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Original Research

The Effect of Breakfast on a Resistance Training Session and Response in Female Collegiate Athletes

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Abstract

International Journal of Exercise Science 18(6): 591-609, 2025. https://doi.org/10.70252/IGQS1507 Breakfast consumption has been shown to be an essential component to a healthy lifestyle in various populations, yet research in this area is limited among female athletes. This study aimed to examine the effect of breakfast consumption on collegiate female athletes during a resistance training session and their nutritional habits throughout the remainder of the day. Twenty-three female collegiate Division I athletes (basketball, volleyball, bowling, and soccer) during the offseason participated in this cross-over study. The study included three visits: baseline measures for heart rate (HR), blood glucose (BG), salivary cortisol (SC), and 5-repetition maxes for strength exercises; and two randomized conditions: a resistance training session with breakfast (experimental) and one with breakfast omission (control). For each condition, BG, HR, and SC was collected after a wait period which immediately preceded a resistance training session. Blood glucose, RHR, SC, heart rate recovery (HRR), and rating of perceived exertion (RPE) was collected after resistance training. A two-way multivariate analysis of variance (MANOVA) was used to examine how the condition (breakfast or breakfast omission) and time (pre and post) affected BG, HR, and SC. BG was more stable between pre and post in the experimental condition compared to the control. Lastly, a Wilcoxon signed-rank test showed that breakfast was associated with increased happiness and lower academic stress. This study showed that consuming breakfast could influence female collegiate athletes emotionally and physiologically, promoting further research as it could be of importance to female athletes, coaches, and administration.

Keywords: Blood glucose, salivary cortisol, heart rate, rating of perceived exertion

Introduction

Resistance training impacts the human body both during training and several hours following.[1,2] In women, resistance training has been shown to increase salivary cortisol (SC), plasma norepinephrine and epinephrine values from the start of resistance training through five minutes following the cessation of the session.[2] At the start of resistance training, catecholamines prime the body for exercise and secretion varies based on intensity, duration and type of exercise.[1] Cortisol, epinephrine, and norepinephrine are responsible for increasing heart rate (HR), breathing rate, increased glucose utilization and thermoregulatory responses.[1] Consumption of food prior to resistance training also impacts substrate utilization during a given session and has shown to alter perceived difficulty and performance of the training session as well.[3–6] Weight training is used within collegiate athletics as a standard team sanctioned activity due to the benefits of better recovery and better preparedness for their desired sport.[7]

Varying the intensity of resistance training, the nutritional behavior, or a combination of the two have been shown to alter resting heart rate (RHR), heart rate recovery (HRR), blood glucose (BG), SC, and rating of perceived exertion (RPE).[3–5,8,9] However, the effect that breakfast and resistance training could have on all of these variables combined is an area that is under-researched in female collegiate athletes.

Research has exhibited that consuming breakfast is beneficial to academic performance,[10] mental health,[10] healthier food choices throughout the day [10], improved cortisol levels[11] and athletic performance[4,12] in children and university students. Previous literature has shown that resistance training is also affected by breakfast in resistance trained men as they were able to perform more repetitions with breakfast consumption (which consisted of 1.5 g/kg of carbohydrates and ~20% of their estimated expenditure).[4] Collegiate athletes tend to perform resistance training in the mornings, prior to classes starting, making breakfast their pre-resistance training meal. Breakfast serves as fuel for the upcoming resistance training session and has shown to have many other benefits impacting the day, making it a vital part of an athlete's schedule.

Resistance training has a profound effect on HR.[1] Following exercise, HR begins to return to baseline. The amount of time it takes to return to baseline is called HRR, and this can be used to determine an individual's aerobic fitness. Those who are aerobically fit can return to their baseline value quicker than someone who is not; therefore, HRR can be used as a health indicator.[13] Athlete populations have been shown to have a faster HRR compared to untrained individuals.[14] While HR and HRR have more supporting research around aerobic exercise, resistance training remodels the heart to provide a HRR similar to those who participate in endurance training.[9] Heart rate is impacted by breakfast consumption and exercise. In preadolescents and those in their twenties, RHR was seen to be higher in those who consumed breakfast.[8] This is thought to be due to the thermic effect of food and the need for increased blood flow to support digestion.[8]

Resistance training also influences BG. Regular resistance training independent of intensity is seen to be advantageous to insulin sensitivity, which can affect blood sugar values along with appetite.[15] Blood glucose levels fluctuate less during moderate intensity exercise assuming carbohydrate reserves are sufficient.[16] Therefore, maintaining BG levels is essential to an athlete's performance, particularly for prolonged high-intensity or ultra-endurance activities.[17] Blood glucose levels can also be modified through resistance training; young women who participated in one week of resistance training had lower levels of fasting BG by the end of the seven-day testing period.[6] In addition, glucose uptake increases with a single bout of resistance training due to glycogen stores and phosphocreatine being used as the primary fuel source for the resistance training session.[3] Breakfast consumption can mitigate the changes in BG due to resistance training. [3]

Resting cortisol levels in athletes versus non-athletes and in men versus women has been inconclusive of any difference.[18] However, as it pertains to resistance training, SC has been shown to be higher immediately following the session in both men and women who regularly participate in resistance training, though it was only with high-intensity training which was classified as three sets of 10 repetitions at 75% of their projected max.[5] High-intensity resistance training can take the body out of a state of homeostasis. Cortisol is then produced to stimulate other reactions that aid the body in returning to homeostasis.[5] Cortisol levels by nature are highest in the morning, however, those who habitually eat breakfast, based on pre-study habits, tend to see lower values upon waking [11] versus those who do not. Cortisol values tend to increase by the presence and anticipation of food, and these levels are even higher following a period of food withdrawal.[19]

Previous research has revealed that components of resistance training and nutritional behavior can be influenced by consuming breakfast. [6,10] Varying the intensity of resistance training, the nutritional behavior or a combination of the two have been shown to alter RHR, HRR, BG, SC, and RPE.[3–5,8,9,20] However, the effect that breakfast and resistance training could have on RHR, HRR, BG, SC and RPE has not been previously studied in female collegiate athletes. Among female athletes it has been noted that only 27% report consuming breakfast regularly and 91% do not consume sufficient calories to match their energy demands throughout the day.[21] The effect breakfast had on a resistance training session, cognitive performance, and hormonal responses in female athletes were investigated in the present study and it was hypothesized that female athletes consuming breakfast would have a higher BG and RHR, and a lower SC, HRR, and RPE when compared to breakfast omission for a resistance training session. Additionally, it was hypothesized that breakfast consumption was going to lead to better focus, better moods and better dietary decisions the remainder of the day compared to omitting breakfast.

Methods

Participants

This study included 23 Division I women's varsity athletes (Age ± SD: 19.8 ± 1.3 years; body mass: 66 ± 8 kg; body height: 167.8 ± 7.8 cm; body fat percentage: 29.4 ± 5.6%; lean body mass: 46.5 ± 7 kg). Participants were at least 18 years of age, of the female sex, and belonged to the basketball (n=3), soccer (n=9), bowling (n=2), or volleyball (n=9) teams. Participants were excluded if they were not in their off-season, not medically cleared to participate in their sport, pregnant, or they screened positive for disordered eating by the Disordered Eating Screening for Athletes (DESA)-6. [22] If they met the inclusion criteria, they were contacted and scheduled for their initial visit. Procedures were explained to the participants and their written consent was provided. This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science*.[23] This study was approved by the institutional review board (protocol #: IRB-2022-277) and conducted in alignment with the Declaration of Helsinki.

Protocol

This was a prospective, cross-over study design, that consisted of three visits (Figure 1 and 2). The initial visit was to establish baseline values for the control and experimental conditions. For the baseline session, participants arrived at the lab following a 10-hour overnight fast and BG, SC, RHR, height, weight, body composition, and five repetition maxes for the resistance training session were taken. A wellness screening (Appendix A) inquired about nutritional tendencies, sleep quality, sleep duration, last menstruation, and other stressors experienced such as current academic stress, practice stress, and outside stressors not related to athletics.

After completing the initial visit, the order of the conditions was randomly assigned. For the control condition, participants arrived having fasted overnight for 10 hours. Breakfast was not provided at any point by the research team but they still waited one hour prior to collection of BG, SC, and RHR to keep times standardized. During the one hour wait period, participants were allowed to drink water and they were asked to complete the wellness questionnaire (Appendix A). Once they completed the survey participants remained seated in a quiet space and they were allowed to read. At the conclusion of one hour, BG, SC, and RHR were taken. The participant was guided through the standardized warm-up and resistance training session by a certified strength and conditioning coach who was blinded to which trial the participant was experiencing (control or experimental). After the resistance training session was completed, participants immediately sat down for five minutes while HRR, BG and SC was retrieved by the researchers. Prior to leaving, participants provided an RPE score for the session using the OMNI perceived exertion scale for resistance training, as it has been previously validated with female participants who were between the ages of 18-30.[25] In the evening, a follow-up survey (Appendix B) was sent to the participants to complete to gauge how breakfast omission affected their behavior and nutritional habits the remainder of the day.

The experimental condition included participants arriving to the facility after a 10 hour overnight fast. Participants were provided an individualized breakfast based on their lean body mass and the Cunningham equation (Daily Caloric Intake = (500 + [22 x LBM]) x an activity factor of 1.5).[26] With the participants being in off-season, they were limited to eight hours of mandatory activity per week, so the activity factor was 1.5. Caloric intake for breakfast was estimated at 25% of the recommended daily caloric intake and the macronutrient breakdown for breakfast provided consisted of 50% carbohydrates (CHO), 30% protein, and 20% fat.[27] Breakfast consisted of an overnight oats variation based on the individual requirements and potential food allergies. Prior habits pertaining to their breakfast consumption was not evaluated. Subjects had 30 minutes to consume breakfast, then rested one hour prior to the resistance training session. Participants completed the wellness survey during this time. At the end of the digestion period, BG, SC, and RHR were taken, and participants were then taken through the same procedures as the control condition, with HRR, BG, SC, and RPE measures taken in the same way, and a different follow-up survey provided in the evening (Appendix B).

The resistance training session was comprised of basic movement patterns, which included a squat, lunge, hinge, push, pull, rotate, and brace. [28] The goblet squat was the squat variation used, where the dumbbell is held at the center of the individual's chest. A lunge was achieved with a lateral lunge, which also exposed athletes to another plane of motion. Hinging was done with dumbbells as a Romanian deadlift, a push was by way of a dumbbell bench press, and a pull as a dumbbell row. Bracing and rotation was expressed as a plank and as Russian twists. These basic movement patterns translate over to movements that are required for a wide array of sports but also everyday life.[28] Intensity was moderate with percentages of 65% - 75% of their 1-RM, using Prilepin's chart to establish corresponding volume.[29] Exercises were paired in agonist–antagonist super sets and rest times were standardized to two minutes between each superset.[29] Participants provided an RPE for each training session at the conclusion of the session. The training session included a 12-minute warm-up and 48-minute resistance training session (Appendix C). The total time of the session was 60 minutes which is the amount of time typically allotted for a resistance training session for collegiate athletes. The participants took part in each condition within the same week with 48 hours in between.

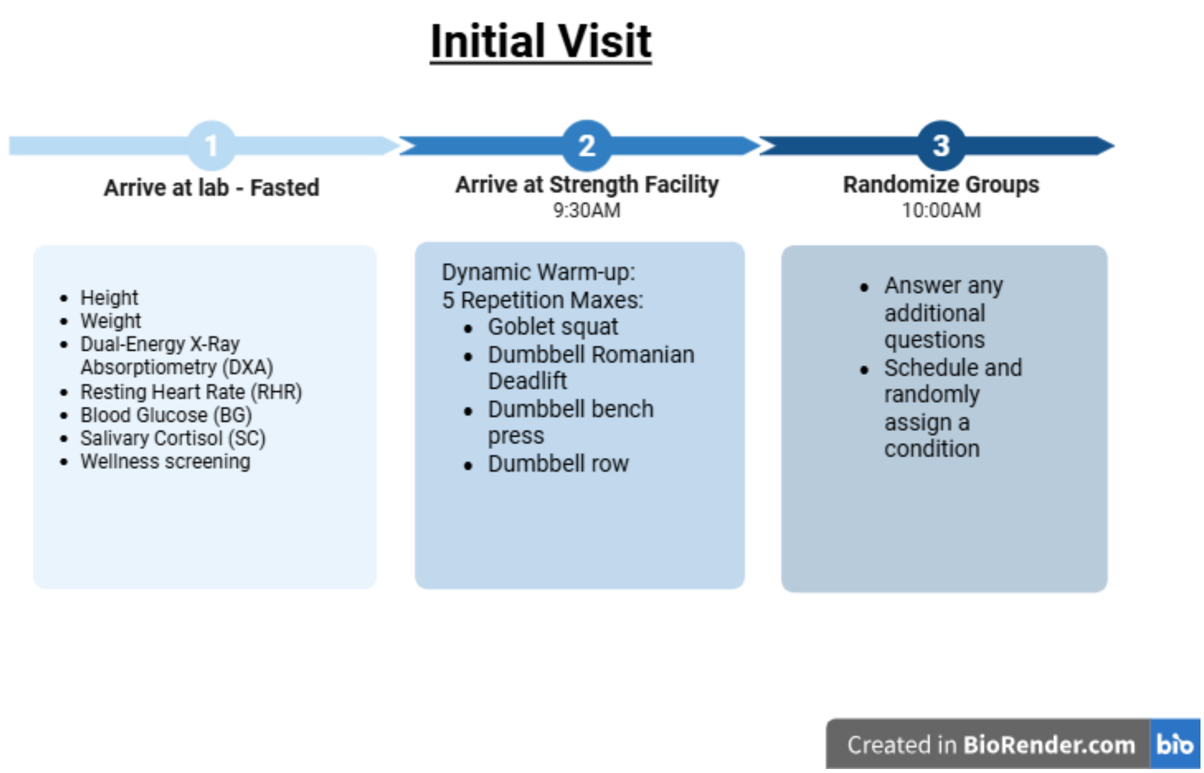

Figure 1. Initial visit timeline.

BG was assessed using a blood glucose monitor (Metene TD-4116, Metene, Santa Clara, CA). The monitor was calibrated prior to any blood analysis. Once their finger dried, a single-use lancet was used to stick their finger. Their finger was wiped with a gauze square to remove the fresh blood and the next drop of blood was used for analysis. Once enough blood pooled on the tip of their finger, the blood glucose strip was placed, and the strip collected a sample. The strip already placed in the base of the monitor analyzed the sample. Once a reading was provided, it was recorded.

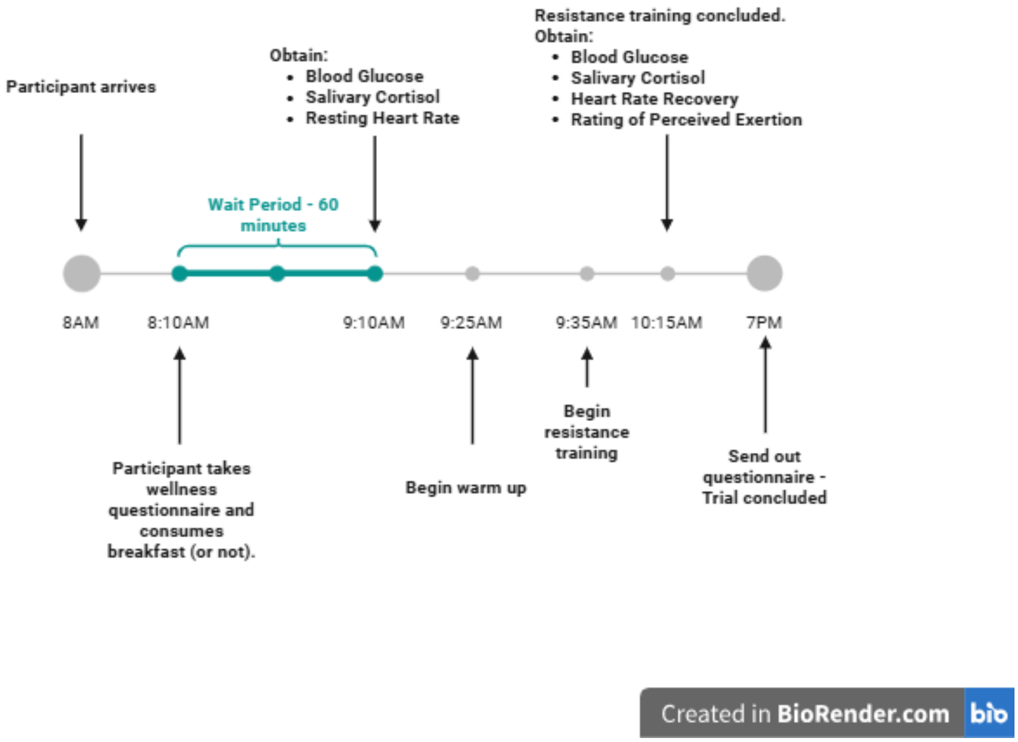

Figure 2. Timeline of each condition.

SC was taken collecting saliva via passive drool method and labeled, stored, and analyzed later via an enzyme-linked immunosorbent assay (ELISA) kit (Aplco, Salem, NH). Ten minutes prior to collection, participants rinsed their mouth with water. The passive drool method requires participants to let saliva pool in their mouth, then with the vial in or close to their mouth, participants tilted their heads forward to let their saliva drip into the vial in a passive manner to prevent bubbles in the sample. Once the participants filled the vial with a volume of 1 mL, the vial was sanitized with an alcohol wipe, labeled and stored at –80 degrees Celsius until they were analyzed. Samples were thawed, vortexed, and transferred to microcentrifuge tubes. They were spun at 1,500 xg for 15 minutes at 4°C. Fifty microliters of each sample supernatant, calibrator, and control were pipetted in duplicate into each well of a cortisol ELISA plate (Aplco, Salem, NH) and assayed according to manufactures instructions. Absorbance at 450 nm was read on a microplate reader, BioTek Synergy H1 (Agilent Technologies, Santa Clara, CA) and a standard curve was generated using the manufacturer supplied calibrators.

RHR was measured via Polar HR monitors (Polar H9, Kempele, Finland). Prior to putting the monitor on but after assuring fit the electrode part of the strip was dampened to improve conductivity.

Body composition was measured via a dual-energy x-ray absorptiometry (DXA) scan (Hologic Horizon W, Marlborough, MA) to determine fat mass (FM) and lean body mass (LBM). Calibration was performed by the technician before the subject arrived. Within the secure software system, a profile with a unique participant ID was created for each subject. Subjects removed shoes, all jewelry, wore tight-fitting clothing during the DXA scan and disclosed if there were any metal objects in their body prior to the scan.

A 5-RM was used in place of a one-repetition max as it is safer option and would still provide a reliable value for percentage based training. [24] A 5-RM was used for all strength movements, in the order that they would be performed in the for the upcoming trials (goblet squat, Romanian deadlift, dumbbell bench press and dumbbell row). Prior to muscular strength testing, participants completed a standard dynamic warm-up protocol. For the muscular strength testing, participants started with a weight that could comfortably perform 10 repetitions with. Weight was increased in increments of no more than 10% until volitional or technical failure. The formula used to approximate their maximum strength values was 1-RM= 7.24 + (1.05 x weight lifted) as this was previously used with college-age female athletes [24]. This method was repeated with each of the strength based movements.

Statistical Analysis

A power analysis was performed, and 34 subjects were required to meet statistical power. However, the sample size was limited due to the number of athletes available during their off-season training and when scoping through existing literature and examining previously accepted study designs, the sample sizes ranged from nine to 20. With that in mind, the current study accepted the sample size of 23 subjects.[4,5,8,12]

Descriptive statistics include means and standard deviations for baseline values of height, weight, body fat percentage, lean body mass, BG, RHR, salivary cortisol, and daily caloric needs. The assumption of normality was examined with a Shapiro-Wilk test. The assumption of sphericity was examined using Mauchly's test. A 2 (condition) x2 (time) repeated measures-multivariate analysis of variance (RM-MANOVA) was conducted to determine the effect of experimental and control conditions on the physiological variables of BG, salivary cortisol, and HR over two time points (pre and post) per condition. A separate 2 (condition) x4 (time) RM-ANOVA was used to determine if there were differences in HRR across time for both the experimental and control conditions. Partial eta-squared effect sizes for the RM-MANOVAs were evaluated using and interpreted as small ($\eta2p = 0.01$), medium ($\eta2p = 0.06$), and large ($\eta2p = 0.14$). A matched pairs t-test was used to compare differences in RPE between conditions. Effect size for the matched pairs t-test was evaluated using Cohen's d and interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$). Due to the scale data of the follow-up survey, a Wilcoxon signed-rank test was used to examine differences in nutritional habits and wellness. Effect size for the Wilcoxon signed-rank test was calculated by dividing the absolute standardized test statistic, Z, by the square root of the number of pairs, n, and interpreted as small ($d = 0.1$), medium ($d = 0.3$), and large ($d = 0.5$). Statistical significance was set at an alpha level of 0.05. Data was analyzed using SPSS (version 27, Chicago, IL).

Results

Resistance Training

During the baseline session five repetition maxes were found for four different movements. A one repetition max was then estimated for each movement and means and standard deviations are presented in Table 1 below.

Table 1. Descriptives for estimated one repetition maxes.

	Mean	Std Dev
Goblet Squat (kg)	42.7	3.1
Dumbbell Romanian Deadlift (kg)	30.2	3.4
Dumbbell Bench Press (kg)	19.2	2.9
Dumbbell Row (kg)	26.6	3.8

Physiological Variables

A 2x2 RM-MANOVA was conducted to test the hypothesis that there would be differences in physiological variables (BG, HR, and SC) based on time (pre and post) and condition (experimental and control). There was no difference in physiological variables based on testing condition ($F(3,28) = 1.456$, $p = 0.248$, Wilks' $\Lambda = 0.865$, $\eta 2p = 0.135$, medium). There was a difference in physiological variables based on time ($F(3,28) = 155.705$, $p < 0.001$, Wilks' $\Lambda = 0.057$, $\eta 2p = 0.943$, large). There was also a difference in physiological variables for the condition by time interaction ($F(3, 28) = 3.350$, $p = 0.033$, Wilks' $\Lambda = 0.736$, $\eta 2p = 0.264$, large). There was a time difference for HR ($F(1,30) = 485.393$, $p < 0.001$, $\eta 2p = 0.942$, large), but not on BG ($F(1,30) = 0.464$, $p = 0.501$, $\eta 2p = 0.015$, small) or SC ($F(1,30) = 1.905$, $p = 0.178$, $\eta 2p = 0.060$, medium). There was an interaction of condition and time for BG ($F(1,30) = 7.012$, $p = 0.013$, $\eta 2p = 0.189$, large), but not for HR ($F(1,30) = 0.840$, $p = 0.367$, $\eta 2p = 0.027$, small) or SC ($F(1,30) = 0.335$, $p = 0.567$, $\eta 2p = 0.011$, small). The results by condition are represented in Figure 3.

Physiological Measures Pre and Post Breakfast and Control

A separate 2x4 RM-MANOVA was conducted to test the hypothesis that there would be differences in HRR for experimental and control conditions based on time. Mauchly's W was significant indicating a violation of sphericity ($W = 0.229$, $p < 0.001$); therefore, a Huynh-Feldt correction was used. Tukey's post-hoc comparisons were used to test for differences between time points. HRR between HR post and HR after one minute was significantly greater than HRR between HR after one minute and HR after two minutes ($t(40) = 10.31$, $p < 0.001$), HRR between HR after two minutes and HR after three minutes($t(40) = 14.27$, $p < 0.001$), and HRR between HR after three minutes and HR after five minutes ($t(40)= 14.62$, $p < 0.001$).There were differences in HRR based on time ($F(1.67, 66.84) = 132.794$, $p < .001$, $\eta 2p = 0.769$, large), but no difference for HRR based on the time by condition interaction ($F(1.67, 132.794) = 1.15$, $p = .316$, $\eta 2p = 0.0279$, small) or for HRR based on condition ($F(1, 40) = 1.640$, $p = 0.208$, $\eta 2p = 0.0394$, small).

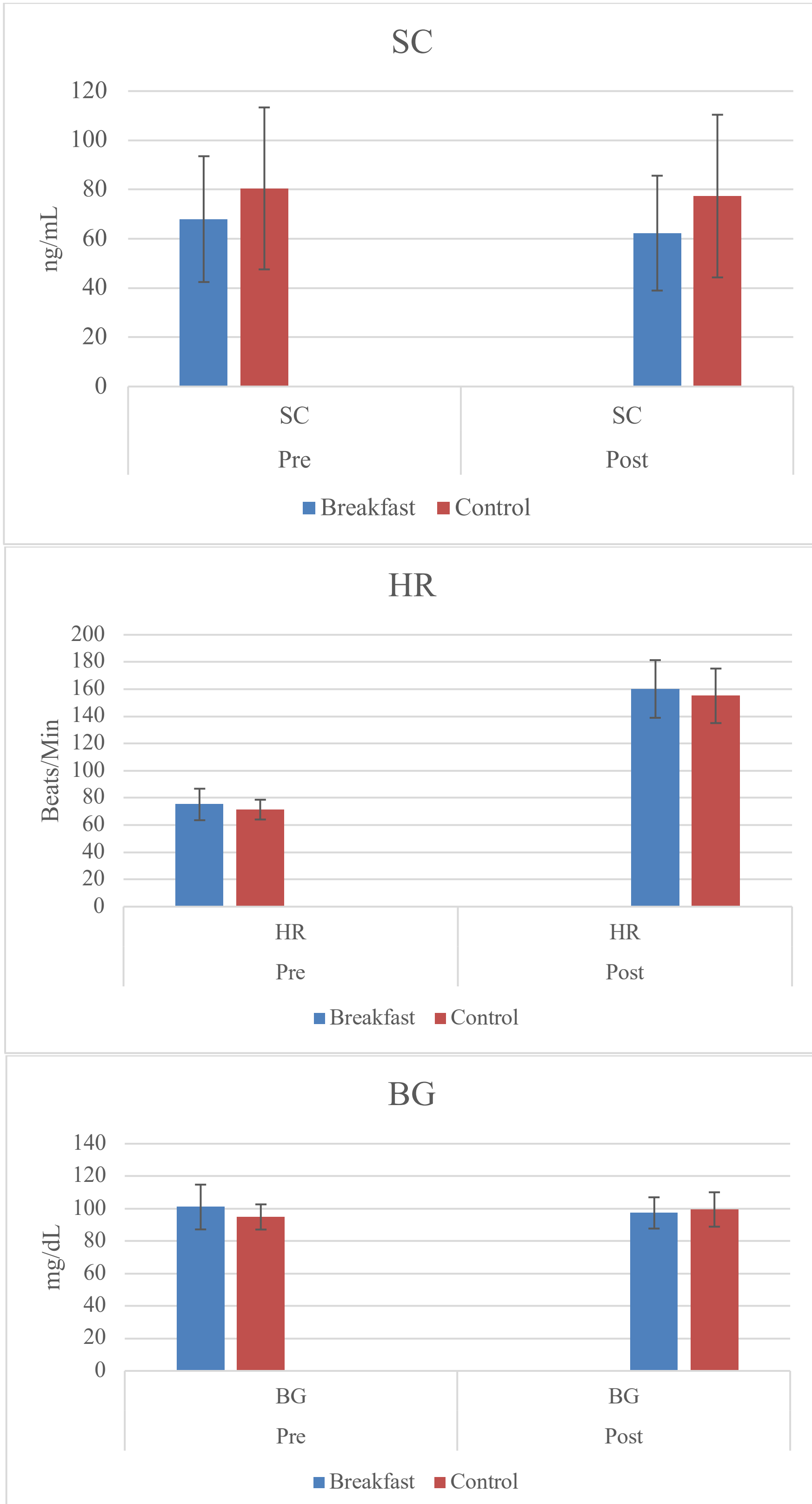

Figure 3. Note: Error bars represent one standard deviation.

RPE was normally distributed (W = 0.925, p = 0.098). There was no difference in RPE between experimental (M=5.5, SD=1.9) and control conditions (M=5.1, SD=1.5) ($t(21) = 1.25$, $p = 0.225$, $d = 0.267$, small).

Wellness and Nutritional Habits

Table 2. Descriptives from Post Intervention Questionnaire.

Category	State/Habit	Control	Experimental	All	Cohen's d
State	Happiness *	**3.78 ± 0.95**	**4 ± 1.03**	**3.88 ± 0.97**	**-0.75**
	Focus	**2.83 ± 2.01**	**2.05 ± 2.01**	**2.47 ± 2.00**	**0.334**
	Anxious	**3.00 ± 1.51**	**2.85 ± 1.5**	**2.93 ± 1.47**	**0.346**
	Fatigue	**3.43 ± 1.12**	**3.45 ± 1.23**	**3.44 ± 1.15**	**0.187**
Nutrition	Soft drinks	**0.65 ± 2.31**	**0.35 ± 0.93**	**0.51 ± 1.77**	**0.071**
	Sweets	**0.48 ± 0.67**	**0.7 ± 0.8**	**0.58 ± 0.72**	**0.333**
	Fruits/Vegetables	**1.13 ± 1.10**	**1.25 ± 0.91**	**1.19 ± 0.99**	**-0.231**
Academics	Classes (# of)	**0.96 ± 0.82**	**0.85 ± 0.88**	**0.91 ± 0.83**	**0.053**
Activity	Practice Difficulty	**0.74 ± 1.32**	**1.1 ± 1.59**	**0.91 ± 1.43**	**-0.291**

Note: Measures in "state" category are based on 5 point Likert scale; measures in "nutrition" category could be filled in with any number; * represents significance; **p-value = 0.05**

Means and standard deviations for the post resistance training wellness and nutritional habits (Appendix B) are presented in Table 2. Means and standard deviations for the pre-resistance training questionnaire (Appendix A) are shown in Table 3. Shapiro-Wilk tests were used to determine if both sets of wellness and nutritional variables were normally distributed. The following variables for the pre-resistance training questionnaire were normally distributed: number of classes (W = 0.914, p = 0.076), soreness (W = 0.925, p = 0.087), and training difficulty for the week (W = 0.955, p = 0.399). The following variables for the pre-resistance training questionnaire were not normally distributed: hours slept (W = 0.891, p = 0.017), meals eaten (W = 0.904, p = 0.031), quality of sleep (W = 0.909, p = 0.038), academic stress (W = 0.864, p = 0.005), and practice difficulty (W = 0.616, p < 0.001), stress (W = 0.783, p = <0.001). The only variable for the post resistance training questionnaire that was normally distributed was focus (W = 0.936, p = 0.197). The following variables for the post resistance training questionnaire were not normally distributed: fruit and vegetable consumption (W = 0.873, p = 0.013), soft drink consumption (W = 0.446, p < 0.001), sweets consumption (W = 0.772, p < 0.001), number of training days in the week (W = 0.844, p = 0.098), fatigue (W = 0.889, p = 0.026), happiness (W = 0.736, p < 0.001), and anxiety (W = 0.884, p = 0.021). A Wilcoxon signed-rank test was used to test the hypothesis that there would be differences in wellness and nutritional habits between experimental and control conditions. For wellness, an increase in happiness was shown when breakfast was consumed (W (19) = 4.50, p = 0.041) compared to the control condition (M = 3.70, SD = 0.923). A decrease in academic stress was also shown when breakfast was consumed (W (22) = 92.0, p = 0.008) compared to the control condition (M = 2.83, SD = 1.15). No differences were observed in fatigue (W (19) = 54.0, p = 0.565) or anxiety (W (19) = 52.5, p = 0.300) between conditions. In terms of nutritional habits, no differences were found in fruits and vegetables (W(19) = 30.0, p = 0.464), soft drinks (W(19) = 13.0, p = 0.930), or sweets (W(19) = 12.0, p = 0.407) consumed throughout the day between experimental and control conditions.

Table 3. Descriptives from Pre-Intervention Questionnaire (not baseline).

Category	State/Habit	Control	Experimental	All	Cohen's d
Sleep	Hours	**6.87 ± 1.74**	**6.33 ± 1.60**	**6.28 ± 1.81**	**0.25**
	Quality*	**3.13 ± 1.18**	**3.6 ± 1.23**	**3.61 ± 1.16**	**-0.33**
Nutrition	Meals (#; day before)	**2.78 ± 0.67**	**2.6 ± 0.88**	**2.78 ± 0.67**	**0.14**
Stress	Academic*; ***	**2.83 ± 1.15**	**2.15 ± 1.04**	**2.26 ± 1.14**	**0.75**
	Other Stress*	**2.3 ± 1.18**	**1.95 ± 1.32**	**2.09 ± 1.31**	**0.32**
Activity	Soreness*	**1.96 ± 0.82**	**1.9 ± 0.97**	**1.87 ± 0.97**	**0.08**
	Practice Difficulty**	**1.52 ± 1.68**	**0.95 ± 0.22**	**0.91 ± 0.29**	**0.36**

Note: * indicates a 5 point Likert scale; ** indicates 1-10 OMNI RPE scale; remainder were as inputted; *** represents significance; **p-value = 0.05**

Discussion

The current study aimed to investigate how breakfast consumption affected female collegiate athletes in several phases of a given day. The present study had three aims: (1) to examine the impact of breakfast consumption on a resistance training session physiologically and perceptually; (2) to examine the impact of breakfast consumption on nutritional habits the remainder of the day; and (3) to examine the impact of breakfast consumption on moods or states of being following the intervention in female collegiate athletes. This design was structured based on previous studies where breakfast consumption was a driving factor in HR, BG, RPE, nutritional tendencies, stress, happiness, fruit and vegetable consumption, consumption of sweets and soft drinks.[3–5,8–11,20] As a result of the present research, in female collegiate athletes: (1) BG decreased from pre to post when breakfast was consumed compared to the control; (2) breakfast had no impact on nutritional habits the remainder of the day; and (3) happiness was higher when breakfast was consumed compared to the control.

This study showed that breakfast did not affect the participants physiologically or perceptually (HR, BG, SC, HRR, RPE) contrary to what was hypothesized and what previous research supported.[4,11,12,30] A hypothesis of this study stated that breakfast consumption would increase BG, RHR, but decrease SC, HRR, and RPE across time. SC and RPE showed no differences based on the condition or the component of time (pre and post). Previous research findings around SC and exercise are inconclusive as one study showed a significant alteration in SC [5] and another did not.[18]

SC in the current study also showed no notable differences between conditions or over time. Previous literature supported the notion that regular breakfast (three or more days a week) consumption results in lower cortisol values and that high intensity resistance training increases cortisol values.[5,11,31] Wang et al [31] compared the acute effects on SC to resistance training and aerobic training. SC was collected before exercise as a baseline value, immediately following the sessions, and 30 minutes post. Also, contrary to our findings, intensity of 75% for a resistance training session altered SC levels in a previous study. [5] In both the resistance training group and the aerobic training group SC was higher 30 minutes post compared to baseline and immediately following.[31] In the present study, breakfast was only provided once and pre-existing breakfast habits were not inquired about. In addition, post-resistance training SC was taken immediately after the training session, unlike a previous study which waited 30 minutes to measure SC and showed significantly higher cortisol levels.[31] Both of these factors could explain the difference in results for SC.

RPE also showed no notable differences due to the condition or time. RPE has been shown to be a reliable way to interpret workload for resistance training in athletes.[32] However, prior to the present study, it was not definitive the effect breakfast consumption had on RPE.[33] Metcalfe [33] found that RPE was higher in those who did not consume breakfast or carbohydrates prior to rowing and cycling, while Horswill et al. [34] showed no difference. The present study collected RPE to use a previously validated way of interpreting workload to see if breakfast consumption had any effect on perception, which it did not. Day et al[32] used a session RPE, inquiring about RPE after each set of the resistance training session and at the completion of the resistance training session. RPE at the end of the resistance training session was used as an average and compared to an average of session RPE values, the session RPE values showed to be a reliable way of assessing not only a specific portion of the resistance training session, but also a way to find RPE of the entire session.[32] The present study only inquired and examined RPE for the entire resistance training session, not each superset. Incorporating a session RPE into the present study after each superset could have been an indication of any alterations in perception during the resistance training session and could have also been used to find the average of the entire resistance training session.

Over time (pre and post) BG, HR, and HRR showed significant findings in the current study: HR was significantly higher post to pre resistance training, HRR displayed a significant decrease in HR post resistance training and each minute following, and for the breakfast group, BG remained more stable pre to post resistance training. HR was significantly higher post resistance training compared to pre resistance training independent of breakfast consumption or omission. During resistance training, there is an increased demand of blood flow to the working muscles to facilitate the transfer of waste products, which increases HR. Therefore, a significant rise in HR from pre resistance training to post resistance training is a standard finding.[8,20] HR has only been shown to be higher by consuming breakfast in those who do not normally consume breakfast.[8] The present study showed no difference in HR response at baseline or post-exercise in either condition. The present study did not collect information regarding participants' normal breakfast habits. Thus, it is unclear if there is simply a difference in habits of the participants or a true physiological response. Further, Nose et al[8] did not disclose the nutritional content of the breakfast provided so caloric and macronutrient comparisons are unable to be made.

HRR was also impacted solely by time from immediately post-resistance training to each minute post-resistance training. HRR has been shown to be an indicator of aerobic fitness level, the quicker an individual returns to their baseline HR, the better their aerobic fitness is [13]. With the sample being female Division I athletes, the decrease minute to minute would be expected with the frequency at which collegiate athletes train. HRR did not have any previous research regarding breakfast and exercise. The methods of HRR were similar to those used Lipinski et al.[35] Lipinski et al[35] utilized a graded exercise test on a treadmill and found HRR from the cessation of exercise, breakfast was not at all a factor in this study.

Breakfast impacted the fluctuation in BG between pre and post resistance training and BG remained stable when breakfast was provided, similar to previous literature.[10] BG was the only variable among the physiological and perceptual measures that displayed a time and condition difference. BG did not increase as hypothesized but showed less fluctuation during the resistance training session when breakfast was consumed. In the breakfast group, BG was higher pre-resistance training and by the end of the resistance training session that value was slightly lower. The spike in BG prior to resistance training was due to breakfast consumption and the 60-minute period that allowed for digestion and more readily available glucose, which was expected based on physiology and previous research.[10] However, in the control group, participants were not at all provided breakfast and BG values reflected a fasted value but following the resistance training session BG was elevated. This is thought to be due to gluconeogenesis, a process that occurs during fasted periods to provide the body with glucose to use by breaking down glycogen.[36]

The present study also examined how breakfast might have affected fruit and vegetable consumption, consumption of sweets and soft drinks, happiness, fatigue anxiety, and stress. It was hypothesized that breakfast consumption would increase fruit and vegetable consumption and decrease sweets and soft drink consumption. Results from the present study indicated that nutritional tendencies were not affected by breakfast consumption despite what previous literature has reported.[10,37] The difference in results can potentially be attributed to the lack of an intervention, regular habits, or age of the sample as previous studies who included adolescents from ages 11 to 15.[37] The present study provided a breakfast intervention, however, did not account for any existing nutritional habits within the participants so the difference in age between the two populations and nutritional habits could have elicited a difference in response. Additionally, in the present study, it was hypothesized that breakfast consumption would be associated with higher reported happiness and lower anxiety, stress, and fatigue. Previous studies associated breakfast with higher happiness, lower fatigue, lower anxiety, and lower stress.[10,38] In the current study, happiness was the only variable that demonstrated a difference between conditions. It is important to note that although happiness was higher with breakfast consumption, this coincided with a decrease in academic stress; therefore, lower academic stress may have also contributed to an increase in happiness. Academic stress was inquired about prior to the breakfast intervention being provided (or not provided) therefore, breakfast was not the reason for the lower academic stress it was just associated with breakfast consumption.

The present study suggested that breakfast consumption maintained more stable BG levels while resistance training due to an increase in available glucose for the body to use and may promote higher levels of happiness[10] throughout the day in female collegiate athletes. While the remainder of the findings were not what is reflected in existing literature, this study was of a unique design. This study was designed to be more practical and to emulate a normal day for a female collegiate student athlete. The previous literature around breakfast and resistance training was primarily done in men and breakfast was not standardized to the participants lean body mass, and the resistance training was performed to failure.[4] Previous literature inquiring about wellness and nutritional habits did not provide a breakfast intervention, they merely asked about existing breakfast habits.[10,37]

By accepting a more practical study design with a sample of collegiate student athletes, the researchers could not completely control for mandatory team activities that still occur during the offseason or academic obligations that arose during the time of this study. Both the mandatory team activities and academic obligations could have created a higher workload for some of the participants and could have affected perceptual measures (RPE and wellness questionnaire).

With the sample comprised of only female athletes, not accounting for menstrual cycle status would also be a limitation to this study. In the pre-resistance training wellness survey, the participant's last menstruation was inquired about however, nothing further was investigated regarding each participant's specific cycle nor was participation limited if the participant utilized oral contraceptives. Both scenarios could have led to altered outcomes as different phases of the menstrual cycle has been shown to impact mood, appetite, exercise, and can influence dietary decisions.[39]

For limitations related to the physiological variables, an area of concern was salivary cortisol. For SC, a few of the samples had to be extrapolated beyond the standard curve because they were more concentrated than the most concentrated calibrator (100 ng/ml). With the use of extrapolated values, there is a possibility that true measured values could have elicited a different result. Another area that could be explored further is adding another BG reading in subsequent hours following the resistance training session as BG is known to fluctuate frequently. This area was not investigated in an effort to keep a practical study design.

Lastly, to meet power, a sample of 34 participants was needed. Due to limitations on athletes being in their competitive seasons or to existing injuries, only 23 were recruited. While other studies utilizing a crossover design validated the sample size of 23, not meeting power could have affected the results.

Despite these limitations, there were efforts made to limit any additional confounding variables. This study accounted for time of day, blinded research assistants, used private and encrypted surveys and both trials were performed within 48 hours of each other which accounted for any potential changes in strength and standardized the amount of time between trials for all subjects.

This study among others showed that happiness can be higher in those who consume breakfast 60 minutes prior to a resistance training session. With that and the increased focus on best practices for mental health among collegiate athletes, specifically anxiety and depression [40], it could be advantageous to further explore if regular breakfast consumption has any effect on student athletes' mental health. Another direction for future research in a similar sample should involve controlling for menstrual cycle phase to account for any associated changes in appetite, mood states, and perception. Solely based on the outcome of this study, breakfast would be recommended in female collegiate athletes primarily for increased happiness (mental health purposes) and to keep a stable BG around training.

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Appendix A – Pre-Resistance Training Session Questionnaire

1. How many hours did you sleep the night before?
2. What was your quality of sleep? (1 = poor, 5 = great)
3. How many meals did you eat yesterday?
4. How sore are you? (1 = not sore, 5 = very sore)
5. How much stress do you feel from academics? (1 = no stress, 5 = very stressed)
6. How hard was practice yesterday? (1 = very easy, 5 = very hard; if did not practice put 0)
7. How much stress do you feel from anything not related to athletics? (1 = no stress, 5 = very stressed)
8.When was your last menstruation?

Appendix B – Post-Resistance Training Questionnaire (Conclusion of the Day)

1. Please enter your name:
2. What group were you apart of today? No Breakfast or Breakfast
3. How many times did you eat today? (Including breakfast you were provided, 1 meal = 1 time, 2 large snacks = 1 meal) *Only the breakfast group will have this in parentheses.*
4. How many times did you consume fruits and vegetables today? *(any)*
5. How many times did you consume any soft drinks today? *(any)*
6. How many times did you consume sweets today? *(any)*
7. Did you have practice today?
8. If yes to #6 how was practice? (1 = poor, 5 = great)
9. Did you feel fatigued today? (1 = very fatigued, 5 = no fatigue at all)
10. Did you feel happy today? (1 = no happiness, 5 = very happy)
11. Did you feel anxious today? (1 = very anxious, 5 = no anxiousness)
12. Did you have classes today?
13. If yes to #12, how many?
14. If yes to #12, how focused were you? (1 = not focused, 5 = very focused)

Appendix C – Resistance Training Program

Dynamic Warm-Up (10 yards of each) - 10 minutes
- Jog down and back
- Walking knee hugs
- Walking toe touches
- High knees
- Walking quad stretch
- Butt kicks
- Forward lunge and twist
- Leg swings
- A-skip
- Lateral lunge
- Shuffle (each way)
- Carioca (each way)

Activation (12 minutes)
- Lateral band walks 3x10 steps each way
- Bear crawl to downward dog 3x5
- TRX rows 3x8

Resistance Training – 48 minutes
1A. Goblet Squat 3x6 at 75%

1B. Plank 3x30 seconds

2A. Dumbbell Romanian Deadlift 3x6 at 75%
2B. Russian Twists 3x12 each

3A. Lateral Lunges 3x5 each
3B. Dumbbell Bench Press 3x6 at 70%
3C. Dumbbell Row 3x6 each at 65%

*Rest time between each set of each superset is 2 minutes.