RESEARCH ARTICLE

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Characterizing the Physiological Demands & Serum Cortisol Levels of Thru-Hiking the Continental Divide Trail

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Abstract: The popularity of thru-hiking is expanding within the outdoor recreation industry, drawing attention to the physiological demands of prolonged endurance activities in natural environments. This study examined the effects of a long-distance thru-hike on circadian rhythm regulation, body composition, and physical fitness parameters in two adult subjects who undertook the Continental Divide Trail in 2021. Serum cortisol concentrations were measured in the morning and evening at four time points: pre-hike, mid-hike, post-hike, and 16 weeks post-hike. Physical fitness testing included assessments of body composition, maximal oxygen uptake, and muscular endurance were conducted at pre-hike, post-hike, and 16 weeks post-hike. Both subjects demonstrated significant physiological adaptations, including changes in evening serum cortisol concentrations and alterations in adipose tissue and muscle mass. The female subject showed marked improvements in lower body muscular endurance and maximal oxygen uptake, while the male subject experienced reductions in muscle mass and muscular endurance, while maintaining aerobic capacity. These findings suggest that thru-hiking may influence endocrine function and physical fitness dependent on initial fitness status and individual physiological characteristics. This study highlights the need for further research to better characterize the health impacts of thru-hiking.

Keywords: Circadian rhythm, Cortisol, Body composition, Thru-hiking, Cardiovascular endurance

1. Introduction

1.1 Continental Divide Trail

The Continental Divide Trail (CDT) is a continuous and challenging footpath that stretches from Mexico to Canada through the Rocky Mountains, spanning approximately 4300-5070 kilometers (km) across five U.S. states: New Mexico, Colorado, Wyoming, Idaho, and Montana. A *thru-hiker* is a common term used to describe an individual that performs 'multiday sports walking' (Happ *et al.,* 2021) on a long-distance trail, such as the Pacific Crest Trail (PCT), Appalachian Trail (ACT), or the CDT. Thru-hiking is growing in popularity within the nature-based tourism and recreation industries (Happ *et al.,* 2021). According to the Continental Divide Trail Coalition (CDTC), it takes most thru-hikers an average of 4-6 months to complete the CDT trail from end-to-end. Out of the 150-400 thru-hikers who attempt to complete the CDT annually, only 61, 120, and 152 reported that they completed in 2020, 2021, and 2022, respectively.

Not only do thru-hikers experience physical injuries and exhaustion while on hiking, but they also persevere through environmental stressors and nutritional challenges. These individuals perform prolonged daily bouts of exercise with significant elevation changes while carrying a backpack filled with supplies, water, and food. Common environmental stressors include extreme temperatures, high solar exposure, harsh weather, and lack of accessibility to drinking water. Nutritionally, their diets tend to be calorically dense, but nutritionally poor, which can lead to gastrointestinal issues (Crouse, 1993; Gardner & Hill, 2002) and a decrease in arterial function (Heinbockel & Craighead, 2021). Despite these challenges, the stress reducing effects of being in nature are known (Aras *et al.,* 2024) and thru-hikers have various motives as to why they chose to embark on these extensive journeys: (A) to increase one's self-esteem; (B) for preventative health reasons; (C) to partake in extreme physical demands;

(D) to immerse themselves in nature, and (E) to have a deeper intrapersonal relationship with themselves (Aras *et al.,* 2024; Cole, 2018; Happ *et al.,* 2021; Hill *et al.,* 2014; Schuring, 2019). Participants in this study were inspired by similar motivations and sought to document the effects of the trail on physical and emotional health.

1.2 Cortisol

Cortisol is a glucocorticoid hormone regulated by the hypothalamic-pituitary-adrenal (HPA) axis. It is commonly referred to as the *'stress hormone'* and used as a biomarker in research (Gatti & De Palo, 2011; Hellhammer et al., 2009; Holsboer, 2001; Matousek *et al.,* 2010; Whitworth et al., 2005). Cortisol is a major contributor to mammalian circadian rhythms and plays a vital role in the psycho-physiological stress responses (Hannibal & Bishop, 2014; Hellhammer *et al.,* 2009; Holsboer, 2001; McArdle *et al.,* 2015). Measuring cortisol is an effective and dependable way to evaluate physiological stress levels in relation to exercise training, depression, anxiety, cardiovascular disease, and stress-related obesity within human subjects (Anderson & Wideman, 2017; García-Sesnich *et al.,* 2017; Gatti & De Palo, 2011; Hellhammer *et al.,* 2009; Knorr *et al.,* 2010; Matousek *et al.,* 2010; Thirthalli *et al.,* 2013; Vicennati *et al.,* 2009).

For a diurnal mammal, the production and release of cortisol fluctuates substantially within a 24-hour cycle (Díaz *et al.,* 2013; Li & Goldsmith, 2012). In a healthy diurnal circadian rhythm, cortisol concentrations are 50-160% higher within the first 20-60 minutes of waking up in comparison to evening cortisol concentrations. This is known as the cortisol awakening response, or CAR (Anderson & Wideman, 2017; Clow *et al.,* 2004; Drogos *et al.,* 2019; Mohd Azmi *et al.,* 2021; Wust *et al.,* 2000). By mid-afternoon, cortisol concentrations reduce by half and continue to lower into the evening, and lowest between 12:00am to 4:00am (Hackney, 2010; Matousek *et al.,* 2010; Mohd Azmi *et al.,* 2021). The measurement of cortisol is dependent on the time of collection due to the significant variations of concentrations throughout a 24-hour period. The lack of cortisol concentration variability within a 24-hour period is related to depression (Gunnar & Vazquez, 2001). Recognizing when serum cortisol concentrations deviate from the normal AM range (9.07–30.83 μg/dL) and PM range (3.99–14.14 μg/dL) is important because the irregularity can indicate underlying dysfunctions in the HPA axis. Cortisol concentrations outside of these ranges have been related to chronic health conditions (Holsboer, 2001; Mohd Azmi *et al.,* 2021; Thirthalli *et al.,* 2013).

Cortisol secretion is also affected by one's psychological stress response within the limbic system (Hellhammer *et al.,* 2009; Thirthalli *et al.,* 2013). Repeated activation of the sympathetic nervous system (SNS) and limbic system can cause the chronic firing of the HPA axis, which can lead to hypercortisolism (Hannibal & Bishop, 2014; Holsboer, 2001). Hypercortisolism occurs due to prolonged periods of elevated cortisol concentrations and the inability to return to homeostatic balance (Hannibal & Bishop, 2014; Knorr *et al.,* 2010; Kudielka *et al.,* 2009; Li & Goldsmith, 2012). This type of cortisol dysfunction is commonly overlooked and is on the rise within the general and chronic disease populations (Giovanelli *et al.,* 2021; Whitworth *et al.,* 2005). Chronically elevated evening cortisol concentrations are associated with psychological conditions, such as anxiety, depression, panic attacks, and post-traumatic stress disorder (PTSD) (Bayoumi *et al.,* 2012; Gunnar & Vazquez, 2001; Hellhammer *et al.,* 2009; Holsboer, 2001; Li & Goldsmith, 2012; Streeter *et al.,* 2012; Thirthalli *et al.,* 2013; Yoshihara *et al.,* 2014). Research supports that hypercortisolism is not secondary to depression, rather it is a developmental factor to the cause of depression due to the neurological pathways being chronically triggered (Holsboer, 2001). In addition to psychological health issues, chronically elevated cortisol concentrations have been associated with a variety of other physiological health problems, such as hypertension, hyperglycemia, insulin resistance, cardiovascular disease, hormone receptor desensitization, weakened immune system, decreased reproductive function, pain, and inflammation (Austin *et al.,* 2016; Engert *et al.,* 2011; Hadley & Levine, 2006; Hannibal & Bishop, 2014; Holsboer, 2001; Matousek *et al.,* 2010; Streeter *et al.,* 2012; Thirthalli *et al.,* 2013). This highlights the need to research abnormal cortisol patterns in humans to prevent the progression of stress-related disorders and promote overall physiological balance.

1.3 Cortisol & Exercise

The HPA axis has acute and chronic responses to exercise training. Elevated cortisol concentrations have been measured for up to 20-120 minutes after a single bout of exercise. The amount of cortisol produced from exercise is respective to the frequency, intensity, time, type, volume, and progression (FITT-VP) of the exercise performed (Bushman, 2018). High intensity exercise, such as marathon training or high-load resistance training, has shown to prolong elevated cortisol concentrations post exercise (Ha *et al.,* 2015; Whitworth *et al.,* 2005). One study supports that low intensity resistance training at 30% 1-rep maximum (1RM) produced 145% less cortisol in comparison to high intensity resistance training at 75% 1RM (McGuigan *et al.,* 2004). The literature suggests that provoking a response in the HPA axis may require a specific exercise threshold (Anderson & Wideman, 2017). Studies support that a minimum of 60% of maximal aerobic capacity (VO_{2MAX}), or a moderate level intensity, is needed to provoke an increase in cortisol concentrations from the HPA axis about 15-30 minutes post exercise. The higher the intensity of exercise, the higher amount of cortisol concentrations produced and released (Anderson & Wideman, 2017; Caplin *et al.,* 2021; Crewther *et al.,* 2008; Hill *et al.,* 2008). Chronic exercise training is known to enhance the elasticity and resiliency of the HPA axis and to promote homeostatic balance (Anderson & Wideman, 2017; Batista *et al.,* 2015; Helgadóttir *et al.,* 2016; Scerbo *et al.,* 2010; Telles *et al.,* 2015; Wegner *et al.,* 2019). Trained individuals have been shown to have higher CAR concentrations and lower evening cortisol concentrations in comparison to untrained individuals. Chronic exercise training helps to regulate the rhythm of cortisol within a 24-hour cycle (Batista *et al.,* 2015; Ogasawara *et* al., 2022).

1.4 Purpose

The purpose of this exploratory case study was to document the within-subject physiological and hormonal adaptations to thru-hiking the CDT. By tracking longitudinal changes in serum cortisol and physical performance, this study offers preliminary insight into the chronic demands of long-distance hiking and provides foundational data for future research. These findings may provide insight for health professionals and outdoor fitness specialists working with individuals engaged in extreme, endurance-based recreational pursuits..

2. Methods

2.1 Participants

A 28-year-old male and 32-year-old female agreed to participate in this case study. Both subjects were moderately active with significant exposure to hiking long-distances within the Rocky Mountains. To prepare for the demanding journey, the subjects would hike about two times per week throughout the 18 months prior and averaged hiking about 8-16 km in each bout. Additionally, the subjects participated in a 128 km thru-hike in the summer of 2020 together. Much of their training took place in the mountains near Yellowstone National Park (YNP) and in the Bitterroot Valley of Montana.

In April 2021, the subjects embarked on a northbound journey along the CDT, starting at the southern terminus in Crazy Cook, New Mexico. Their goal was to traverse the 5,000 km trail through the Rocky Mountains and reach the Canadian border at Waterton Lake, Montana, before substantial snowfall at the end of September or early October 2021. Throughout the hike, subjects took days off-trail to recover and resupply. Additionally, food drops were organized and strategically planned throughout the trip.

2.2 Measurements

The subjects agreed to (1) complete eight serum cortisol samples via venipuncture; (2) perform three physical fitness test batteries (e.g., body composition measurements, muscular endurance tests, and maximal treadmill tests); and (3) provide data from their electronic tracking devices. All venipuncture samples were completed at Livingston Healthcare (LHC), except the MID samples were collected at the Steamboat Medical Group (SMG). All physical fitness testing was completed at LHC in the Cardiopulmonary Rehabilitation Gym (CHG). Morning and evening cortisol measurements were collected at PRE, MID, POST, and 16-week POST (16wkPOST) CDT hike. Additionally, each subject had their body composition, muscular endurance, and maximal volume oxygen uptake (VO_{2MAX}) measured at PRE, POST, and 16wkPOST CDT hike. The schedule for sample collections is outlined in Table 1.

2.3 Procedures

Serum cortisol samples were collected one day prior to the fitness test batteries for the PRE, POST, and 16wk-POST measurements. Each subject was scheduled for eight serum cortisol collections: six serum cortisol samples at LHC for the PRE, POST, and 16wkPOST and two at SMG during the MID phase along the CDT. For the most accurate measurements, the subjects were instructed to: (A) avoid vigorous activity within 24 hours prior to testing, (B) refrain from eating a meal within 2 hours prior to testing, and (C) withhold consumption of alcohol, caffeine, nicotine, and over-the-counter medications. Each serum cortisol collection day had two venipunctures from the antecubital space of the arm: (1) 8:00 am (morning) and (2) 5:00 pm (evening). Each sample was equivalent to about 4 milliliters (mL) of blood and the total amount of blood taken for the study was about 32 mL over the course of 9+ months.

Serum cortisol samples were analyzed by certified clinical laboratories at Livingston Healthcare (MT) and Steamboat Medical Group (CO) using standard hospital protocols. Specific assay validation data (e.g., analytical platform, detection limits, and intra-/inter-assay coefficients of variation) were not accessible to the researchers, as all testing was conducted independently under institutional procedures.

Each of the three fitness testing batteries (PRE, POST, and 16wkPOST) required two days of data collection, which began the day after serum cortisol measurements were collected. On Day 2, the subjects were to complete anthropometric measurements and assessments of upper and lower body muscular endurance. Seven days later, on Day 3, VO_{2MAX} treadmill testing was conducted. All testing adhered to COVID-19 safety protocols and was administered by trained health professionals. Due to the lack of accessibility on the CDT, no fitness testing was planned for the MID-sample collection.

2.4 Instruments & Software

Subjects were requested to share the electronically recorded data from the INEVIFIT scale application on their cellular devices and each subject's respective SUUNTO 9 Black [MODEL: SS050142000] watch.

The watches contained a global positioning system (GPS) and captured the following data on a daily basis: (1) distance traveled (km); (2) elevation gain (m); (3) elevation loss (m); estimated kilocalories expended (kcal); (4) average daily heart rate (HR) (bpm); (5) daily peak heart rate (PHR) (bpm); (6) total moving time per day (Hrs:Min:Sec); (7) average moving pace (Min:Sec/km).

2.5 Analysis

The study design was observational and exploratory in nature, aiming to document individual physiological and hormonal responses to an extended thru-hiking experience. Results are intended to serve as a preliminary reference and cannot be generalized to larger populations. Due to the small sample size (n = 2), this study was not designed or powered to support statistical inference. No inferential statistics were conducted. Instead, the repeated-measures design across four collection phases (PRE, MID, POST, and 16wkPOST) allows for within-subject comparisons over time. This design allows for preliminary observation of the physiological demands associated with thru-hiking and serum cortisol response. All data processing, summary statistics, and figure/table generation were completed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA).

Table 1 Summarized outline of the data collection process.

Phase of CDT Hike	Day of Collection	Data Collected
PRE	Day 1 of 3	AM & PM Serum Cortisol at LHC
PRE	Day 2 of 3	Body Composition & Muscular Endurance Testing at LHC
PRE	Day 3 of 3	VO2MAX Treadmill Testing at LHC
MID	Day 1 of 1	AM & PM Serum Cortisol at SMG
POST	Day 1 of 3	AM & PM Serum Cortisol at LHC
POST	Day 2 of 3	Body Composition & Muscular Endurance Testing at LHC
POST	Day 3 of 3	VO2MAX Treadmill Testing at LHC
16wkPOST	Day 1 of 3	AM & PM Serum Cortisol at LHC
16wkPOST	Day 2 of 3	Body Composition & Muscular Endurance Testing at LHC
16wkPOST	Day 3 of 3	VO2MAX Treadmill Testing at LHC

3. Results

The subjects began their hike at the southern terminus of the CDT on the Mexico-New Mexico border. They concluded their hike at the Montana state border within Yellowstone National Park. Subjects did not hike all the way to the Canadian border due to weather, time, and physical injury. Subjects hitchhiked to skip portions of the trail due to wildfire closures, snow, and personal injury. The amount of distance skipped is unknown and could be estimated to be up to 640 km, depending on the route taken. Male subject reported to have hiked a total of 2481.4 km over a span of 156 days with 48 off days and a base pack weight of 12.0 kg. Female subject reported to have hiked a total of 2212.5 km over a span of 156 days with 57 off days and a base pack weight of 13.2kg. Female subject reported back, foot and knee injuries.

3.1 AM & PM Serum Cortisol

Morning serum cortisol collections were taken at 08:00:00 MST for the PRE, MID, POST and 16wkPOST CDT hike. The evening serum cortisol collections were taken at 17:00:00 MST for the PRE, MID, POST and 16wkPOST CDT hike. Normal serum cortisol concentrations range from 9.1–30.8 μg/dL in the morning and from 4.0–14.1 μg/dL in the evening (Mohd Azmi *et al.,* 2021).

3.2 Anthropometrics & Exercise Testing Procedures

Body composition measurements were collected at PRE, POST and 16wkPOST CDT for both subjects and were collected via an INEVIFIT scale.

Batteries were replaced prior to each day of measurements. Subject results for ACSM Push-up Test and NRPT Squat Test for PRE, POST, and 16wkPOST are summarized in Table 2, Figure 2 (a) and (b), respectively. Female subject experienced musculoskeletal injuries and opted out of the VO_{2MAX} testing and performed a sub-maximal test instead for the POST sample collection. The linear equation for slope intercept was used to estimate the VO_{2MAX} $y = 0.4077x - 37.894, R^2 - 0.9985$). Figure 3 summarizes the VO_{2MAX} values of the male and female subjects. Additionally, the maximum heart rate (MHR) for VO_{2MAX} tests reported for PRE, POST, and 16wkPOST measurements: male subject 193 bpm, 192 bpm, and 193 bpm and female subject 177 bpm, 169 bpm, and 168 bpm, respectively.

3.3 Electronic Tracking Devices

Each subject had their own respective Suunto 9 watch. Data collected from their watches were gathered and summarized in Table 3 below.

4. Discussion

4.1 Anthropometrics

Both subjects experienced noteworthy changes in weight, adipose tissue and lean muscle mass when comparing PRE, POST, and 16wkPOST CDT hike measurements (See Table 2). Although, the female subject began with a notably higher body fat percentage (37.2%), she improved from a Class II to Class I obesity classification per the Centers for Disease Control and Prevention (CDC) guidelines (CDC, 2022) from PRE to 16wkPOST.

Table 2. Body composition measurements from INEVIFIT scale at PRE, POST, and 16-week POST (16wkPOST) CDT hike for male and female subjects.

MALE	PRE	MID	POST	16wk POST	FEMALE	PRE	MID	POST	16wk POST
Height (cm)	174.0	–	174.0	174.0	Height (cm)	167.6	–	167.6	167.6
Weight (kg)	70.2	–	67.4	68.5	Weight (kg)	83.9	–	82.4	85.9
BMI	23.7	–	22.7	23.1	BMI	30.0	–	29.5	30.7
Body Fat (%)	11.2	–	9.1	10.2	Body Fat (%)	37.2	–	31.3	32.4
Visceral Fat (kg)	4.5	–	3.6	4.1	Visceral Fat (kg)	3.6	–	3.6	4.1
Body Water (%)	61.8	–	63.2	62.4	Body Water (%)	45.7	–	49.6	48.8
Muscle Mass (kg)	58.0	–	57.1	57.4	Muscle Mass (kg)	48.4	–	50.5	51.6
BMR (Kcal)	1545.0	–	1503.0	1521.0	BMR (Kcal)	1454.0	–	1439.0	1474.0
Bone Mass (kg)	2.9	–	2.8	2.8	Bone Mass (kg)	2.9	–	2.9	3.0

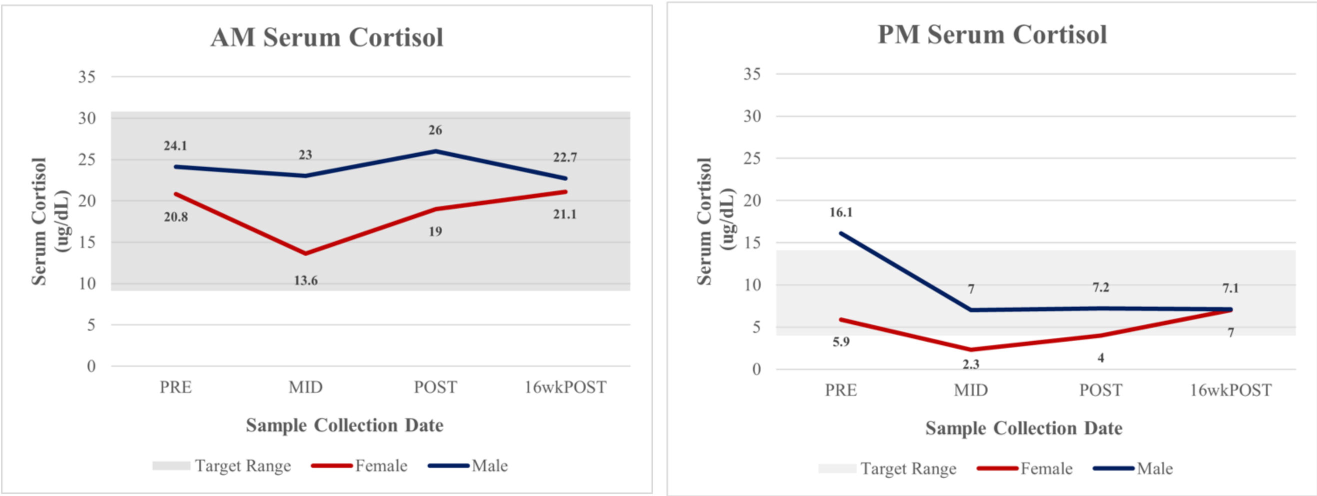

Figure 1 (a) Morning serum cortisol levels and **(b)** evening serum cortisol levels collected at PRE, MID, POST, and 16-week POST (16wkPOST) CDT hike for male and female subjects. Shaded areas represent normal AM (9.1–30.8 μg/dL) and PM (4.0–14.1 μg/dL) reference ranges.

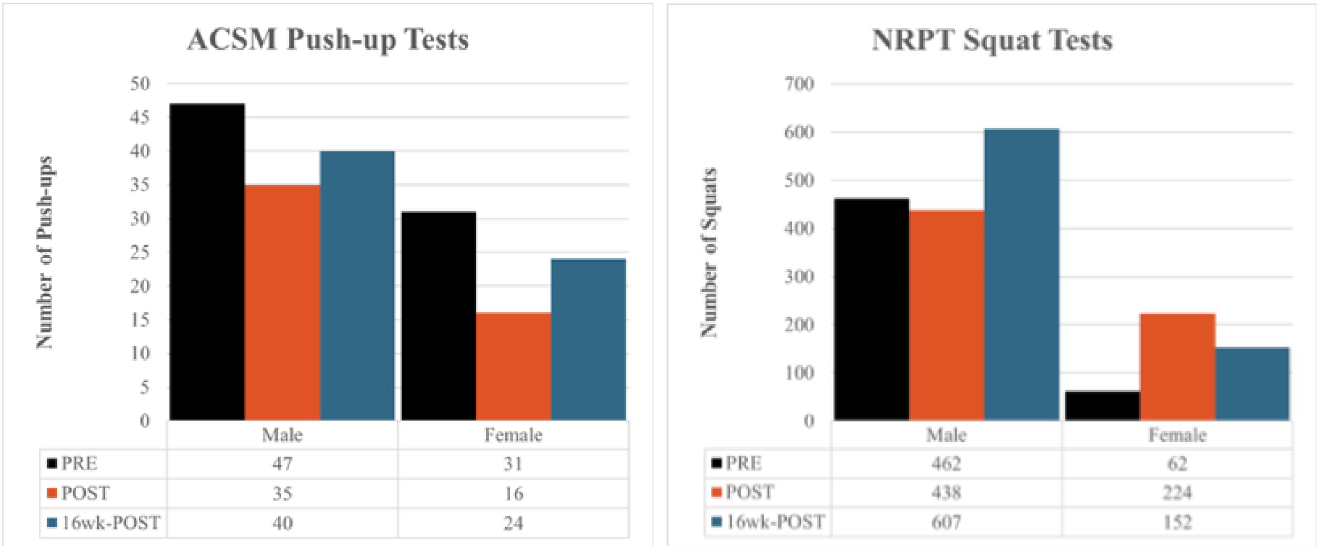

Figure 2 (a) ACSM Push-up Test and **(b)** NRPT Squat Test performance at PRE, POST, and 16-week POST (16wkPOST) CDT hike for male and female subjects.

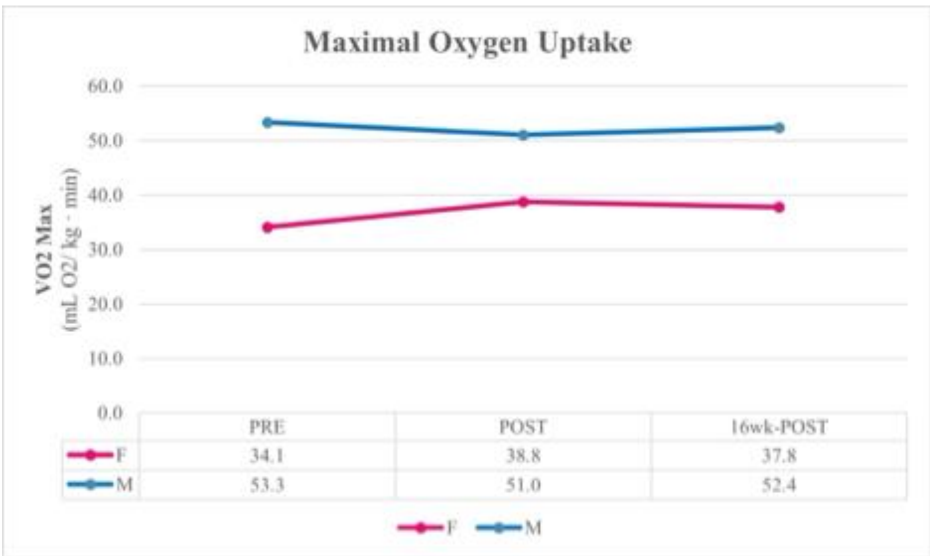

Figure 3. VO_{2MAX} results for PRE, POST, and 16wkPOST CDT hike for male and female subjects. Female subject's POST VO_{2MAX} was estimated using submaximal treadmill testing and the linear equation for slope intercept was used to estimate the VO_{2MAX} $(y = 0.4077x - 37.894, R^2 - 0.9985)$.

Table 3 Electronically recorded data from male and female subjects' Suunto 9 watches during CDT hike.

		Male		Female	
	Unit	Mean	SD	Mean	SD
Distance per day	km	22.6	5.6	21.7	4.8
Daily Estimated Calorie Expenditure	Kcal	3294.8	1345.4	2957.7	1150.7
Daily Heart Rate	bpm	108.0	5.5	105.4	9.9
Daily Peak Heart Rate	bpm	163.0	9.4	168.5	15.0
Daily Elevation Gain	m	541.0	340.4	553.0	318.3
Daily Elevation Loss	m	555.0	413.4	554.0	392.0
Moving Pace	min:sec/km	16:06		17:10	

The female subject's body mass decreased by 1.5 kg from PRE to POST CDT hike. This reduction in body mass was primarily attributed to a loss of adipose tissue (-5.9%), combined with an increase in muscle mass (+2.1 kg). The data also suggests a decrease in subcutaneous adipose tissue, as reflected in a reduction of body fat percentage of 5.9%, while visceral fat mass remained unchanged from PRE to POST CDT hike. When comparing the PRE, POST, and 16wkPOST measurements for the female subject, data suggests a sustained decrease in adipose tissue mass and continued gain in muscle mass. Although there was an overall increase in visceral fat mass by 0.5 kg from PRE to 16wkPOST CDT hike measurements, the data shows a maintained reduction of body fat (-4.8%) from PRE to 16wkPOST. Furthermore, an additional increase of 0.9 kg of muscle mass was measured from POST to 16wkPOST CDT hike, summing a total of 3.2 kg of muscle mass gained from PRE to 16wkPOST CDT hike for the female subject This data suggests that thru-hiking may be beneficial for individuals with higher adipose tissue composition for long term weight loss and muscle gain when performing this type of extreme recreational activity.

Although weight loss and muscle gain are usually the goal of most fitness enthusiasts, there can be disadvantageous health effects that thru-hikers can experience. For example, the male subject had decrease in weight loss from PRE to POST CDT hike due to a reduction in adipose tissue (-2.1%), visceral adipose tissue (-0.9kg), and muscle mass (-0.9kg). Additionally, there was a minimal decrease in bone mass (-0.1 kg) from PRE to POST CDT hike. There was an overall loss of body mass (-1.7kg) and muscular mass (-0.6kg) from PRE to 16wkPOST CDT hike, suggesting a long-term muscular catabolism in the male subject. Previous research highlights that thru-hiking can negatively impact the body due to extensive daily physical exertion and suboptimal nutrition (Heinbockel & Craighead, 2021). Although diet was not factored into this study, subjects reported eating calorically dense and nutritionally poor options to sustain their hunger throughout the trail. Additionally, depending on the initial body composition measurements, thru-hiking may have long-term beneficial or deleterious effects on one's body. More studies are needed to (A) develop a deeper understanding of the physiological demands of tissue utilization for fuel while on the trail and (B) explore the advantageous and disadvantageous long-term health effects on thru-hikers.

4.2 Muscular Endurance

The muscular endurance testing data further supports the changes observed via the BIA scale data collected at PRE, POST and 16wkPOST. Despite the low back, knee and foot injuries reported by the female subject, she showed an increase of 361% in squat performance from PRE to POST CDT hike, likely due to the increase in muscular mass (+2.1kg) from PRE to POST hike. The female had a 48.4% decrease in upper body muscular endurance shown via the push-up performance testing from PRE to POST CDT hike. This result was expected due to the lack of upper body resistance training performed while on the CDT. In contrast, the male subject presented a more adverse response to his muscular endurance performance. There was a decrease in lower body muscular endurance performance (-5.2%) for the squat test from PRE to POST CDT hike. Similarly, the male subject had a decrease in upper body muscular endurance (-25.5%) from PRE to POST CDT hike. While the decrease in upper body muscular endurance could be attributed to lack of training, the decrease in lower body muscular endurance performance could be due to the decrease in muscle mass (-0.9kg) from PRE to POST CDT hike for the male subject. It is likely that caloric intake was insufficient to meet the energy demands of hiking over 21+ km daily with significant elevation changes. This inadequate energy intake may explain the male subject's loss of both adipose and lean muscle tissue. Such physiological demands could have long-term health implications, underscoring the need for further research to understand the effects of prolonged thru-hiking on body composition and overall health.

4.3 Aerobic Performance

Thru-hikers undergo a staggering physical achievement when partaking in these types of extreme recreational activities. The subjects within this study traveled an average of over 21 kilometers per day while traversing elevation gains of 550 meters and losses of 550 meters with loaded backpacks. Both subjects were classified as having *good* cardiorespiratory fitness according to American College of Sports Medicine (ACSM) standards for cardiorespiratory fitness by age and sex (ACSM, 2018). The 28-year-old male's and 32-year-old female's VO_{2MAX} measurements were within the 60th–70th percentile and 65th–70th percentile, respectively, for their PRE CDT hike measurements. There was no distinct change in the male subject's VO_{2MAX} results. The male subject averaged a faster pace than the female subject by 1:04 (min:sec/km), suggesting that the male subject may not have been able to improve his maximal aerobic capacity due to this pacing limitation imposed on him via his travel companion. The female subject experienced an estimated 13.8% increase in VO_{2MAX} from PRE to POST and maintained a 10.8% increase into the 16wkPOST CDT hike measurements. This substantial increase elevated her ACSM cardiorespiratory fitness classification from "good" to "excellent," and placing her in the 80^{th}-85^{th} percentile. This improvement suggests that thru-hiking, as a form of chronic exercise training, may significantly enhance maximal aerobic capacity.

4.4 Effects on HPA Axis

Research suggests that an individual will need to complete at least 15-30 minutes of exercise at one's 60% VO_{2MAX} to provoke an acute response from the HPA axis to secrete cortisol (Anderson & Wideman, 2017; Crewther *et al.,* 2008; Hill *et al.,* 2008). The male subject's Heart Rate Maximum (HRM) was determined to be 193 bpm during the PRE VO_{2MAX} testing. The male subject had an average Daily Peak Heart Rate (DPHR) of 163 bpm (85% of HRM) and had an average Daily Heart Rate (DHR) of 108 bpm (56% of HRM). The female subject's HRM was determined to be 177 bpm during the PRE VO_{2MAX} testing. The female subject had an average DPHR of 169 bpm (95.5% of HRM) and an average DHR of 105 bpm (59.3% of HRM). With the data presented from this study, it is reasonable to suggest that the subjects attained PHR values above their respective 60% VO_{2MAX} thresholds daily. The intermittent high-intensity exercise bouts on hiking days likely prompted a repeated activation of the HPA axis, triggering cortisol release on an acute level multiple times a day.

More research is needed to determine duration and frequency thru-hikers achieve exercise intensity levels of 60% VO_{2MAX} or higher while on trail to fully understand the physiological effects on the HPA axis. These cumulative effects may also have a long-term effect on the HPA axis as supported by previous studies with chronic exercise (Anderson & Wideman, 2017; Batista *et al.,* 2015; Crewther *et al.,* 2008; Helgadóttir *et al.,* 2016; Ogasawara *et al.,* 2022; Scerbo *et al.,* 2010; Telles *et al.,* 2015; Wegner *et al.,* 2019). The serum cortisol data suggests that the chronic exercise training effects of thru-hiking did not affect CAR concentrations because of both the male and female subject remained within normal range limits and there were no distinct differences throughout the course of the study. There was a large decrease in evening (PM) cortisol concentrations for both the male (-56.5%) and female (-61%) subject from PRE to MID measurements. This decrease in evening serum cortisol levels was maintained from the POST and 16wkPOST measurements for the male subject, suggesting long-term positive effects on HPA axis regulation. The female subject began to steadily increase her PM serum cortisol concentration from MID to 16wkPOST, suggesting that long-term effects on the HPA axis will vary from individual to individual.

Long-distance hiking is known to produce positive effects on one's mental health (Aras *et al.,* 2024; Ma *et al.,* 2024; Mau *et al.,* 2021). This study suggests that thru-hiking influences the HPA axis by reducing evening serum cortisol concentrations which can be attributed to chronic exercise training in nature. There is potential that thru-hiking may affect cortisol variability, homeostatic balance, and HPA axis resiliency via reducing evening cortisol concentrations. These beneficial changes to the HPA axis may affect one's psychological health. Findings support that thru-hiking could be used as an additional tool to help individuals mitigate health conditions caused by elevated evening cortisol concentrations, such anxiety, depression, panic attacks, and posttraumatic stress disorder (PTSD)(Austin *et al.,* 2016; Batista *et al.*, 2015; Bayoumi *et al.,* 2012; Caplin *et al.,* 2021; Engert *et al.,* 2011; Gunnar & Vazquez, 2001; Hadley & Levine, 2006; Hannibal & Bishop, 2014; Hellhammer *et al.,* 2009; Holsboer, 2001; Li & Goldsmith, 2012; Matousek *et al.,* 2010; Ogasawara *et al.,* 2022; Streeter *et al.,* 2012; Thirthalli *et al.,* 2013; Yoshihara *et al.,* 2014) Consistent with findings from prior research, the chronic exercise demands of the CDT likely promoted endocrine resiliency and adaptation with the HPA axis (Anderson & Wideman, 2017; Batista *et al.,* 2015; Helgadóttir *et al.,* 2016; Scerbo *et al.,* 2010; Telles *et al.,* 2015; Wegner *et al.,* 2019). Thru-hiking may serve as a valuable model for examining how chronic exercise training can impact stress regulation, mental health, and long-term HPA axis function.

4.5 Limitations

This study is limited by its observational nature and small sample size, which restricts the generalizability of the findings. While heart rate and GPS data provided valuable insights into the physical intensity of the hikes, the absence of precise measurements that quantify the time spent above the 60% VO_{2MAX} threshold limits the ability to fully assess the depth of physiological adaptation. Additionally, the female subject's musculoskeletal injuries and her inability to complete a maximal VO_{2MAX} test immediately POST CDT further constrained the evaluation of her aerobic fitness outcomes. Dietary intake and nutritional strategies were not quantified or standardized, leaving both energy balance and tissue fuel utilization unaccounted for. Future research should incorporate detailed dietary tracking and nutritional analysis for thru-hikers to better understand the relationship between energy intake and body composition changes.

This case study involved two self-selected, moderately active adult participants who volunteered to complete the research protocol across a 9-month timeline. Due to the logistical, financial, and environmental constraints associated with data collection in remote backcountry settings, a small-sample case-study design was the most practical approach. Although the repeated-measures format enabled meaningful within-subject comparisons across four phases, the study was not powered for inferential statistical analysis and is not intended to support broad generalizations. Findings are purely descriptive and intended to serve as preliminary observations. There is a need for replication in larger and more diverse cohorts to enhance reliability and external validity.

6. Conclusion

This case study provides valuable evidence of the physiological and endocrine responses associated with prolonged thru-hiking on the Continental Divide Trail. Both subjects demonstrated significant adaptations in body composition, muscular endurance, and serum cortisol concentrations, highlighting the demanding nature of long-distance hiking. The reductions in evening cortisol levels from PRE to MID hike suggest that thru-hiking may contribute to enhanced stress regulation and improved HPA axis resiliency during due to chronic exercise training. Notably, the male subject maintained lower evening cortisol levels at 16wkPOST hike, whereas the female subject's levels returned toward baseline, indicating potential individual variability in long-term adaptation. These findings underscore the potential of thru-hiking to serve as a model for studying the interplay between chronic exercise training, stress physiology, and health outcomes. They also emphasize the dual potential for beneficial and adverse effects, depending on baseline characteristics, injury status, and recovery strategies. While this study provides novel insights, further research is needed with larger cohorts to refine understanding of the chronic effects of thru-hiking. More research will help to develop evidence-based recommendations for preparation, nutrition, and recovery that promote optimal health and minimize risk for negative long-term health outcomes.

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Ethics Approval Statement

This study was reviewed and approved by the Montana State University Institutional Review Board (IRB), Bozeman, Montana (IRB Approval Number: Protocol #: 2021-65-MH030921).

Does this article pass screening for similarity?

Yes

Data Availability Statement

Additional data tables and raw data files are available upon reasonable request.

Informed Consent

Written informed consent was obtained from both participants prior to their inclusion in the study.

Conflict of Interest

The authors declare that there was no conflict of interest.

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