in the "down position." The same loads were used for testing post-race. Upper and lower body submaximal procedures were used to avoid injury the week before the ultra-endurance event.

Statistical Analysis

All data were analyzed for delta, averages, and percentage changes from pre to post-race.

Results

Race Information

The subject completed a total of 8,835 km in 44 days and 42 minutes. It took the subject 22 days and 6 hours to ride from Antelope Wells, NM to Banff, AB, Canada on the northbound route for a total distance of 4,418 km which was classified as an individual time-trial (not part of the actual Tour Divide Race). During this time trial the subject traveled at an average speed of 8.3 km per hour with an average pace of 198.5 km per day. The subject stayed in Banff for approximately 18 hours for food and maintenance before beginning the southbound route of the actual Tour Divide race. On the return route, which was the actual race, the subject rode a total of 4,601 km at an average speed of 8.45 km per hour (average pace of 202.8 km per day) which took the subject approximately 20 days and 13 hours to complete. Table 1 presents a summary of environmental conditions throughout the race. On average the subject slept 4-5 hrs. per day throughout the 44-days. Other than for sleeping purposes, the subject spent approximately less than one hour off the bike for restroom breaks and food purchase.

Date	**Location (City, State)**	**Time**	**Race Time (Days: Hrs: Min)**	**Distance Traveled (Km)**	**Temp (°C)**			**Wind Speed (Mph)**		**Elev.**
					Min	**Mean**	**Max**	**Mean Wind Speed**	**Max Wind Gust**	**(m)**
41419	START:	3:00 AM MT	0	0	14.4	24.3	31.7	9.32	28.77	1422
41419	Silver City, NM	10:46 PM MT	0.013726852	187	14.4	25.2	34.4	10.93	33.37	1797
41421	Reserve, NM	7:37 AM MT	0.086539352	196	15	24.2	33.3	7.48	25.32	1760
41422	Grants, NM	6:55 AM MT	0.127719907	224	0.5	15	26.4	7.6	32.22	1969
41422	Cuba, NM	7:18 PM MT	0.136319444	193	4.4	19.2	27.2	8.06	27.62	2105
41423	El Rito, NM	6:22 PM MT	0.177337963	116	11.7	19	25	11.51	39.13	2096
41425	NM-CO State Line (Chama, NM)	4:55 PM MT	0.217997685	94	-1.6	12.9	23.9	12.08	40.28	2399
41426	Gunnison, CO	3:19 PM MT	0.300219907	206	3	9.2	18	5.75	29.92	2348

41428	Breckenridge, CO	1:11 AM MT	0.348738426	179	11	16.2	22	7.02	46.03	2926
41429	Steamboat Springs, CO	2:03 AM MT	0.391006944	167	9	12.6	17	16.8	48.33	2052
41429	CO-WY State Line (Dixon, MT)	7:07 PM MT	0.427858796	No data	7.8	12.8	20.6	7.13	17.26	769
41430	Rawlins, WY	11:36 AM MT	0.464305556	204	0	9.6	21.7	6.1	23.02	2083
41431	Boulder, WY	8:29 PM MT	0.512141204	270	2.8	14.3	24.4	6.33	no data	2139
41433	WY-ID State Line (Ashton, ID)	6:30 PM MT	0.594097222	306	13.9	20.7	28.3	8.4	27.62	1603
41435	Lima, MT	12:31 AM MT	0.63994213	179	7.8	20.2	30	10.47	35.67	1907
41435	Polaris, MT	10:58 AM MT	0.672199074	103	12	22.3	33	5.41	25.32	1952
41436	Butte, MT	11:27 AM MT	0.714201389	117	8.9	17.8	27.8	8.52	no data	1688
41437	Lincoln, MT	10:20 AM MT	0.755092593	174	8.3	14.2	24.4	4.72	25.32	1382
41439	Eureka, MT	9:49 PM MT	0.846400463	330	8	14.8	19	6.21	18.41	787
41441	Elkford, BC	4:39 AM MT	0.9178125	146	8.9	17.1	25	5.75	24.79	1300
41441	Banff, AB	9:41 PM MT	0.929641204	161	-0.2	10.9	19.1	3.57	24.35	1463
41443	Elkford, BC	2:48 AM MT	0.974861111	161	10.7	16.6	24.2	6.67	25.31	1300
41444	Eureka, MT	9:49 AM MT	1.046400463	146	12	15	23	4.03	no data	787
41445	Bigfork, MT	5:45 PM MT	1.093576389	130	8	10.1	12	9.67	25.32	908
41447	Lincoln, MT	3:11 AM MT	1.166793981	200	6.1	12.5	19.4	5.29	21.86	1382
41448	Butte, MT	9:14 AM MT	1.212662037	174	5	14	24.4	4.26	no data	1688
41449	Polaris, MT	12:33 AM MT	1.223298611	117	10.6	17.6	24.4	6.21	33.37	1952
41449	Lima, MT	1:42 PM MT	1.257430556	103	8.3	18.3	25	7.94	25.32	1907
41450	WY-ID State Line (Ashton, ID)	2:09 PM MT	1.299409722	179	11.1	16.9	23.9	11.51	27.62	1603
41452	Boulder, WY	7:53 AM MT	1.378391204	306	5	19.3	32.2	6.56	no data	2139
41453	Rawlins, WY	6:21 AM MT	1.418993056	270	10.6	23.9	35.6	5.75	no data	2083
41453	CO-WY State Line (Dixon, MT)	1:19 PM MT	1.423831019	No data	10.6	22.2	33.9	2.42	no data	769
41454	Steamboat Springs, CO	8:19 AM MT	1.462025463	204	15	19.3	25	8.86	28.77	2052
41455	Breckenridge, CO	10:08 AM MT	1.504953704	167	9	10	11	4.95	no data	2926
41456	Gunnison, CO	3:38 PM MT	1.550439815	179	11	15.1	24	5.06	25.32	2348
41457	Del Norte, CO	1:54 PM MT	1.590902778	206	6.1	15.8	28.3	7.13	32.22	2403
41458	NM-CO State Line (Chama, NM)	12:19 PM MT	1.631469907	158	7.2	16.6	28.3	8.29	31.07	2399
41458	El Rito, NM	10:48 PM MT	1.63875	94	12.8	19.4	29.4	10.24	32.22	2096

41459	Cuba, NM	7:44 PM MT	1.678287037	116	15	22.3	31.7	7.25	27.62	2105
41460	Grants, NM	4:23 PM MT	1.717627315	193	17.6	23.8	30.5	6.79	32.22	1969
41462	Silver City, NM	3:42 PM MT	1.800486111	420	21.1	28.2	35.6	7.48	31.07	1797
41463	FINISH:	3:42 AM MT	1.833935185	187	20	26.6	32	6.56	23.02	1422

Table 1: Summary of environmental conditions during the race

Dietary Analysis

There was a significant difference in total energy and macronutrient consumption pre- to during race intake (Table 2). Total energy intake during the race increased by 1,541 kcals (41.4%) over pre-race food consumption. The average daily carbohydrate and fat intake increased by 367g (113.5%) and 23g (12.9%) during the race, respectively. However, total protein intake actually decreased 59g (-28.2%).

Nutrients	PRE	During Race (% Change)	Delta Values
Gram Weight (g)	2115.1	2,750.3 (30.0)	635.8
Calories (kcal)	3723.2	5,263.9 (41.4)	1540.6
Fat (g)	182.9	206.4 (12.9)	23.5
Fat Percentage of Total Calories (%)	43.6	35.6 (-18.3)	-8
Protein (g)	209.6	150.5 (-28.2)	-59.2
Protein Percentage of Total Calories (%)	22.2	11.5 (-48.1)	-10.9
Carbohydrates (g)	322.5	688.4 (113.5)	366
Carb Percentage of Total Calories (%)	34.2	52.8 (54.5)	18.6
Dietary Fiber (g)	21.6	25.1 (15.9)	3.4
Soluble Fiber (g)	0.9	1.5 (75.6)	0.7
Total Sugars (g)	74.6	302.3 (305.1)	227.7

Table 2: Changes in dietary intake

Resting Energy Expenditure, Body Composition and Body Water

The subject experienced a 20.9% (1,632 to 1,973 kcal/day) increase in resting energy expenditure 48-hrs post-race compared to pre-race measures. Table 3 presents changes in body mass. The subject lost a total of 8.4 kg (-8.9%) immediately following the race (2 hr.). After 24, 48 and 72 hr., the subject was still 8.6 (-9.1%), 8.0 (-8.5%), and 7.7 (-8.2%) kg below his pre-race weight, respectively. Three weeks post-race the subject was still 11.0 kg (-11.7%) below pre-race body mass. Table 4 presents changes observed in body composition and body water as measured via BIA. The subject lost 7.2 (-38.3%) kg of fat mass and 1.9 (-2.8%) kg of fat-free mass according to post-race DEXA analysis 3-weeks after the completion of the race. This resulted in a decrease of 6.4 percent body fat (-31.2%).

	PRE	2-HR POST (% Change)	48-HR POST (% Change)	72-HR POST (% Change)	96-HR POST (% Change)	3-WK POST (% Change)
Body Mass (kg)	94.3	85.9 (-8.9)	85.7 (-9.1)	86.3 (-8.5)	86.6 (-8.2)	8
Delta Value		-8.4	-8.6	-8	-7.7	-11

Table 3: Body mass changes

	PRE	2-HR POST (% Change)	48-HR POST (% Change)	72-HR POST (% Change)e)
BIA FFM (kg)	66.7	69.4 (4.10)	63.6 (-4.65)	65.0 (-2.60)
BIA FM (kg)	27.6	16.5 (-40.20)	22.1 (-19.9)	21.3 (-22.8)
BIA BF % (%)	29.3	19.2 (-34.47)	25.8 (-11.90)	24.6 (-16.0)
BIA ECF (L)	48.1	50.1 (4.16)	45.8 (-4.78)	46.9 (-2.49)
BIA ECF (%)	51	58.3 (14.31)	53.5 (4.90)	54.3 (6.47)
BIA ICF (L)	26.1	28.1 (7.66)	25.7 (-1.53)	25.0 (-4.21)
BIA ICF (%)	54.2	56.2 (3.69)	56.1 (3.51)	53.4 (-1.48)
BIA TBW (L)	22	21.9 (-0.45)	20.1 (-8.64)	21.9 (-0.45)
BIA TBW (%)	45.8	43.8 (-4.37)	43.9 (-4.15)	46.6 (1.75)

Table 4: Body composition and body water changes. BIA = bioelectrical impedance analysis; FFM = free fat mass; FM = fat mass; BF % = body fat percentage; ECF = extracellular fluid; ICF = intracellular fluid; TBW = total body water

Performance Tests

Table 5 presents maximal cycle ergometer data. Upon completion of the race, the subject experienced a 22.5% decrease in absolute O_2

peak (L/min) 96-hrs post and a 6.9% decrease 3 wk post, still far below the pre-test value. Relative O2 peak (ml/kg/min) decreased 15.6% and -1.5% at 96-hrs and 3-wk post, respectively. There was also a decrease in peak resistance achieved, 25.0% at 96-hrs post and 12.5% 3-wk post compared to the pre-race value. Table 6 presents data regarding the changes observed in anaerobic capacity. The subject experienced a 24.2% decrease in peak power 96-hrs post and a 20.1% decrease 3-wk post compared to the pre-race testing. The subject also experienced a 20.3% decrease in mean power 96-hrs post, but only a 5.8% decrease 3-wk post compared to pre-race testing. There was a 20.9% decrease in total work completed 96-hrs post and a 6.6% decrease 3-wk post. Time to peak power increased 247% 96-hrs post and remained at 247% above baseline when tested 3-wk post. The maximal number of pull-ups and bench press repetitions completed decreased by 15 (-50%) and 20 (-57.1%) repetitions at 96-hrs post, respectively. The maximal number of leg press repetitions completed decreased by 20 repetitions (-66.7%) at 96-hrs post.

	PRE	96-HR POST (% Change)	3-WK POST (% Change)
Peak VO2 (L/min)	4.37	3.39 (-22.43)	4.07 (-6.87)
Peak VO2 (ml/kg/min)	46.3	39.10 (-15.55)	45.60 (-1.51)
METS	13.23	11.17 (-15.57)	13.03 (-1.51)
Peak Time (min)	12	9.25 (-22.92)	8.25 (-31.25)
Peak Resistance (W)	400	350.00 (-12.50)	350.00 (-12.50)
Peak HR (bpm)	178	147.00 (-17.42)	127.00 (-28.65)
Peak SBP (mm Hg)	170	158.00 (-7.06)	154.00 (-9.41)
Peak DBP (mm Hg)	68	68.00 (0.00)	68.00 (0.00)
Peak RPE	20	20.00 (0.00)	20.00 (0.00)

Table 5: Maximal cycle ergometer test. HR = heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure; RPE = rate of perceived exertion

	PRE	96-HR POST (% Change)	3-WK POST (% Change)
Peak Power (W)	2238	1696.01 (-24.22)	1788.61 (-20.08)
Mean Power (W)	808.9	644.84 (-20.28)	761.82 (-5.82)
Minimum Power (W)	312.7	406.09 (29.88)	607.57 (94.32)
Time to Peak Power (sec)	0.22	0.76 (247.23)	0.76 (247.27)
Time to RPM Max (sec)	0.66	1.00 (51.21)	0.98 (48.94)
Mean Power/Body Mass (W/kg)	8.58	7.43 (-13.40)	8.53 (-0.55)
Peak Power/Body Mass (W/kg)	23.73	19.54 (-17.67)	20.03 (-15.61)
Fatigue Slope (W/sec)	64.72	44.17 (-31.75)	347.26 (436.56)
Rate of Fatigue (%)	86.03	76.06 (-11.59)	66.03(-23.25)
Total Work (J)	24267	19203.32 (-20.87)	22674.82 (-6.56)

Table 6: Anaerobic Capacity Changes. RPM = revolutions per minute

Clinical Chemistry Panels

Table 7 represents changes in serum lipids and glucose. The subject experienced a 39% decrease in triglyceride levels immediately following the race with a concomitant increase in HDL levels (24%) while total cholesterol remained unchanged. Several blood parameters increased following the race as seen in Table 8, including a 91.7% and 94.7% increase in AST and ALT levels, respectively. These values remained elevated at 96-hrs post-race. Creatine kinase concentration increased by 210.4% immediately following the race and remained elevated 24, 48 and 72-hrs post-race with increases of 29.9%, 46.0% and 19.5% compared to baseline, respectively. Minor changes were observed in electrolyte status following the race. Table 9 summarizes changes in whole blood markers of clinical health. White blood cells were elevated immediately post-race (97%) and remained elevated up to 72 hr. post-race.

	PRE	2-HR POST (% Change)	24-HR POST (% Change)	48-HR POST (% Change)	72-HR POST (% Change)
Total Cholesterol (mg/dl)	142	142 (0.00)	142 (0.00)	138 (-2.82)	143 (0.70)
HDL Cholesterol (mg/dl)	45	56 (24.44)	58 (28.89)	51 (13.33)	50 (11.11)
LDL Cholesterol (mg/dl)	82	77 (-6.10)	71 (-13.41)	78 (-4.88)	85 (3.66)
Triglycerides (mg/dl)	74	45 (-39.19)	64 (-13.51)	46 (-37.84)	42 (-43.24)
Glucose (mg/dl)	97	84 (-13.4)	127 (30.93)	90 (-7.22)	101 (4.12)
Sodium (mmol/L)	141	136.0 (-3.55)	139.0 (-1.42)	140.0 (-0.71)	141.0 (0.00)
Potassium (mmol/L)	4	4.1 (2.50)	4.4 (10.00)	4.4 (10.00)	n/a
Chloride (mmol/L)	105	105.0 (0.00)	108.0 (2.86)	108.0 (2.86)	110.0 (4.76)

Table 7: Serum lipid, glucose, and electrolyte changes. HDL = high density lipoprotein; LDL = low density lipoprotein

	PRE	2-HR POST (% Change)	24-HR POST (% Change)	48-HR POST (% Change)	72-HR POST (% Change)

Citation: Jagim A, Levers K, Galvan E, Joubert D, Rasmussen C, et al. (2014) Effects of an Ultra-Endurance Event on Body Composition, Exercise Performance and Markers of Clinical Health: A Case Study. Bioenergetics 3: 119. doi:10.4172/2167-7662.1000119

BUN (mg/dL)	21	21.0 (0.00)	22.0 (4.76)	22.0 (4.76)	21.0 (0.00)
Creatinine (mg/dL)	1.04	1.03 (-0.96)	1.03 (-0.96)	0.96 (-7.69)	0.96 (-7.69)
BUN/Creatinine	20.2	20.4 (0.97)	21.4 (5.78)	22.3 (13.49)	21.9 (8.33)
CK (U/L)	87	270.0 (210.34)	113.0 (29.89)	127.0 (45.98)	104.0 (19.54)
AST (U/L)	24	46.0 (91.67)	35.0 (45.83)	35.0 (45.83)	35.0 (45.83)
ALT (U/L)	19	37.0 (94.74)	33.0 (73.68)	28.0 (47.37)	30.0 (57.89)
Total Protein (g/dL)	7	7.1 (1.43)	7 (0.00)	6.6 (-5.71)	6.8 (-2.86)
TBIL (mg/dL)	0.8	0.6 (-25.00)	0.5 (-37.50)	0.5 (-37.50)	0.4 (-50.00)
BMC (g)	2391.3	n/a	n/a	2357.4 (-1.42)	n/a
Albumin (g/dL)	4.8	4.4 (-27.27)	4.2 (-31.82)	4.1 (-27.27)	4.3 (-22.73)
Globulin (g/dL)	2.2	2.7 (22.73)	2.8 (27.27)	2.5 (13.64)	2.5 (13.64)
Alb:Glob Ratio	2.2	1.6 (-27.27)	1.5 (-31.82)	1.6 (-27.27)	1.7 (-22.73)
Calcium (mg/dL)	9.3	9.2 (-1.08)	9.3 (0.00)	9.0 (-3.23)	9.1 (-2.15)
ALK (U/L)	70	87.0 (24.29)	88.0 (25.71)	85.0 (21.43)	83.0 (18.57)

Table 8: Markers of catabolism and bone status. BUN = blood urea nitrogen; CK = creatine kinase; AST = aspartate aminotransferase; ALT = alanine aminotransferase; TBIL = total bilirubin; ALK = anaplastic lymphoma kinase

	PRE	2-HR POST (% Change)	24-HR POST (% Change)	48-HR POST (% Change)	72-HR POST (% Change)
WBC (x103/uL)	4.6	9.10 (97.83)	7.00 (52.17)	5.10 (10.87)	5.10 (10.87)
RBC (x106/uL)	5.07	4.86 (-4.14)	4.90 (-3.35)	4.71 (-7.10)	4.84 (-4.54)
Hematocrit (%)	44.1	42.30 (-4.08)	43.70 (-0.91)	41.50 (-5.90)	42.70 (-3.17)
Hemoglobin (g/dL)	14.5	14.40 (-0.69)	14.30 (-1.38)	13.80 (-4.83)	14.50 (0.00)
MCV (fL)	87	87.10 (0.11)	89.10 (2.41)	89.10 (1.26)	88.20 (1.38)
MCH (pg/cell)	28.7	29.60 (3.14)	29.10 (1.39)	29.40 (2.44)	29.90 (4.18)
MCHC (g/dL)	33	34.00 (3.03)	32.70 (-0.91)	33.30 (0.91)	33.90 (2.73)
RBCDW (%)	13.4	13.80 (2.99)	14.00 (4.48)	14.00 (4.48)	8.96 (8.96)
Platelet Count (103/uL)	192	260.00 (35.42)	230.00 (19.79)	229.00 (19.27)	251.00 (30.73)

Table 9: Whole blood markers.WBC = white blood cell; RBC = red blood cell; MCV mean corpuscular volume; MCH = mean corpuscular hemoglobin; MCHC = mean corpuscular hemoglobin concentration; RBCDW = red blood cell distribution width

Discussion

Despite a rapid growth in ultra-endurance event popularity, there is a limited body of research examining the physiological effects of these events on the human system. There is a limited amount of literature available that explores the physiological effects of ultra-endurance athletic events lasting longer than 10 days with the exception of military and skiing expeditions of 50 days or more [2,9,16]. The primary purpose of this case study was to observe the effects of an ultra-endurance event on body composition, lower and upper body muscular endurance, anaerobic capacity, aerobic capacity, and markers of clinical health. However, different from previous research, this particular case study examines an ultra-endurance event where the subject was self-supported and faced extreme changes in weather from triple digit temperatures to snow-covered conditions. For example, temperatures in the warmer regions covered during the race ranged from 32-37°C while temperatures in the mountains got as cold as -1°C as seen in Table 2. Furthermore, the subject reached elevations up to 2,400 m imposing additional physiological demands upon the cyclist. The examination of the physiological adaptations to such harsh and long-duration competitive conditions in a highly trained athlete serves to expand our knowledge on the tolerance and adaptability of the human system.

Energy Intake and Expenditure

Based on the assessment of energy intake during the race, it was estimated that the subject was consuming an average of 5,255 kcal (22 megajoules [MJ]) per day, which is similar to energy intakes seen in previous competition events of this nature [10,11,17]. Comparable studies have reported high energy expenditures in subjects performing ultra-endurance competitions for extended periods of time [2, 11, 17, 18]. Stroud and colleagues estimated energy expenditures to be between 5,971-11,942 kcal (25-50 MJ) per day for two subjects trekking across Antarctica with an average daily exercise time of 10 hours. Bircher et al. [4] reported daily energy expenditures around 12,659-14,092 kcal (53-59 MJ) per day by a cyclist who completed a 2,272 km race in 5 days. Similarly, Saris et al. [18] estimated energy expenditures of cyclists during the Tour de France to be approximately 5,971 kcal (25 MJ) per day on average. However, daily expenditures as high as 7,643 kcal (32 MJ) were observed with an average daily mileage around 161 kilometers. Energy expenditures of Ironman length triathlons have averaged up to approximately 60 MJ per day [2]. In fact, it was estimated that one cyclist who completed a 24-hour cycling event and covered 694 km had an energy expenditure of 82.7 MJ [5]. Daily energy expenditures of the present study are likely most similar to those seen during the Race Across America (RAAM) during which cyclists ride approximately 22 hours a day in order to complete the 5,000 km race. It's been estimated that energy expenditures during the RAAM race average between 50-92 MJ per day [2]. Due to a heart rate monitor malfunction during the race, we were unable to estimate energy expenditures using the regression equation developed from baseline aerobic capacity testing. However, it can be assumed that daily energy expenditures exceeded energy intake due to the observed loss in body mass following the race. We speculate that the subject's daily energy expenditure was higher than those seen by professional riders in the Tour de France, similar to Trans-Am cyclists, and slightly lower than riders competing in the RAAM, as both the Tour Divide and Trans-Am races are self-supported and require similar time to be spent off the bike despite different terrain. The Tour Divide covers much more difficult terrain on a mountain bike compared to a paved road course used by road cyclists in the Tour de France, RAAM, and Trans-Am. However, despite more difficult environmental conditions experienced by our Tour Divide rider, he spent nearly six hours (average 4-5 hours sleep and <1 hour eating/miscellaneous rest per day) off the bike compared to a RAAM rider who typically spends significantly less time off the bike per day due to the aid of their support team. The Tour Divide rider may have also spent additional time off the bike to simply carry his bike over impassable terrain, which would greatly change his energy expenditure compared to a racer biking on the road. Considering all of these variables, it is difficult to directly compare the daily energy expenditure between various types of ultra-endurance cycling events, leading to pure speculation due to equipment failure for daily heart rate data that we initially set out to collect. Unlike previous research in the ultra-endurance literature, specific diets, food items or even supplements were not feasible options. Therefore, significant decreases in protein consumption in conjunction with increases in dietary carbohydrate and fat intake were expected due to the foods and beverages that were available on the route. Most of the food and beverage items were purchased from establishments in small, rural towns such as gas station food marts, bars, and fast food restaurants.

The subject experienced a 20.9% (1,632 to 1,973 kcal/day) increase in resting energy expenditure 48-hrs post-race compared to pre-race measures. Similar elevations in resting energy expenditure 24-48-hrs following higher intensity, long duration aerobic exercise in highly trained subjects have been seen in previous research before a gradual return to baseline values by 72-96-hrs post-exercise [19-24]. The significant increase in REE post-race for trained endurance athletes is likely due to excess Post-Exercise Oxygen Consumption (EPOC) as a result of the oxygen debt attained during the long, repetitive duration of the extreme aerobic activity.

Body Composition

The subject lost a total of 8.4 kg (-8.9%) immediately following the race. This loss in body mass is similar to those observed in previous studies in which subjects underwent prolonged periods of high energy expenditure with limited energy intakes [10,4,17,25]. Frykman et al. [10] found a 1.3% and 8.6% loss in body mass in two individuals who completed a self-supported 2,928-km ski trek in 86 days. In a similar study, researchers observed a 25% loss in body mass after a 95 day trek across Antarctica despite attempts to match energy intake with daily energy expenditure [17]. In the current study, the subject experienced a 38.3% loss in fat mass and a 2.8% loss in fat-free mass. Trained ultra-endurance athletes are highly efficient, using fat as their primary energy substrate, with subcutaneous adipose sources acting as main resource for long-duration endurance performance [6,10,16]. Furthermore, compared to the ski trek athletes, the ultra-endurance athlete in the current study may have also lost a greater quantity of fat mass due to the increased work load. The majority of body mass derived from fat stores demonstrates an energy deficit experienced by the subject throughout the race that was compensated via the use of internal adipose stores. These decreases in fat mass and fat-free mass were also similar to those observed in the cross-country skiers [10]. Nindl et al. [25] found a 4% loss in body fat percentage in soldiers following 62 days of Army Ranger Training in conjunction with restricted caloric intake and high daily energy expenditures. Furthermore, the soldiers also experienced a 5 kg (-6.6%) decrease in fat-free mass and 5 kg (-42.6%) decrease in fat-mass following the training period. These results are similar to the 2 kg decrease in fat-free mass and 7 kg decrease in fat-mass observed in the present study. As a means for comparison 11 female ultra-runners completed a 100-km run in approximately 12-hrs and experienced a 1.5 kg decrease in total body mass, but no changes were recorded in muscle and fat mass [26]. Contrarily, Knechtle et al. [27] investigated body composition changes in both male (n=43) and female (n=6) ultra-endurance runners during a 210 mile (338 km) run performed within 5 days. As a result of this competition, body mass and fat mass did not change, but skeletal muscle mass decreased significantly by an average of 0.6 kg [27]. However, these anthropometric measures were calculated from skinfold measures and not directly measured. To compare to another extreme endurance cycling case study, Bircher et al. [4] followed one male cyclist during the XXAlps 2004 extreme endurance cycling race that covered approximately 1,411 miles (2,272 km) and was completed in 5 days and 7 hours. This cyclist experienced a 2 kg body mass decrease over the race duration, of which 1.21 kg was fat-free mass and 0.790 kg was fat mass [4].

Aerobic Capacity

The subject experienced a 15.5% decrease in absolute O_2 peak 96-hrs post and a 1.5% decrease 3-wk post, which is nearly a full recovery of the pre-race aerobic capacity. Similar decreases in aerobic capacity have been observed following ultra-endurance events [10,17]. Stroud et al. [17] observed decreases in aerobic capacity of 23% and 20.6% in two individuals who trekked across Antarctica for 95 days. In a similar study, researchers observed a 6.13% decrease in aerobic capacity following an 86-day self-supported trek across Greenland [10]. The observed decrease in peak HR 96 (-17.4%) and 3-wk (-28.7%) following the race likely contributed to the decrease in maximal aerobic capacity. Previous reports have also found reductions in maximal HR following extended periods of intense training [28-30]. This reduction in maximal HR may have contributed to the reduced aerobic capacity as a result of a decreased cardiac output. However it's difficult to conclude whether or not this reduction is a direct result of a physiological phenomenon or the reduced power output and time to exhaustion exhibited during the post-race testing periods, as was seen in the present study. Despite similar decreases in aerobic capacity following other ultra-endurance events, the aerobic capacity recovery time is unknown. The nearly full recovery of aerobic capacity 3-wk post-race is valuable information for ultra-endurance cyclists and the design of their periodized training program.

Anaerobic Capacity

The subject experienced a 24.2% decrease in peak power 96-hrs post and remained below baseline by 20.1% at 3-wk post compared to the pre-race testing. Similar decreases in anaerobic power and capacity have been observed following ultra-endurance events [10, 25]. Nindl et al. [25] observed decreases of 17.5% to 22.3 % in explosive power following 5 weeks of Army Ranger Training. In a similar study, Frykman et al. [10] observed decreases of 15% and 23% in peak power of two individuals who completed a trek across Greenland. Furthermore, the subject also experienced a 20.3% decrease in mean power 96-hrs post, but only a 5.8% decrease 3-wk post compared to pre-race testing suggesting that the subject's anaerobic capacity was recovering, returning back to pre-race values.

Muscular Fitness

The subject experienced a 50% decrease in upper body muscular endurance and a 57.1% decrease in the number of sub-maximal bench press repetitions completed. The decreases in upper body strength and endurance could be attributed to the decrease in fat-free muscle mass as well as to the subject's reconditioning. Lower body strength performance on the leg press decreased by 20 repetitions (-66.67%) at 96-hrs post. Decreases in lower body strength and endurance are likely attributable to the high volume of cycling completed throughout the race in conjunction with poor nutritional options resulting in an overall decrease in lower body muscle mass. Similar decreases in lower body muscular endurance have been observed following prolonged ultra-endurance events. Frykman et al. [10] observed a 16% decrease in the number of back squat repetitions completed using a 100 lb. external load following a three month ultra-endurance event. Similarly, Nindl et al. [25] found a 21% reduction in maximal lift capacity in soldiers following 8 weeks of Army Ranger training.

Markers of Clinical Health

Several blood parameters increased following the race including a 91.7% and 94.7% increase in AST and ALT levels, respectively. These values remained elevated at 96-hrs post-race. Others have found 6-8 fold elevations AST concentrations [31] following a marathon possibly indicative of exertional rhabdomyolysis [31]. Another study following ultra-endurance runners completing a 1600-km ultramarathon found more than four-fold increases in ALT and more than six-fold increases in AST concentrations post-performance. Despite these elevations post-race, it is difficult to determine if these values correlate directly to liver damage as AST and ALT are found both in the liver and skeletal muscle [32].

Creatine kinase is often used as a marker of muscle damage and has been shown to increase following continuous bouts of endurance exercise due to possible leakage from damaged skeletal muscle [33,34]. Creatine kinase concentration increased by 210.3% to 270.0 U/L immediately following the race and remained elevated 24, 48 and 72-hrs post-race with percentage increases of 29.9%, 46.0% and 19.5% compared to baseline (87.0 U/L), respectively. The same 1600-km ultramarathon study completed by Fallon et al. found a creatine kinase increase of more than 2059% over the pre-race values [32]. Ultra-endurance running has been found to significantly increase creatine kinase levels compared to ultra-endurance cycling or triathlon events that only see modest increases in post-exercise creatine kinase values still within normal physiological ranges [2]. The modest increase in cycling or triathlon events may be due to the non-weight bearing nature of these activities. The minor increase in creatine kinase levels in the current case study may be due to the non-weight bearing cycling, athlete training status, genetic factors, and the extremely long duration of the submaximal cycling activity.

Conclusion

In conclusion, it appears that completing a 44-d extreme ultra-endurance mountain biking race results in a substantial decrease in fat and fat free mass. Additionally, prolonged ultra-endurance performance facilitates decreases in aerobic capacity, anaerobic power, muscular strength endurance as well as increases in markers of muscle damage suggesting a state of overtraining. Based on the results of the present case report it appears as though more than 3 weeks may be required in order to return to baseline levels of endurance performance, anaerobic power and body composition.

Competing Interests

The Sydney and J.L. Huffines Institute for Sports Medicine and Human Performance at Texas A&M University provided funding for this study through a research grant to the Exercise and Sport Nutrition Laboratory at Texas A&M University. All researchers involved independently collected, analyzed, and interpreted the results from this study and have no financial interests concerning the outcome of this investigation.

Acknowledgements

The authors would like to acknowledge the experimental support of Dr. Stephen Crouse, Dr. Steve Martin, and Dustin Joubert of the Applied Exercise Science Laboratory at Texas A&M University for allowing us to conduct our pre- and post-race performance testing in their facility. We would also like to thank Abigail O'Connor, Brandi Bonin, Charlie Seesselberg of the Exercise and Sport Nutrition Laboratory for their assistance throughout the study.

Funding

This research was supported by the Sydney and J.L. Huffines Institute for Sports Medicine and Human Performance at Texas A&M University.

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