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CORTISOL, PHYSICAL ACTIVITY, AND WEIGHT LOSS IN A RANDOMIZED CLINICAL TRIAL

Shawn S. Smith
University of Kentucky, big3s1987@gmail.com

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Shawn S. Smith, Student

Dr. Kelly Webber, Major Professor

Dr. Kelly Webber, Director of Graduate Studies

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THESIS

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Shawn S. Smith

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Director: Dr. Kelly Webber, PhD, MPH, RD, LD

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ABSTRACT OF THESIS

CORTISOL, PHYSICAL ACTIVITY, AND WEIGHT LOSS IN A RANDOMIZED CLINICAL TRIAL

Abnormal cortisol levels may be an important factor in the ability of an individual to lose weight and maintain weight loss. This study examined overweight and obese individuals who participated in a weight loss program. Cortisol, physical activity, and weight loss were measured at regular intervals and examined for possible relationships

KEYWORDS: Cortisol, Physical Activity, Weight Loss, Stress, Exercise

Shawn S. Smith

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By

Shawn S. Smith

Dr. Kelly Webber, PhD, MPH, RD, LD
Director of Thesis

Dr. Kelly Webber, PhD, MPH, RD, LD
Director of Graduate Studies

December 11, 2014
Date

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Chapter 1. Introduction

Booming obesity rates plague America, affecting both adolescents and adults. Obesity is associated with numerous diseases such as diabetes, heart disease, and certain cancers. Reducing the prevalence of obesity is of paramount concern (Carlson and Gerrier, 2006). According to a recent study, the U.S. is expected to spend $344 billion on health care costs attributable to obesity in 2018 if obesity rates continue to increase at their current rates. This estimate would translate to obesity-related expenditures accounting for more than 21% of the nation's direct health care spending in 2018 (United Health Foundation, 2009). As such, it is of great importance that initiatives are taken to combat the escalation in obesity in America.

Shifting from an obese state towards a healthier body weight reduces many health risks associated with obesity such as insulin resistance, diabetes mellitus, hypertension, dyslipidemia, sleep apnea, hypoxemia and hypercarbia, and osteoarthritis (Pi-Sunyer, 1993). Unfortunately, a reduction and sustained weight loss can be a very daunting task for most individuals. According to an NHANES study conducted between 1999 and 2006, 35% of total participants surveyed (n=14,306) were successful at maintaining a weight loss of at least 5% for more than a year (Kraschnewski et al., 2010). However, intensive, structured, behavioral-based programs can result in a significant amount of weight lost (Anderson et al., 2001). Many of these programs encompass calorie restriction, progressive physical activity, and lifestyle and behavioral changes (Hill, Thompson, & Wyatt, 2005). Even still, many individuals fall short of their weight loss goals despite adherence to a weight loss program.

Exercise, dieting, and behavioral modifications are not the only determinants of body weight. Genetic, hormonal, and metabolic factors heavily influence body weight and condition (Anderson et al., 2001). The overabundance or lack of cortisol, a stress-related hormone, may be a key player in the ability of an individual to reduce and maintain body weight. When stress is induced via intrinsic or extrinsic forces, a myriad of physiological responses are produced in the body in order to reestablish equilibrium. One such physiological adaption is the release of cortisol. Studies have shown abnormally high or low cortisol concentrations are related to dysregulation of the hypothalamic-pituitary-adrenal axis (HPA), chronic stress, upper body fat, and insulin resistance (Bose et al., 2009). Abnormal cortisol production has also been positively linked with obesity and impaired carbohydrate metabolism (Rosmond et al., 2000). More notably, obesity has been proposed to produce a chronic, stressful state which is characterized by a wide range of diseases and symptoms including metabolic syndrome (Kyrou et al., 2006). In summary, these conditions associated with cortisol abnormalities seem to create an undesirable environment for optimal weight loss.

If excessive cortisol does in fact inhibit normal metabolic function, it would be beneficial to conduct research that explores possible mechanisms leading to overproduction. Low intensity physical activity is one promising approach to cortisol reduction. A study conducted in 1992 showed that brisk walking and other forms of low-intensity exercise improved mood, lowered salivary cortisol, and improved resting heart rate and blood pressure (Jin, 1992). If such a relationship exists, adopting a low-intensity exercise program may provide an appropriate treatment for both lowering of cortisol and reduction of bodyweight in obese individuals. Analyzing cortisol levels in obese and overweight individuals may also present a possible hormonal and metabolic explanation as to why individuals fail to lose weight despite caloric restriction and increased physical activity. If such a correlation is present, it could provide a new strategy to reduce the risk of obesity.

Chapter 2. Methodology

Research Purpose

The purpose of this research is to add to the body of knowledge exploring the relationship of cortisol, obesity, and weight loss. The main objective of this research is to determine if excessive cortisol levels at baseline suppress the ability of obese adults to lose weight during a weight loss program. The central hypothesis for this research is that individuals who have elevated levels of cortisol at baseline will fail to produce significant weight loss at 10 and 20 weeks follow-up. Additionally, increasing levels of physical activity will be correlated with decreasing levels of cortisol at 10 and 20 weeks follow-up.

Research Questions

- Is there a correlation between baseline cortisol levels in research participants and weight loss at 10 and 20 weeks?
- Does cortisol at 10 weeks predict weight lost at 20 weeks?
- Is there a correlation between week 20 cortisol levels and weight loss at 20 weeks?
- Is there a correlation between change in physical activity level and change in cortisol levels from baseline to 10 weeks and baseline to 20 weeks?

Study Design:

This was a two group randomized experimental design study. One group received a standard weight loss program and one group received a stress management based intervention built on research in neuroscience and principles of the attachment theory. The active intervention portion of the study lasted ten weeks and a follow-up (no face-to-face contact) period of ten weeks occurred before final evaluations. There was no deception involved in this study.

Study Population:

The study was conducted from February to July 2014. Both males and females were recruited. After providing written consent and a signed physician's consent form, along with completing baseline assessments, individuals (n=49) were randomized to one of two groups, each of which received a 10-week face-to-face intervention. The 10-week intervention period was followed by a 10-week low-contact period to assess maintenance of changes.

Inclusion criteria: Participants must have (1) been 25-55 years of age (2) had a BMI of $\geq$ 28 and $\leq$45 (3) met criteria for at least one additional risk factor for metabolic syndrome (waist circumference or blood pressure) (4) owned and used a smartphone.

Exclusion criteria: Participants must not have: (1) had a medical diagnosis of orthopedic or joint problems that may have prohibited regular exercise; (2) endorsed any of the first three items on the Physical Activity Readiness Questionnaire (PAR-Q): heart problems, chest pain, faintness or dizzy spells; (3) endorsed any of the other items on the PAR-Q without a physician's consent; (4) had a hospitalization for a psychiatric disorder within the last year; (5) had a history of anorexia or bulimia nervosa; (6) had a medical diagnosis of cancer or HIV; (7) had a diagnosis of a major psychiatric disorder (i.e. bipolar disorder or schizophrenia) or taken anti-psychotic medications; (8) been pregnant, nursing, or planning to become pregnant within the study period; (9) been less than 9 months post-partum; (10) had a weight loss of $\geq$ 10 pounds in the last six months; (11) been on more than two medications for hypertension control; (12) greater than stage 3 kidney disease; (13) been taking insulin to control diabetes; (14) been taking Coumadin; (15) been taking Lasix (16) and anyone, who in the opinion of the study investigators, were not considered a good candidate for the study. All of this information was self-reported in the initial screening phone call.

Dr. Webber and the research assistant conducted study information sessions for potential participants during January and February 2014. These sessions were conducted in a classroom at the University of Kentucky. Interested and qualified participants were asked to receive approval from their primary care physician, sign study consent forms, and fill out questionnaires: Demographics, Paffenbarger Physical Activity Questionnaire (Ainsworth et al., 1993), the Center for Epidemiological Studies Depression Scale (Radloff, 1977), the Perceived Stress Scale (Cohen, Kamarck, and Mermelstein, 1983 and Cohen and Williamson, 1988), the Block 2005 Food Frequency Questionnaire (Block et al., 1990), the Yale Food Addiction Scale (Gearhardt et al., 2008), the Eating Attitudes Test-26 (Garner et al., 1982 and Mintz and O'Halloran, 2000), and the Short Form-36 Quality of Life Survey (Melville et al., 2003). Participants were also asked to schedule appointments at the UK Clinical Research Development and Operations Center (CR-DOC) for baseline assessments of height, weight, waist circumference, blood pressure, and blood draw for fasting blood glucose, insulin, high sensitivity c-reactive protein, lipid panel, and telomere length. The cortisol mouth swab was dropped off at the lab at this time. Once measurements at the CR-DOC were taken, participants were randomized to study group.

Each study group was divided into smaller groups of 8 or 9 participants each. Each group met once per week (90 minute sessions) for ten weeks at the offices of the certified Emotional Brain Training (EBT) provider or on campus in a classroom or conference room with a Registered Dietitian. The stress management (EBT) based group followed the Wired for Freedom weight loss book provided by the Institute for Health Solutions and was led by the certified EBT provider. The control group received weekly group sessions based on the Diabetes Prevention Program for ten weeks provided by the Project Coordinator or Dr. Webber, both registered dietitians.

During the first week of the study, subjects were instructed to wear a New Lifestyles-1000 (NL; LeesTown, MO) medical grade activity monitor for 7 consecutive days. This monitor was chosen for its simplicity, durability, low cost, seven-day memory capability, accuracy, reliability, and ability to assess time spent in moderate-to-vigorous activity. The subjects were instructed to place the activity monitor on their waistband at the anterior midline of the thigh, on the right side of the body, according to manufacturer's recommendations. Subjects placed the monitor on their waistband (or a nylon belt provided) upon awakening in the morning and took it off when they went to bed at night, unless they came into contact with water (e.g., bathing and swimming). To avoid reactivity, all activity monitors were sealed using stickers after stride length, time of day, and an intensity threshold were internally programmed. Stride length was measured by the average of two- 20 step “normal length and paced” walks down a hallway corridor. The researchers set the NL activity monitor moderate-to-vigorous physical activity (MVPA) threshold at an appropriate activity setting for the subjects (setting #3), based on recommendations from the manufacturer.

Participants were contacted and scheduled for an assessment visit at 10 weeks conducted at the CR-DOC. Participants were given a cortisol mouth swab kit, instructions, ice packs, and a small container. Participants were asked to use the kit to get a cortisol sample immediately on awakening or between 7 and 9 am on the morning before their visit at the CR-DOC lab. The same measurements and assessments completed at baseline were taken at 10 weeks, with the exception of height. Each participant received $50 for attending the 10-week assessment to ensure adequate follow-up rates. Participants were again asked to wear the New Lifestyles-1000 activity monitors for seven days. The monitors were given out at the 10 week face-to-face group session and participants were asked to return in one week to drop off the monitors.

The last 10-weeks of the study involved only email and phone call contact with participants. No face-to-face groups were conducted.

At week 19 participants were asked to come in and get the physical activity monitors to use for the last week of the study. Participants were again asked to wear the New Lifestyles-1000 activity monitors for seven days. The monitors were retrieved from participants at their final assessment visit at the lab. Participants were given a cortisol mouth swab kit, instructions, ice packs, and a small container. Participants were asked to use the kit to get a cortisol sample immediately on awakening or between 7 and 9 am on the morning before their visit at the CR-DOC lab.

Participants were contacted and scheduled for an assessment visit at 20 weeks to be conducted at the CR-DOC. The same measurements and assessments taken at baseline were taken at 20 weeks, with the exception of height. Each participant received $75 for attending the 20-week assessment to ensure adequate follow-up rates. Participants were also mailed all of their lab values if they completed the entire study and all three assessments.

Statistical Methods:

Descriptive statistics were used to characterize the sample. Data were checked using the Kolmogorov-Smirnov test for normality (McClave, Dietrich, and Sincich, 1997). Data were not normally distributed, so nonparametric tests were used. Spearman's rho was used to test for correlations (McClave, Dietrich, and Sincich, 1997). Linear regression was used to predict 20-week weight loss.

Chapter 3. Literature Review

Weight Loss: Safe, effective methods

Weight loss is, quite logically, the primary solution to obesity. Surgical procedures are effective as well, but are only recommended to select candidates. There are a vast array of methods available to an individual attempting to lose weight. However, not all are widely accepted as safe and effective. According to the 2013 American Heart Association/American College of Cardiology/The Obesity Society Guideline for the Management of Overweight and Obesity in Adults, an energy deficit is required to lose weight and the following dietary techniques are an acceptable means to do so:

"Specification of an energy intake that is less than that required for energy balance, usually 1,200 to 1,500 kcal/day for women and 1,500 to 1,800 kcal/day for men (kcal levels are usually adjusted for the individual's body weight and physical activity levels); Estimation of individual energy deficit of 500kcal/day or 750kcal/day or 30% energy deficit; and Ad libitum approaches where a formal energy deficit is not prescribed, but lower calorie intake is achieved by restriction or elimination of particular food groups or provision of prescribed foods."

(Jensen MD, et al., 2013)

Along with a reduced-calorie diet, physical activity and behavioral therapy are also integral parts of many successful weight loss programs. The following parameters describe how effective, on-site comprehensive-lifestyle interventions address physical activity and behavioral therapy:

"...increased physical activity (such as brisk walking) for $\geq$ 150 minutes/week (equal to $\geq$ 30 minutes/day, most days of the week). Higher levels of physical activity, approximately 200 to 300 minutes/week, are recommended to maintain lost weight or minimize weight regain long-term (>1 year)."

"Comprehensive lifestyle interventions usually provide a structured behavior change program that includes regular self-monitoring of food intake, physical activity, and weight. These same behaviors are recommended to maintain lost weight, with the addition of frequent (i.e. weekly or more often) monitoring of body weight."

(Jensen MD, et al., 2013)

The importance of calorie reduction, increased physical activity, and self-monitoring behaviors is of chief importance in weight loss maintenance as well. The Look AHEAD study provided data that showed those who maintained a greater than 10% weight loss at the conclusion of the study all practiced high levels of physical activity, reduced caloric intake, and monitored their bodyweight frequently (Wadden, et al., 2014).

Cortisol: Profile and Functions

Hormones are extremely powerful molecules manufactured in the human body. They are used for communication between tissues with the ultimate goal of regulating bodily processes and behaviors. There are over fifty different hormones in the human body, each with a specific host of functions. When released from a gland via the network known as the endocrine system, the hormone travels to the target tissue to transmit information that will lead to a specific action.

Cortisol, a hormone produced in the adrenal glands, is a glucocorticoid whose main function is to restore homeostasis as a result of the stress response. Whenever a stress response is triggered or a low blood sugar level is detected, cortisol is released from the adrenal cortex and is used to stimulate the process of gluconeogenesis in the liver. As glucose is formed from various amino acids, blood sugar rises and more energy is available. Cortisol also plays an important role in glycogenolysis, an important process for utilization of potential energy that also ultimately leads to an increase in blood glucose levels. Cortisol is simply the key to activating the mechanisms which ensures a steady supply of glucose to the body.

In addition to metabolic function, cortisol plays a role in immune function. Cortisol prevents an over-activation of the inflammatory response. This is beneficial because chronic inflammation leads to damaging of tissue. Cortisol keeps inflammation in check by blocking T-cell proliferation and inhibition of histamine secretion. This is mimicked in the pharmaceutical world, where derivatives of cortisol such as hydrocortisone and prednisolone are used as means to control inflammation and suppress the immune response.

Hypercortisolism Among the Obese

Obesity is a known characteristic of hypercortisolism (Cushing's Syndrome), but it is still unclear as to whether hypercortisolism is a characteristic of obesity. Signs and symptoms of hypercortisolism are: upper body obesity, severe fatigue and muscle weakness, high blood pressure, backache, elevated blood sugar, easy bruising, and bluish-red stretch marks on the skin. Prolonged periods of synthetic glucocorticoid steroids, tumors of the pituitary glands and adrenal glands, and ectopic adrenocorticotropic hormone (ATCH) are all common causes of hypercortisolism. Currently, there is no consensus in the literature concerning the relationship between obesity and high levels of cortisol.

Strain, Zumoff, Levin, and Fukushima (1980) found that there was not a significant elevation of cortisol production due to obesity, but with greater increases in lean body mass. However, it has also been suggested that an increase in visceral fat accumulation positively correlates to elevated cortisol secretion in women (Marin et al., 1992). This suggests that both added muscle mass and fat mass contribute to higher levels of cortisol. This is evidenced by a study conducted by Mlynaryk, Gillies, Murphy, and Pattee (1961) which concluded that production of cortisol is proportional to bodyweight in general.

Weight Loss and Cortisol Levels

Hormonal changes occur within the body when bodyweight is dramatically lost or gained. The HPA (hypothalamic-pituitary-adrenal) axis, which controls cortisol production, is particularly subject to altered function when such a weight change occurs. However, the direction in which weight loss influences cortisol levels remains controversial.

Massive weight loss among morbidly obese subjects has been shown to increase free cortisol and decreased cortisol binding globulin levels (Manco et al, 2007). This increase in cortisol levels with massive weight loss may occur due to an adaptive phenomenon related to environmental changes which induced stress. Cortisol levels have also been increased due to weight reduction among subjects with depression, suggesting weight loss does account for changes in the functioning of the HPA axis (Casper et al, 2007).

In obese vs healthy weight children, obese children with insulin resistance had higher levels of cortisol than healthy weight children. Upon weight reduction, the obese children with insulin resistance experienced a decrease in cortisol levels (Reinehr et al, 2004). Diet may also play a contributing factor in the way in which weight loss influences cortisol production. Johnstone, Faber, and Andrew (2004) found that obese men who lost weight with a very low calorie diet vs starvation normalized their cortisol production from an over-productive state.

There seems to be several covariates in the relationship between weight loss and cortisol production. Given the complex and intricate function of the endocrine system and the HPA axis, well-controlled studies are needed in order to draw more solid conclusions concerning this relationship.

Effects of Physical Exercise on Cortisol Levels

Physical activity promotes many favorable effects on the human body such as weight control, reduced risk of certain major chronic diseases, strengthening of tissues, and improvement in mental health and energy. Many of these benefits are a result of the action of hormones in the body. Growth hormone is released during and after intense anaerobic exercise, boosting protein synthesis, body fat catabolism, energy production, and well-being. Insulin production and sensitivity are also improved through regular exercise. Cortisol, the stress-related hormone, is no exception to stimulation when exercise occurs.

The degree to which cortisol is affected by exercise seems to be dependent on several variables. Kindermann et al. (1982) examined exercise duration and intensity on cortisol concentrations by assigning participants to three different treadmill regimes. Upon completion of the physical activities, it was determined an anaerobic intensity and longer duration increased cortisol levels more than aerobic intensity and shorter exercise periods. These relationships can also be seen in studies conducted by Hill et al. (2008) and Farrell et al. (1983). Higher intensity exercises such as sprinting resulted in stronger releases in cortisol while lower intensity exercises such as yoga led to a much lower release of cortisol or sometimes an improvement of baseline cortisol levels. Duration, no matter what form of exercise used, also had a positive relationship with cortisol release.

When a stressful event such as exercise stimulus occurs, the body responds by releasing cortisol. Therefor, an individual who exercises regularly experiences more frequent cortisol responses when compared to an inactive individual. This leads to speculation as to whether this response is desensitized when routinely mediated through physical exercise. If this theory were true, regularly active individuals would experience a blunted cortisol response to exercise when compared to inactive individuals. Rudolph and McAuley (2010) compared the cortisol response of 13 male cross-country runners and 13 non-runners after bouts of 30 minute exercise on a treadmill. At the conclusion of the experiment, no significant group differences in cortisol responses were found. However, perceived exertion was positively related to post-exercise cortisol levels in both groups, suggesting a subjective component playing a role in the cortisol response.

Chapter 4. Results

Descriptive Statistics

The population sample (n=49) had a mean baseline BMI of 36.56 (±4.45) kg/m^2, a mean age of 44.69 (±8.36) years and a mean baseline waist circumference of 43.15 (±4.37) inches. The sample was mostly non-Hispanic white (n=40, 81.6%), 14.3% (n=7) was African-American, 2% (n=1) was Hispanic/Latino, and 2% (n=1) was Asian. Out of the entire population sample, 16.3% (n=8) were male and 83.7% (n=41) were female. Marital status data was collected, and 69.4% (n=34) were married, 14.3% (n=7) were divorced, 14.3% (n=7) were never married, and 2% (n=1) was not reported. Graduate/Professional degrees were earned among 20.4% (n=10) of the sample population, 34.7% (n=17) earned Bachelor's degrees, 22.4% (n=11) had some college coursework, 18.4% (n=9) earned Associate's degrees, and 4.1% (n=2) earned a High School degree. Mean baseline steps taken per week was 33,232.56 (±15363.76), mean baseline moderate to vigorous physical activity (MVPA) in minutes per week was 75.67 (±61.77), and mean baseline cortisol levels were 0.46 (±.43).

Table 4.1 Physical Characteristics of the Population Sample

BMI (kg/m²)	Waist Circumference (inches)	Age (years)
36.56 ± 4.45	43.15 ± 4.37	44.69 ± 8.36

Note: BMI, Waist Circumference, and Age are given as mean ± standard deviation

Table 4.2 Baseline Physical Activity and Cortisol Level

Steps Per Week	MVPA in Minutes	Cortisol Levels
33,232.56 ± 15363.76	75.67 ± 61.77	0.46 ± 0.43

Note: Steps Per Week, MVPA, and Cortisol Levels are given as mean ± standard deviation

Predictors of Weight Loss

There was no correlation between baseline cortisol levels and weight loss at either 10 weeks (r=0.24, p=0.12) or 20 weeks (r=0.07, p=0.65). Cortisol levels at 10 weeks did correlate with greater weight lost at 20 weeks (p=0.05). The linear regression model explained 7% of the variance weight loss when baseline and 10-week cortisol levels were included. There was no correlation between week 20 cortisol levels and weight loss at 20 weeks (r= 0.18, p=0.25).

There was no correlation between number of minutes in MVPA and change in cortisol levels between baseline and 10 weeks (r= 0.17, p=0.29) or baseline and 20 weeks (r= 0.04, p=0.82). Number of steps was also not correlated with change in cortisol levels between baseline and 10 weeks (r=0.26, p=0.11) or baseline and 20 weeks (r=0.03, p=0.84).

Table 4.3 Cortisol Levels among Groups

	Baseline	10 weeks	20 weeks
Emotional Brain Group	0.42 ± 0.53	0.39 ± 0.22	0.52 ± 0.57
Registered Dietitian Group	0.50 ± 0.31	0.46 ± 0.32	0.42 ± 0.2

Note: Cortisol levels are given as mean ± standard deviation

Table 4.4 Moderate-to-Vigorous Physical Activity (in minutes) among Groups

	Baseline	10 weeks	20 weeks
Emotional Brain Group	80.17 ± 65.55	96.13 ± 76.62	69.04 ± 61.04
Registered Dietitian Group	70.95 ± 58.72	102.71 ± 103.46	69.2 ± 93.14

Note: MVPA is given as mean ± standard deviation

Table 4.5 Steps per Week among Groups

	Baseline	10 weeks	20 weeks
Emotional Brain Group	34546.26 ± 15889.90	38048.58 ± 19333.42	30751.71 ± 24009.56
Registered Dietitian Group	31859.14 ± 15039.68	36688.29 ± 24000.36	26469.76 ± 25704.95

Note: Steps per week is given as mean ± standard deviation

Chapter 5. Discussion

The first goal of this study was to determine if there was a correlation between baseline cortisol levels and weight loss at 10 or 20 weeks. It was hypothesized that a higher baseline cortisol level would negatively influence weight loss at 10 and 20 weeks. It was determined there was no correlation between weight lost at 10 weeks ($p=0.12$) or 20 weeks ($p=0.65$) with baseline cortisol levels. Previous findings both support and oppose a correlation between these two variables. Manco et al. (2007) found subjects who lost a significant amount of weight both increased free cortisol levels and decreased cortisol binding globulin levels. Johnston, Faber, and Andrew (2004) encountered normalizing of their subject's cortisol levels after weight loss. All of these studies utilize different weight loss methods and programs along with different subjects with various conditions and co-morbidities. This large variance in research design among this and other studies performed in the past may explain the lack of consistent evidence supporting a relationship between cortisol and weight loss.

The second goal of this study was to determine if cortisol levels at 10 weeks were related to weight loss at 20 weeks. A hypothesis was formulated that supported the theory of higher cortisol levels at 10 weeks with an impedance of weight lost at 20 weeks. Results determined that the inverse of the hypothesis occurred. In a linear regression model, cortisol levels at 10 weeks predicted weight loss at 20 weeks. Previous studies provide a mixture of conclusions, but the overall catabolic nature of cortisol may explain the relationship seen in this study. Since cortisol's primary function is to raise blood sugar through gluconeogenesis, it is intuitive to interpret cortisol elevation with increased utilization of protein and fat for energy. With chronic catabolic metabolism, one might expect bodyweight to continually fall given the constant proteolysis and lypolysis occurring in the body to sustain energy levels.

The third objective was to examine a possible relationship between cortisol levels at 20 weeks and weight loss at 20 weeks. It was hypothesized that cortisol levels at 20 weeks would be higher among participants who lost the least amount of weight. No correlation was found between cortisol at 20 weeks and weight loss at 20 weeks. Reinehr et al. (2004) discovered that obese children with insulin resistance experienced a decrease in cortisol levels after weight reduction. The difference between this study and the results might be from utilizing all diabetic participants. Since insulin and cortisol work antagonistically from one-another, cortisol may behave differently in humans with compromised insulin function.

The final goal of this study was to determine whether a relationship exists between change in activity levels and cortisol levels from baseline to 10 weeks and baseline to 20 weeks. It was hypothesized that higher activity levels would result in lower cortisol levels in both time periods. Two methods of measuring physical activity were used: minutes of moderate-to-vigorous physical activity (MVPA) and total number of steps. Neither measure of physical activity was related to change in cortisol levels at 10 or 20 weeks. Studies conducted by Hill et al. (2008) and Farrell et al. (1983) determined that longer, more intense exercise (with which MVPA is analogous) was related with larger releases of cortisol when compared to lower intensity exercise such as yoga. With the instruments used to collect physical activity data in this study, it was impossible to determine if and how long lower-intensity exercise was performed. Additionally, the previous studies measured cortisol immediately post-exercise. Since cortisol was measured in 10 week intervals in this study upon waking, any acute interpretation of the cortisol response to exercise would be null.

Strengths, Limitations, and Future Research

One strength of this study was the length of time and manner of which physical activity data was collected. Physical activity was recorded via New Lifestyles-1000 activity monitor which kept track of movement over three seven-day periods. If worn appropriately, the activity monitors provide a reliable and accurate method of recording physical activity. An accurate depiction of physical activity was important in determining potential relationships with cortisol and weight loss data. Another strength of this study was the high retention rate which resulted in a good amount of data collected by the end of the study. This could have been due to monetary compensation, regular follow ups and monitoring, and relatively non-invasive methods of data collection given the comprehensive nature of all variables examined.

This study encountered several limitations. One of the main limitations of the study was the amount of participants examined. Only 49 participants were included in data collection and slightly fewer had full data at the conclusion of the study. Increasing participant sample sizes could have led to more sensitive analysis.

Another limitation of this study may have been the methods of which cortisol was measured. Over a 20-week period, salivary cortisol was measured at baseline, and at 10 and 20 weeks. Since cortisol levels rise and fall systematically in a diurnal pattern, measurements may read drastically different according to the time of day. A salivary cortisol test only provides a small window in which to study an individual's cortisol patterns. In order to determine if a chronic pattern of cortisol elevation or suppression is occurring, 24-hour urinary cortisol tests or midnight plasma cortisol tests might be more appropriate.

If more work were to be conducted concerning this topic, more controls need to be put in place in order to help delineate the relationship between cortisol and weight loss. Previous studies predominantly study subjects with one or more severe co-morbidities, varying dietary approaches, and inconsistent exercise intensities. An ideal study would implement standardized weight loss diets along with low to moderate intensity exercise in order to minimize stress and the associated cortisol response.

Conclusion

The results of this study provided little solid evidence supporting the influence of cortisol on the ability to lose weight. In fact, cortisol levels predicted quite the opposite of what was expected by the end of the research study. However, this process helps to illustrate the complexity and unpredictable nature of human metabolism. Hormones are responsible for several different roles in our bodies. As a biological machine, our bodies work in a symphony of processes that interplay and influence one-another, making the isolation of one sole variable difficult to explain a cause and effect model in the human body.

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Vita: Shawn S. Smith

Educational Institutions Attended:

- University of Kentucky, Lexington, KY 2008-2012 (B.S. Dietetics)
- University of Kentucky, Lexington, KY 2013-2014 (M.S. Dietetic Administration expected)