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EFFECT OF RESISTANCE TRAINING ON POWER, STRENGTH, AND PERFORMANCE IN COLLEGIATE CHEERLEADERS

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EFFECT OF RESISTANCE TRAINING ON POWER, STRENGTH, AND PERFORMANCE IN COLLEGIATE CHEERLEADERS

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ABSTRACT

This study investigated the muscular power, strength and sport-specific performance changes in female collegiate cheerleaders who participate in resistance training, versus those who did not. Previous research (1, 9, 11, 13, 16, 18, 20) indicates that collegiate cheerleaders should participate in resistance training programs, however, this is the first study to have investigated the effects of one. Twenty-two female collegiate cheerleaders between the ages of 18-23 years were recruited from the University's cheerleading team and completed the study. Participants were divided into. resistance training (RT) (n = 12; age: 19.74±0.96 years; height: 161.95±7.99 cm; body mass: 64.37±13.80 kg; body fat %: 40.37±0.96%; lean body mass: 12.38±1.99 kg) or control (CON) (n = 10; age: 20±1.4 years; height: 161.85±6.24 cm; body mass: 59.99±6.59 kg; body fat %: 34.1±8.62%; lean body mass: 11.96±1.01 kg). The RT group participated in a ten week, full-body, strength, and power emphasized resistance training program, while the CON group did not. All participants continued their regular participation of all team duties and responsibilities. Resistance training resulted in significant improvements ($p \leq 0.05$) in relative lower and upper body strength of 19.4% and 9.84%, respectively. Conclusion: Full-body, strength and power focused resistance training performed for ten weeks elicits strength improvements in female collegiate cheerleaders.

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PREFACE

This thesis is written to comply with the University of Rhode Island graduate school Manuscript Thesis Format. This thesis contains one manuscript: *Effect of Resistance Training on Power, Strength, and Performance in Collegiate Cheerleaders*. This manuscript has been written in a form suitable for publication in *Journal of Strength & Conditioning Research*.

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CHAPTER 1

INTRODUCTION

Cheerleading has evolved from crowd leading on the sidelines of sporting competitions to having its own competition aired on ESPN. According to the International Cheerleading Union (ICU), there are over 3 million cheerleaders in the world (1). As cheerleading shifted to a competitive sport, participation has continued to increase (1). Competitive cheerleaders are expected to be able to lift, throw, and spin their teammates to perform skills at the top of their capabilities. These skills require the athletes to accept and produce high amounts of force (3). The rise in popularity has led to an increase in difficulty of skills and an increase in risk of injury over recent years, contributing to the need for strength and conditioning programs to achieve peak performance (11, 14, 16, 20).

Participating in a resistance training program is advantageous for competitive collegiate athletes to appropriately increase training demands, minimize training error and ensure adequate recovery (22). Prioritizing these aspects of training allows for athletes to maximize their athletic potential (10). Although previous literature supports the importance of cheerleaders participating in resistance training programs to improve performance (1, 9, 11, 13, 16, 18, 20), most collegiate cheerleading teams do not have access to a qualified and certified strength and conditioning coach at their college or university (1, 15, 28). Of the 349 collegiate cheerleading teams listed on USA

Cheer College Program Directory only 19 teams have access to a strength and conditioning coach (28). Considering the increased difficulty of sport-specific skills, it is important to analyze the differences between cheerleaders who participate in resistance training intervention and those who do not, to determine if resistance training increases muscular power, strength and enhances the performance of sport-specific skills and minimize injury risk.

A limited amount of research is available on resistance training in cheerleaders (9). Most of what is known discusses injury prevalence, injury rehabilitation and eating disorder risk among cheerleaders (4, 16, 17, 19, 20. 23). The available literature suggests that competitive collegiate cheerleaders who perform resistance training have improved functional movement capacities (13) and experience significant improvements in shoulder stability (9). Cheerleaders who participate in resistance training believe the implementation of strength and conditioning programs improve their ability to perform difficult skills and improve their strength and power (14), although a majority of cheerleaders do not participate in a program that adequately prepares them for the high demands of the sport (6, 28). To perform these difficult skills, a high level of physical fitness must be maintained. When considering the physical fitness status of female collegiate cheerleaders, literature suggests collegiate cheerleaders' physical fitness scores are similar to those of other collegiate athletes, such as female basketball, dance, gymnastic, swimming, tennis and volleyball players (18). Skills within cheerleading, like tumbling, are shared with gymnastics as well as high amounts of power, jump height and muscular strength to be able to properly execute sport-specific skills (12). Previous literature has suggested that resistance training programs lead to increased performance in female competitive gymnasts as a result of increased power, jump height and muscular strength (12). In this study, the participants and their coaches noted there were noticeable improvements in power and the performance of the gymnasts' skills, in addition to the statistically significant ($p \leq 0.05$) improvements in both muscular strength and power (15). This suggests that more research is needed in regard to the needs of collegiate female cheerleaders and how to maximize their sport performance via a resistance training program.

Therefore, the purpose of this study was to investigate if female collegiate cheerleaders who participated in a resistance training program experienced changes in muscular power, muscular strength, and sport-specific performance compared to those who did not. The authors hypothesized that collegiate cheerleaders who participated in resistance training would experience significant improvements in 1) sport-specific skill performance, 2) muscular power, and 3) muscular strength compared to the control group.

CHAPTER 2

REVIEW OF LITERATURE

Understanding the Components of Cheerleading. Collegiate cheerleading involved a variety of components, including tumbling, stunting, and tossing, all of which contribute to a team's overall performance. The roles and responsibilities of collegiate cheerleaders can vary depending on a team's level of experience and type of team, although the basic components typically include bases, backspots, flyers, and tumblers. A base, backspot, and flyer are all positions in cheerleading related to stunting. On an all-girl cheerleading team, each stunt group typically includes four cheerleaders: two bases, one backspot, and one flyer. Bases typically stand on the side of the flyer and lift or throw the flyer by the bottoms of their feet. The backspot stands in the back of the stunt group and typically lifts or throws the flyer by their ankles. The flyer is the athlete in the group who gets lifts or thrown by their stunt group. They often perform skills that involve spinning, twisting, flipping, and holding positions that showcase flexibility. Co-ed teams typically consist of bases and flyers who all tumble, without the use of backspots. Whereas all-girl collegiate teams typically consist of bases, backspots, and flyers who all tumble. Tumbling involves a series of acrobatic skills such as flips, similarly, showcased in the sport of gymnastics. On the national collegiate cheerleading championship score sheet, judging involves the difficulty and execution of both standing and running tumbling (27). Standing tumbling typically involves a flip or series of flips starting from the standing position, while running tumbling typically involves a series of flips with connection from a cartwheel or round-off. Stunting refers to various lifts or pyramids where flyers stand at the top of a bases or multiple bases. Pyramids specifically require a multi-tiered structure, with bases and backspots on the ground creating the structure, a “mid-layer”, who is typically either a flyer or a base taking a different role for the performance of a pyramid, and a flyer who stands on top of the “mid-layer”. Typically, another group of bases and backspot launches this flyer into the air for the “mid-layer” to then grab ahold of as the flyer lands on their thigh or shoulders. The most fundamental skill of this launching of the flyer is called a “Toe Pitch” and is often used as a drill or warmup progression to subsequently perform a more difficult skill.

Basket tosses are also a component that is required to compete in a national collegiate cheerleading competition since it is judged using a score sheet (27). This skill involves bases, a backspot, and a flyer. Basket tosses are similar to a toe pitch, although the set up slightly varies in a way that allows the bases to produce more power, therefore launch the flyer into the air to perform flips and twists in the air before the flyer gravitates back down to be caught. Basket tosses and toe pitches vary in their setup and the subsequent actions involving the flyer. In basket tosses, the flyer is caught after being launched, whereas in toe pitches, the flyers are transferred to another structure. All of the skills mentioned are components included on the national collegiate cheerleading championship score sheet, where each team is judged based on the difficulty and execution of their skills.

Cheerleading and Resistance Training. There is limited literature exploring the effects of resistance training on athletic performance in cheerleaders. Despite evidence suggesting enhanced performance among college athletes with dedicated strength and conditioning coaches, most collegiate cheerleading programs lack access to such resources (28). The accessibility of strength and conditioning is primarily limited to Division I colleges and universities with nationally ranked athletic programs (28). While there remains a gap in the literature regarding the true effects of resistance training programs on cheerleading performance, research efforts have attempted to assess the physiological capacities of these athletes (1, 15, 18). Such research provides insights into the physiological responses to the demands and training regimens of collegiate cheerleaders, independent from participation in strength and conditioning programs. Although this information may be helpful when considering the adaptations to cheerleading participation, it does not reveal how performance can be aided.

Thomas and colleagues conducted a cross-sectional study aiming to assess the physical fitness status of collegiate cheerleaders and compare it to that of their collegiate athlete counterparts (18). The study included 18 participants from a collegiate cheerleading team, with 7 being females ages 18 to 22 (18). Various assessments were administered, including cardiovascular fitness, body composition, muscular endurance, strength, and flexibility (18).

Results revealed that female cheerleaders scored within the 80th percentile (VO_{2max}: 40.7±5.8 ml/kg/min) for cardiovascular fitness assessments, according to the Aerobics Research Institute (18). Comparable scores were observed with basketball, dance, gymnastics, swimming, tennis, and volleyball college-level athletes (18). Body composition analysis (body fat %: 15.5%) revealed comparable scores to that of gymnasts. Muscular endurance assessments, including abdominal crunches (64.7±18.7 repetitions) and push-ups (24.3±7.6 repetitions), placed female cheerleaders beyond the 80th percentile and within the 75th percentile respectively, with normative values not provided (18). Upper body strength testing results (1 Repetition Maximum (1RM) Bench Press: 37.0±7.7 kg) fell within the 60th percentile for females, aligning with basketball athletes (18). Lower body strength testing results (Isokinetic quad strength: 75.1±6.9%) were within normal range for healthy, active females. Flexibility testing indicated female cheerleaders scored above the 90th percentile (sit-and-reach: 44.9±7.0 cm) (18).

Overall, the study concluded that the fitness levels of collegiate cheerleaders surpassed normative values for various athletic measures for their age and sex (18). These levels were comparable to other collegiate athletes (18). The authors recommend the inclusion of proper conditioning programs to adequately prepare for the specific demands of their sport (18). The findings of this study may not accurately reflect the current fitness profiles of modern-day collegiate cheerleaders since the sport of cheerleading has evolved since the study's year of publication.

In response to Thomas et al. (2004) (18), Davis et al. (2004) conducted a very similar study within the same year exploring the performance characteristics of Division IA nationally ranked intercollegiate (1). The authors state the differences from the results of Thomas et al. (2004) (18), with the rationale that the assessments used in the Physiologic Profile of the Fitness Status of Collegiate Cheerleaders were general fitness tests and may not provide sufficient information to relevant practitioners regarding sport-specific requirements of competitive collegiate cheerleading (1). In a study by Davis et al. (2004), both male and female cheerleaders were recruited from a co-ed DIA competitive cheerleading team (1). The participants in this study participated in weight training and plyometrics sessions in addition to their practice schedule and other responsibilities including cheering at athletic events (1). The authors assessed similar components of physiological fitness compared to Thomas et al. (2004) (18), including body composition, flexibility, muscular strength, power, and endurance (1). The assessment of these components of fitness using physiological assessments were matched to the sport-specific skills performed within positions (1). Specific to this team and typical for competitive collegiate co-ed cheerleading teams, males were bases while females were flyers (1).

Results revealed that female cheerleaders' mean percent body fat was 28.2±2.5% using bioelectrical impedance analysis (BIA) and 17.1±3.1% using the seven-site skinfold test, with significant differences between the two methods for measuring percent body fat ($p = 0.0357$) (1). A series of flexibility tests were conducted throughout several ranges of motion (1). Lower body flexibility scores for females resulted in scores ranging from advanced intermediate to advanced. Upper body strength testing assessed through 1RM bench press resulted in 33.7±3.3 kg for female cheerleaders (1). Power was assessed by both vertical jump and Wingate Anaerobic Test (WAnT), resulting in a mean outcome of a 45.5±5.2 cm vertical jump and a 10.5±1.3 W/kg maximum power output on the WAnT, which is recognized as excellent lower body power scores (1). Muscular endurance assessments for female participants included maximal number of parallel bar dips at 75% body weight, abdominal crunches, and push-ups, resulted in 21.5±9.0, 69.3±16.3, and 40.3±11.9 repetitions, respectively (1).

While this study specifically examines co-ed collegiate cheerleaders (1), the identified shared responsibilities between the flyer and base, as well as the common aspects of co-ed and all-girl cheerleading, suggest that the findings may have broader applicability. This information could potentially be relevant to all-girl collegiate cheerleaders and individuals occupying different positions within the cheerleading context. Since these athletes’ assessments were chosen based on the requirements and skills subject to their position (1), the results of this study may only provide insight to the athletes who share the same position on co-ed collegiate cheerleading teams.

A more recent study investigated differences in training specificity in collegiate cheerleaders who lack formal strength and conditioning (15). The study involved 31 collegiate cheerleaders (7 males and 24 females) who were surveyed to identify whether their activity outside of routine responsibilities predominately emphasized aerobic, anaerobic, or a combination of both training methods (15). All participants completed testing to assess balance, muscular strength, muscular power, agility, muscular endurance, and aerobic fitness (15).

The questionnaire results revealed two distinct groups based on the participant'' training behaviors: the anaerobic group and the mixed group (incorporating both aerobic and anaerobic training) (15). The authors concluded that there was an absence of an identifiable aerobic group, leading to an absence of this particular group in the study (15). Notably, the anaerobic group performed better in tasks measuring muscular strength and power compared to the mixed group (3 Repetition Maximum (3RM) Squat: anaerobic = 135.69±31.69% BW, mixed = 116.33±14.21% BW, $p = 0.038$, $d = 0.84$; Standing Broad Jump (SBJ): anerobic = 203.36±24.1 cm, mixed = 183.39±15.52 cm, $p = 0.011$, $d = 1.01$) (15). This study highlights the presence of different training groups within collegiate cheerleading teams of those who lack formal strength and conditioning programs (15). However, since there were no testing measures that specifically assess cheerleading performance, no data were available to determine the impact of training specificity on sport performance. While Routman et al. (2023) provide insight on the applicability between the testing measures and components of cheerleading, aside from the significant difference in 3RM and SBJ performance between groups, no significant differences were observed in the remaining testing measures (15).

Considering the relevance of 3RM Squat and SBJ to cheerleading-specific skills, both described as anaerobic tests (15), and the significant differences in performance between groups, engaging in anaerobic training may contribute to enhanced cheerleading-specific skill performance. The study results suggests that the skills performed, and the responsibilities undertaken by collegiate cheerleaders may or may not induce adaptations in components such as balance, reactive strength, agility, muscular endurance, aerobic fitness, and grip strength. Further research is warranted to understand whether the lack of differences in the performance of these tests stem from participation in cheerleading, shared components between anaerobic and mixed training groups, or from a lack of supervised and periodized training.

A study exploring resistance training intervention response in collegiate cheerleaders, which to the authors knowledge is the only study exploring the effects to a resistance training program, was conducted by Laudner et al. (2004) (9). This study involved 41 Division I collegiate cheerleaders, with 24 participants assigned to the experimental group and 17 to the control group (9). The research aimed to explore the impact of a 6-week standard upper extremity strength and conditioning program on glenohumeral laxity and stiffness (9).

The enhancement of shoulder stability and the reduction of laxity resulting from a structured strength and conditioning program provides benefits for collegiate cheerleaders by mitigating the risk of injuries associated with shoulder laxity and decreased stiffness (9). While this study does not directly address the potential impact on cheerleading-specific skills (9), there is potential that such improvements could positively influence performance.

Considering the shared components between the intervention in this study and a full-body strength and conditioning program, it is reasonable to assume that similar effects would be observed in this type of intervention, potentially benefiting the performance of skills of cheerleading. However, it is important to acknowledge that the publication does not disclose participant'' sex, which may affect the interpretation of the data (9).

Resistance Training and Sports Related to Cheerleading. Although literature investigating the effects of resistance training intervention in collegiate cheerleaders have yet to be explored, this topic has been widely investigated throughout female collegiate sports (24). Skills of cheerleading including tumbling is shared with gymnastics (1). Considering the shared skills and related demands of gymnastics to cheerleading, it can be presumed that the results of previous literature exploring the effects of a resistance training intervention with female collegiate gymnasts would apply to female collegiate cheerleaders.

In a study by French et al. (2004), researchers investigated the long-term changes in total body power of Division I collegiate gymnasts and the impact of supplemental resistance training styles (5). Twenty female gymnasts, ages 18-22, participated in the study (5). Resistance training programs were periodized throughout the training year to allow for appropriate adaptations based on the demands of their sport (5). During the baseline year, participants followed a machine-based conditioning regimen (5). The remainder of the duration of the study, the participants followed a strength/power resistance training regimen (5). All participants continued their regular gymnastics practices throughout the study (5). To understand the changes in power output over time, body mass (kg), total skinfold thickness (mm), CMJ peak power output (W), CMJ time to peak power (s), SJ peak power output (kg), and SJ time to peak power (s) were assessed (5).

Change in peak power during CMJ was significant ($p \geq 0.05$) and mechanical power continued to increase following the introduction of the strength/power regimen (5). At each proceeding assessment, mean peak power was significantly greater than performance at baseline. CMJ peak power output increased from baseline to post-intervention by 1010 W, reflecting a 46% increase with a large (≥ 0.8) statistical effect ($d = 1.26$) (5). CMJ time to peak power improved by 0.239 seconds, reflecting a 36% change in rate of force application with a large statistical effect ($d = 2.2$) (5).

SJ peak power output increased by 900 W following the introduction of the strength/power training regimen ($d = 2.00$) (5). Time to peak power improvements were significant at the second assessment after the introduction of the strength/power training regimen, in each proceeding assessment when compared to baseline reflecting a 0.151 second improvement with a statistically large effect (d = 1.53) (5).

Body mass changed from baseline to post- intervention by a 3.19 kg mean increase, although this change was not significant ($p \leq 0.05$) (5). Skinfold thickness notably decreased; however, these changes were not statistically significant ($p \leq 0.05$) but are worth noting considering a greater distribution of lean muscle mass as a result of the resistance training intervention (5). This aspect helps increase performance since this improves the power-to-weight ratio, leading to improved ability to develop muscular power, therefore improving the ability perform skills with higher difficulty (5).

Participants of this study improved their ability to produce power, which provided additional aid in sport-specific performance as reflected in the improved placing during competitions (5). The largest improvements of placing were observed in floor exercise, an event displaying sport-specific skills of floor routines include leaping and tumbling - both power-based skills (5).

Addition to the literature. The existing literature regarding the physiological profiles of collegiate cheerleaders tend to be outdated, leading to be potentially inaccuracies as cheerleading at the collegiate level has progressed immensely since the date of publication (21). The changes to the score sheets at the Collegiate Cheerleading Championships over the years has shown that the skills performed by collegiate cheerleaders have become more competitive and difficult and the emphasis on execution continues to intensify (27). Not only does a team need to perform skills that are of the utmost difficulty in their division, but they must also execute them with precision and full capability of mastery. The studies provided offer insights into the performance of cheerleaders on physiological capability assessments; however, they fail to investigate the distinguishing characteristics of nationally ranked teams compared to those failing to advance to finals or attain high placements. Furthermore, these studies do not assess the potential effects of engagement in resistance training programs on performance enhancement within the context of cheerleading. Of the studies investigating the physiological profiles of cheerleaders, these participants were recruited from co-ed teams, further highlighting the need for exploration in female collegiate cheerleaders solely. Additionally, resistance training variables affecting the performance of cheerleading-specific skills are unknown. This is especially important when considering that cheerleading has undergone significant evolution over the past 20 years, transforming into a more dynamic and competitive sport. Most existing literature pertaining to cheerleading was published prior to the significant change in the sport. The demand for insights and guidance within the realm of performance and cheerleading is increasing, driven by the expanding competition within the collegiate space. Furthermore, with its recognition as an International Olympic Committee (IOC) sport, there is potential for inclusion in the 2028 Los Angeles Summer Olympic Games, emphasizing the need for comprehensive understanding and support in this field. Considering the athletes on the IOC Premier Cheerleading teams are also athletes who compete at the College Cheerleading National

Competitions, not only would the insights imposed from exploring the effects of resistance training on cheerleading performance be applicable to the collegiate setting, but also in the global Olympic space. Such gaps impose a need to explore the ways in which enhance cheerleading performance. Therefore, aim of this study is to examine the effects of a resistance training program on power, strength, and sport-specific skill performance in female collegiate cheerleaders.

CHAPTER 3

METHODOLOGY

Study Design: Female collegiate cheerleaders were recruited from a University's All-Girl Cheerleading team to participate in a 10-week resistance training intervention study examining its effects on muscular power, muscular strength, and sport-specific performance. During this process, the research team clearly stated that the athlete's participation in the study would at no time alter or interfere with the participant's position and membership status on the cheerleading team.

Participants: Twenty-four female collegiate cheerleaders (n=24) who compete annually at the Universal Cheerleader's Association's College Cheerleading National Championship participated in the study. All participants were current members of the team throughout the duration of the study. A total of 22 female collegiate cheerleaders completed the study. A total of 2 participants dropped out during the study intervention period, however reasons for dropouts were unrelated to the study and due to outside circumstances. Participating in resistance training (RT) (n = 12; age: 19.74±0.96 years; height: 161.95±7.99 cm; body mass: 64.37±13.80 kg; body fat %: 40.37±0.96%; lean body mass: 12.38±1.99 kg) or control (CON) (n = 10; age: 20±1.4 years; height: 161.85±6.24 cm; body mass: 59.99±6.59; body fat %: 34.1±8.62%; lean body mass: 11.96±1.01 kg) (Table 1). To be included in this study, all participants must be a cheerleader at the university, be able to perform a standing back tuck, toe pitch, straight-ride basket toss, have not participated in a program of regular resistance training ≥ 3 times per week for the past 6 months, be 18-23 years old, female, not pregnant or plan to become pregnant during the duration of the study, able to secure transportation to the University of Rhode Island, and be able to read, speak, and understand English. Participants were excluded if they did not meet all the inclusion criteria. The study was approved by the University of Rhode Island IRB.

Procedures: After IRB-approved participant consent was given, participants completed a Nutritional History Questionnaire and Physical Activity History Questionnaire. Participants were matched based on one repetition maximum (1RM) strength measures and birth control status and then randomly assigned into one of two groups; RT or no resistance training (CON) (12). Baseline measures were assessed prior to group randomization and the start of the intervention. Stratified randomization was used to have an appropriate number of positions per group. Every group consisted of two bases, one back and one flyer. Both groups participated in baseline and post-intervention testing for muscular power testing, muscular strength testing, sport-specific performance testing, body composition, dietary intake and heel densitometry testing.

Anthropometric Measures: Height was assessed in centimeters (cm) using a stadiometer (Seca 213, Chino, CA). The measurement involved positioning the participant with feet together and flat on the floor, ensuring contact of the head, shoulders, buttocks, and heels with the stadiometer. To maintain consistency, participants were instructed to inhale and hold their breath during measurement. Duplicate measurements were taken, and the average was recorded.

Weight measurements, conducted both before and after the intervention, were in kilograms (kg) using a digital scale (Tanita WB-100, Arlington Heights, IL). To enhance accuracy, the scale was calibrated, and participants were weighed at the scale's center after removing shoes and excess clothing. Duplicate measurements, rounded to the nearest tenth of a kilogram, were averaged and documented.

Body Composition: Whole body and regional body composition (dry lean mass (DLM), body fat mass (BFM), skeletal muscle mass (SMM), and percent body fat (PBF)) was assessed via bioelectrical impedance analysis (InBody 770, InBody Corp., Cerritos, CA). Participants were asked prior to testing to consume their normal amount of water they consume on a day-to-day basis. Body composition was assessed at baseline and post- intervention.

Dietary Intake. Participants were provided instructions on how to accurately maintain a 3-day food log, covering two weekdays and one weekend day. They were given a log in to the Automated Self-Administered 24-Hour Dietary Recall (ASA24) website to record the foods and beverages they consumed. Macronutrient and overall dietary content were derived from the dietary intake data obtained from the food logs and further assessed for changes as dietary intake that may influence body composition outcomes. Descriptive characteristics such as total calorie consumption (kcals), carbohydrate (CHO), and protein (PRO) were derived from these assessments. The evaluation of diet logs occurred both before and after the intervention.

Power Testing: The assessment of muscular power involved a Countermovement Jump with Arm Swing (CMJ-AS) utilizing Novel Loadsol insole force-sensors (Novel Electronics, St. Paul, MN, USA), operating at a frequency of 100 Hz. This specific variation of the movement was selected for its high level of sport-specificity. The Novel Loadsol insole force-sensors, integrated with the Loadsol-s application via iPad (apple Inc, Cupertino, CA, USA), were employed to capture take-off velocity (m/s), flight time (s), flight height (m), and peak propulsive force (N). Participants were equipped with Loadsol insoles fitted according to their foot size. All participants performed the CMJ-AS.

To maintain accuracy, the Loadsol devices were zeroed between participants and when drift occurred during measurements. Prior to the measured trials, participants were familiarized with the CMJ-AS through a demonstration and explanation by the researcher. Practice trials were conducted before fitting the participants with the Loadsol insoles. Participants were instructed to complete the test explosively by jumping as high as they can while executing proper form of a CMJ-AS. Each participant completed a minimum of two successive trials, and the highest values from these trials were utilized for baseline and post- testing analyses.

Sport-Specific Performance Testing: Following power testing, the evaluation of sport-specific performance including key aspects of cheerleading; stunting and tossing.

Stunting in collegiate cheerleading as includes pyramid work, involving the flyer positioned on the thigh of another athlete, known as the “mid-layer”, who in turn stands on the shoulders of another athlete, labeled as the “bottom-layer”. Executing this skill typically entails bases and a backspot releasing the flyer into the air. This skill is called a Toe Pitch. To comprehend changes in the acceleration (m/s) of the concentric phase of the toe pitch, an APDM Opal Wireless Inertial Measurement Unit Sensor (APDM Inc., Portland, OR, USA) was utilized. Flyers wore the sensor aligned with their sacrum, secured with a belt over their clothing.

Similarly, for the basket toss, a skill required completed by all competitive collegiate teams, Novel Loadsols and APDM Opal sensors were utilized. Typically performed with flipping or spinning when competed, a Straight-Ride Basket Toss served as a fundamental drill to assess changes in force exerted by bases and backspots and displacement characteristics of flyers. Bases and baskspots were instructed to complete both skills explosively by jumping as high as they can while executing proper form of a Straight-Ride Basket Toss and Toe Pitch.

Muscular Strength: Lower and upper body muscular strength was assessed through 1RM barbell back squat and 1RM shoulder press exercises (12). The selection of 1RM shoulder press was based on its sport-specificity, as determined by Davis et al. (2004) (1). Participants performed 8-10 repetition at approximately 50% of their estimated 1RM, followed by an additional set of 3-5 repetitions at around 85% of their estimated 1RM. A rest time of 2-3 minutes was employed for the warmup sets. Successive maximal trials, separated by 2-3 minutes of rest, were used to determine individual 1RM for each resistance exercise. The Borg Category-Ratio (CR-10) scale was also used to gauge the intensity of 1RM attempts, ensuring accuracy in determining true 1RM values. Participants continued to complete maximal trial attempts with incrementing weight until they could no longer maintain proper form or complete a successive repetition. For barbell back squat 1RM, acceptable form was described as a depth no higher than where the participants inguinal fold becomes aligned with the top of their knee, with feet remaining flat. For shoulder press 1RM, acceptable form was described as full shoulder flexion and elbow extension without utilizing the lower body, reflecting a “strict” shoulder press movement. The highest amount of weight (kg) was recorded for each exercise 1RM. Relative strength measures, defined as the participant’s 1RM score divided by their body weight, was determined to understand changes between baseline and post-intervention while controlling for body weight.

Resistance Training Intervention: Throughout the duration of the study, all participants continued to participate in their routine responsibilities of being a member on the university’s team including practice, game performances, and clinics. During the time of the study, this period was considered the off-season for the team's competitive season. Practices were held 1-2 times per week consisting of skills training and basketball game time-out performance practice. Participants were not practicing in the same stunt groups during practice as they were assigned to for testing procedures due to the randomized control design of the study. Participants in the RT group completed a resistance training intervention while the CON group did not participate in any intervention and were asked to not participate in any resistance training program between their baseline and post- testing. Those assigned to the RT group were asked to not complete any resistance training outside of the study's program.

The periodized resistance training program implemented with the RT group emphasized full-body strength and power with progressive overload. The training program was periodized into light, moderate and heavy intensity days (12). Light intensity training days consisted of exercises performed at <65% of their 1RM, ranging from 10 to 12 repetitions, with rest periods of 1 minute. Moderate intensity training days consisted of exercises performed at 65-85% of their 1RM, ranging from 6 to 10 repetitions, with rest periods of 2 minutes. Heavy intensity training days consisted of exercises performed at >85% of their 1RM, ranging from 3 to 6 repetitions, with rest periods of 3 minutes. Training was performed for every other day for 10 weeks in duration, for a total of 30 training sessions. All participants in the RT group started their training with a pre-planned dynamic warmup routine before initiating their pre-determined program for that specific training day. The prescribed movements for each training day comprised of an upper and/or lower complex movement followed by a series of assistance movements and ending with an abdomen/core exercise. Over the 10-week training period, exercise selection progressed from only strength-focused movements to incorporating beginner-level Olympic weightlifting style exercises and loaded plyometrics. All exercises were monitored by the researcher to ensure safety, proper form and consistency with the program and participants.

Statistical Analysis: The sample size (n) was determined based on the samples used in previous related studies and considerations of the typical size of cheerleading teams. Descriptive statistics (means and standard deviation) were used to characterize participants' demographic and anthropometric data. Data normality was assessed using the Shapiro-Wilk test. Confidence intervals were calculated to understand the variance of the data. Differences in relative muscular strength, muscular power and performance of sport-specific skills were analyzed through two-way analysis of variance (ANOVA) with a Bonferroni adjustment. Group differences between changes in anthropometric data were assessed using a one-way MANOVA. Analyses were set to a significance of $p \leq 0.05$. SPSS (SPSS Inc, Chicago, IL) and Excel (Microsoft Corporation) were used statistical analysis.

CHAPTER 4

FINDINGS

Anthropometrics: A one-way MANOVA was used to evaluate the difference in anthropometric data across groups. Five anthropometric measures were examined, including body weight (BW), dry lean mass (DLM), body fat mass (BFM), skeletal muscle mass (SMM), and percent body fat (PBF). All variables were analyzed in terms of delta change, representing the change between baseline and post-intervention data. Results are presented as mean and standard deviations (Table 1).

Prior to analysis, preliminary assumption checks were performed. All assumptions were met prior to further analysis.

TABLE 1. Group Anthropometrics

	RT (n=12)			CON (n=10)			
	Pre, Mean ± SD	**Post, Mean ± SD**	**Unadjusted, Δ (±SD)**	**Pre, Mean ± SD**	**Post, Mean ± SD**	**Unadjusted, Δ (±SD)**	**Sig. ($p \leq 0.05$)**
Age (years)	19.75 ± 0.96			20 ± 1.41			
Height (cm)	161.95 ± 7.99			161.85 ± 6.24			
Weight (kg)	64.37 ± 13.80	65.85 ± 13.49	1.48 ± 1.62	59.99 ± 6.59	60.72 ± 6.62	0.73 ± 1.14	0.236
BFM (kg)	18.13 ± 7.16	19.36 ± 7.12	1.05 ± 1.29	15.47 ± 3.12	15.72 ± 4.10	0.25 ± 2.06	0.278
SMM (kg)	25.62 ± 4.50	25.89 ± 4.54	0.27 ± 0.74	24.79 ± 2.42	25.07 ± 2.43	0.27 ± 0.78	0.947
DLM (kg)	12.38 ± 2.00	12.50 ± 2.05	0.11 ± 0.40	11.96 ± 1.01	12.09 ± 1.09	0.13 ± 0.34	0.912
BF (%)	27.61 ± 5.68	28.66 ± 5.55	1.05 ± 1.73	25.53 ± 4.56	26.07 ± 4.59	0.54 ± 2.54	0.584

RT = Resistance training group (experimental), CON = control group, N = number of participants, (cm) = measure in centimeters, (kg) = measure in kilograms, BFM = Body Fat Mass, DLM = Dry Lean Mass, LBM = lean body mass, BF (%) = body fat content measured as a percentage of total body mass

All values for pre- and post- intervention are expressed as means and SD. Unadjusted, Δ is expressed as the difference between pre- and post- values. Significance reflects the value of Unadjusted, Δ.

Descriptive statistics are presented in table 1. Overall unadjusted change score differences between groups across the combined dependent variables did not reach statistical significance ($F(5, 16) = 0.676$, $p = 0.648$; Wilks' $\Lambda = 0.826$; partial $\eta^2 = 0.174$). No statistically significant differences in unadjusted change scores for any of the dependent variables were found between groups and are presented in table 1.

Dietary Intake: Examination of adherence to dietary records at baseline and post-intervention revealed that none of the participants provided complete records encompassing at least one day of record for both baseline and post-intervention periods. Consequently, the necessary assumptions and differences between baseline and post-intervention dietary records cannot be reliably determined due to insufficient data.

Muscular Power: A two-way ANOVA was employed to explore the influence of time and group intervention on the take-off velocity (m/s), flight time (s), flight height (m) and peak propulsive force (N) of CMJ-AS. All variables were run as individual ANOVAs. The highest values between trials at baseline and post-intervention trials were analyzed. Data are presented as mean and standard deviation, unless otherwise specified. To ensure the validity of the analysis, residual analysis was conducted to assess the assumptions of the two-way ANOVA. Outliers were identified through boxplot inspection, revealing outliers. However, as the outliers fell within 3 standard deviations of the mean, it was considered appropriate for inclusion in further analysis.

Shapiro-Wilk's normality test indicated all data as normally distributed beside a violation of normality for peak propulsive force (N) for RT group at post-intervention ($p < 0.001$). Due to the robustness of the analysis and the context of the variables, the authors chose to run the analysis regardless of the violation. Homogeneity was met ($p \leq 0.05$). Descriptive results are displayed in Table 2.

TABLE 2. Group CMJ Performance Measures

	RT (n=12)			CON (n=10)		
	Pre, Mean ± SD	**Post, Mean ± SD**	**Sig. ($p \leq 0.05$)**	**Pre, Mean ± SD**	**Post, Mean ± SD**	**Sig. ($p \leq 0.05$)**
CMJ-AS TOV (m/s)	2.43 ± 0.22	2.59 ± 0.19	0.072	2.45 ± 0.08	2.49 ± 0.07	0.701
CMJ-AS FT (s)	0.50 ± 0.04	0.53 ± 0.04	0.072	0.50 ± 0.02	0.51 ± 0.01	0.701
CMJ-AS FH (m)	0.30 ± 0.05	0.35 ± 0.05	0.063	0.31 ± 0.06	0.32 ± 0.02	0.745
CMJ-AS PPF (N)	853.98 ± 137.43	839.85 ± 69.62	0.826	844.44 ± 75.85	798.59 ± 96.08	0.517

RT = Resistance training group (experimental), CON = control group, n = number of participants, SD = standard deviation, CMJ-AS = countermovement jump with arm swing, TOV = take-off velocity, (m/s) = measure in meters per second, FT = flight time, (s) = measure in seconds, FH = flight height, (m) = measure in meters, PPF = peak propulsive force, (N) = measure in newtons
All values for pre- and post- intervention are expressed as means and SD.

Subsequent analysis of simple main effects for take-off velocity revealed no significant interaction of time and group ($F(1, 40) = 0.918$, $p = 0.344$, partial $\eta 2 = 0.022$). Main effects of time and group, individually, did not reach statistical significance ($F(1, 40) = 2.339$, $p = 0.134$, partial $\eta 2 = 0.055$ and $F(1, 40) = 0.306$, $p = 0.583$, partial $\eta 2 = 0.008$, respectfully).

Analysis of simple main effects for flight time (s) revealed no significant interaction of time and group ($F(1, 40) = 0.918$, $p = 0.344$, partial $\eta 2 = 0.022$). Main effects of time and group, individually, did not reach statistical significance ($F(1, 40) = 2.339$, $p = 0.134$, partial $\eta 2 = 0.055$ and $F(1, 40) = 0.306$, $p = 0.583$, partial $\eta 2 = 0.008$).

Analysis of simple main effects for flight height (m) revealed no significant interaction of time and group ($F(1, 40) = 1.102$, $p = 0.300$, partial $\eta 2 = 0.027$). Main effects of time and group, individually, did not reach statistical significance ($F(1, 40) = 2.350$, $p = 0.133$, partial $\eta 2 = 0.055$ and $F(1, 40) = 1.102$, $p = 0.572$, partial $\eta 2 = 0.008$).

Analysis of simple main effects for peak propulsive force (N) revealed no significant interaction of time and group ($F(1, 40) = 0.112$, $p = 0.740$, partial $\eta 2 = 0.003$). Main effect of time and group, individually, did not reach statistical significance ($F(1, 40) = 0.399$, $p = 0.531$, partial $\eta 2 = 0.010$ and $F(1, 40) = 0.287$, $p = 0.595$, partial $\eta 2 = 0.007$).

Sport-Specific Skills: A two-way ANOVA was employed to explore the influence of time and group intervention on the peak combined planes acceleration of sport-specific skills, including basket toss and toe pitch. The highest peak accelerations between trials for each skill were analyzed. Data are presented as mean and standard deviation, unless otherwise specified.

To ensure the validity of the analysis, residual analysis was conducted to assess the assumptions of the two-way ANOVA. Shapiro-Wilk's normality test indicated a violation of normality for the CON group in the basket toss skill. To address this, the data was transformed using the LG10 transformation method, resulting in a normalized distribution ($p > 0.05$). Homogeneity of variances was assessed using Levene's test, which indicated homogeneity ($p = 0.640$). Descriptive results are displayed in Table 3.

TABLE 3. Group Sport-Specific Skill Performance Measures

	RT (n=4)			CON (n=2)			
	Pre, Mean ± SD	**Post, Mean ± SD**	**Unadjusted, Δ (±SD)**	**Pre, Mean ± SD**	**Post, Mean ± SD**	**Unadjusted, Δ (±SD)**	**Sig. (p < 0.05)**
Basket Toss Acceleration (m/s^2)	2.24 ± 0.13	2.13 ± 0.17	-38.18 ± 105.30	2.22 ± 0.07	2.14 ± 0.14	36.27 ± 37.55	0.283
Toe Pitch Acceleration (m/s^2)	1.96 ± 0.31	2.18 ± 0.09	44.41 ± 88.77	2.02 ± 0.03	2.08 ± 0.14	-43.69 ± 65.80	0.36

RT = Resistance training group (experimental), CON = control group, n = number of participants, SD = standard deviation, (m/s^2) = measure in meters per second squared
All values for pre- and post- intervention are expressed as means and SD.
Participants in each group were flyers.
All values for pre- and post- intervention are expressed as means and SD. Unadjusted, Δ is expressed as the difference between pre- and post- values. Significance reflects the value of Unadjusted, Δ.

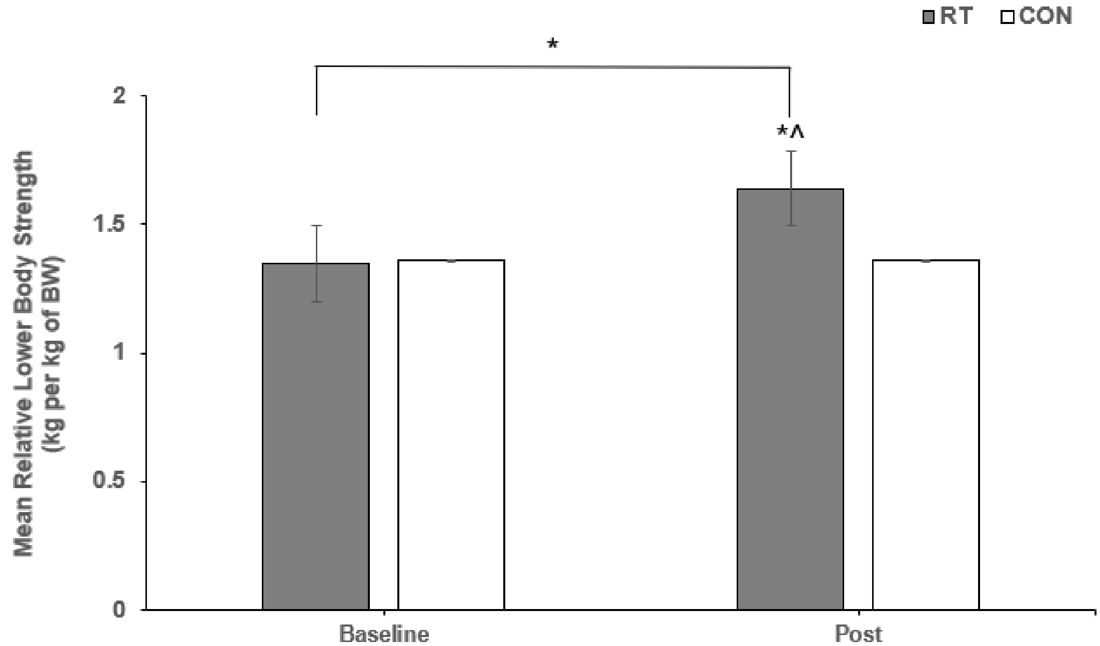
Subsequent analysis of simple main effects revealed no significant differences between the interaction of time and group ($F(1, 19) = 0.006$, $p = 0.697$, partial $\eta 2 = 0.008$), or time, irrespective of the group ($F(1, 19) = 0.067$, $p = 0.798$, partial $\eta 2 = 0.004$), and group, irrespective of time ($F(1, 19) = 0.034$, $p = 0.856$, partial $\eta 2 = 0.002$).

Muscular Strength: A two-way ANOVA was conducted to examine the effects of time and intervention group on upper and lower body relative strength. All data are presented as mean ± standard deviation unless otherwise stated. Residual analysis confirmed that the assumptions of the two-way ANOVA were met, with no outliers detected, normally distributed residuals (Shapiro-Wilk's normality test, $p > 0.05$), and homogeneity of variances (Levene's test, $p > 0.05$).

Lower Body Relative Strength: The two-way ANOVA revealed a significant interaction between time and group for lower body relative strength ($F(1, 40) = 9.333$, $p = 0.004$, partial $\eta 2 = 0.189$), indicating differential effects of Time on relative strength between the RT and CON groups. Subsequent analysis of simple main effects for time and group revealed significant differences. There was a significant main effect of time on lower body relative strength ($F(1, 40) = 9.717$, $p = 0.003$, partial $\eta 2 = 0.195$), irrespective of group. Additionally, a significant main effect of group on lower body relative strength was observed ($F(1, 40) = 7.612$, $p = 0.009$, partial $\eta 2 = 0.160$), irrespective of time.

Mean lower body relative strength for the RT group and CON group at baseline were 1.35±0.14 and 1.36±0.14, respectively. Pairwise comparisons with Bonferroni adjustment revealed that at baseline, there was no significant difference in lower body relative strength between RT and CON groups (MD = 0.014, 95% CI [-0.122 to 0.151], $F(1, 40) = 0.044$, $p = 0.835$, partial $\eta 2 = 0.001$) (Figure 1). Mean lower body relative strength for the RT group and CON group at post-intervention were 1.64±0.21 and 1.36±0.13, respectively. Post-intervention, the RT group exhibited a statistically significant improvement in lower body relative strength compared to the CON group (MD = 0.278, 95% CI [0.141 to 0.414], $F(1, 40) = 0.044$, $p < 0.001$, partial $\eta 2 = 0.297$) (Figure 1).

Figure 1. Mean Differences in Relative Lower Body Strength



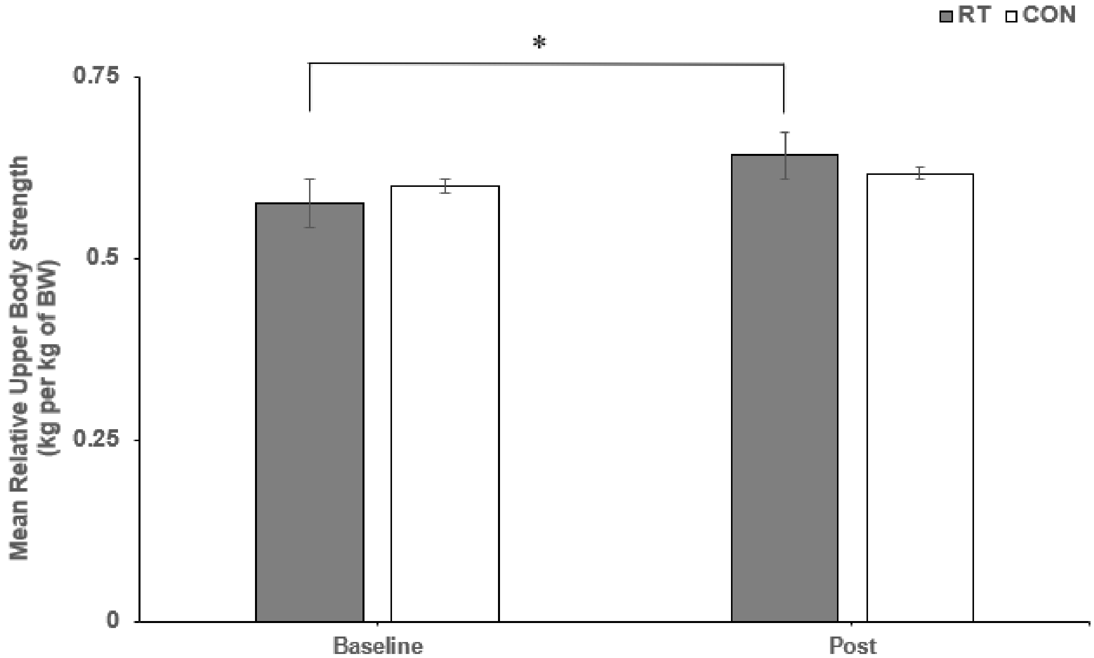
kg = kilogram, BW = body weight
*Denotes between group significance of $p \leq 0.05$ *^ Denotes within group significance of $p \leq 0.05$

Mean lower body relative strength for baseline and post-intervention in the RT group were 1.35±0.14 and 1.64±0.21, respectively. In the RT group, improvement from baseline to post-intervention was statistically significant in lower body relative strength (MD = 0.295, 95% CI [0.165 to 0.425], $F(1, 40) = 20.953$, $p < 0.001$, partial η2 = 0.344) (Figure 1). Mean lower body relative strength for baseline and post-intervention in the CON group were 1.36±0.136 and 1.36±0.13, respectively. The CON group did not exhibit a statistically significant difference in lower body relative strength between baseline and post-intervention, (MD = -0.003, 95% CI [-0.146 to 0.140], $F(1, 40) = 0.002$, $p = 0.967$, partial η2 < 0.001) (Figure 1).

Upper Body Relative Strength: There was no significant interaction between time and group for upper body relative strength ($F(1, 40) = 1.606$, $p = 0.212$, partial η2 = 0.039). However, there was a significant main effect of time on upper body relative strength ($F(1, 40) = 5.158$, $p = 0.029$, partial $\eta 2 = 0.114$), regardless of group. There was no significant main effect of group on upper body relative strength ($F(1, 40) = 0.001$, $p = 0.981$, partial $\eta 2 = 0.000$).

Mean upper body relative strength for the RT group and CON group at baseline were 0.58±0.08 kg/kg of BW and 0.60±0.04 kg/kg of BW, respectively. Mean upper body relative strength for the RT group and CON group at post-intervention were 0.64±0.07 kg/kg of BW and 0.62±0.05 kg/kg of BW, respectively. Pairwise comparisons with Bonferroni adjustment indicated no significant differences between RT and CON groups for upper body relative strength at baseline or post-intervention, (MD = -0.023, 95% CI [-0.077 to 0.030], $F(1, 40) = 0.773$, $p = 0.384$, partial $\eta 2 = 0.019$) and (MD = 0.024, 95% CI [-0.029 to 0.078], $F(1, 40) = 0.833$, $p = 0.367$, partial $\eta 2 = 0.020$), respectively (Figure 2).

Figure 2. Mean Differences in Upper Body Relative Strength



kg = kilogram, BW = body weight
*Denotes between group significance of $p \leq 0.05$

Mean upper body relative strength for baseline and post-intervention in the RT group were 0.58±0.076 kg/kg of BW and 0.64±0.07 kg/kg of BW, respectively. There was a statistically significant improvement in upper body relative strength between baseline and post-intervention in the RT group (MD = 0.066, 95% CI [0.015 to 0.117], $F(1, 40) = 6.885$, $p = 0.012$, partial $\eta 2$ = 0.147) (Figure 2). Mean upper body relative strength for baseline and post-intervention in the CON group were 0.5985±0.03707 kg/kg of BW and 0.6172±0.04807 kg/kg of BW, respectively. The CON group did not exhibit a statistically significant difference in upper body relative strength between baseline and post-intervention (MD = -0.019, 95% CI [-0.075 to 0.037], $F(1, 40) = 0.462$, $p = 0.501$, partial $\eta 2$ = 0.011) (Figure 2).

In summary, RT led to significant improvements in lower body relative strength compared to the CON group. However, no significant differences were observed between groups for upper body relative strength. Specifically, resistance training resulted in statistically significant improvements in both lower and upper body relative strength from baseline to post-intervention. Conversely, the CON group did not experience any significant changes in relative strength from baseline to post-intervention. No significant differences were found between group and time for all other measures, including anthropometrics, muscular power, and sport-specific skill.

CHAPTER 5

CONCLUSION

This study examined the effect of a resistance training intervention on muscular strength, muscular power, and the performance of sport-specific skill in female collegiate cheerleaders. Major findings included significant improvements ($p \leq 0.05$) in muscular lower and upper body muscular strength following a 10-week resistance training intervention in the RT group. This finding supports the tertiary hypothesis that cheerleaders in the RT group will exhibit significant improvements in muscular strength compared to the CON group.

The CON group did not elicit statistically significant changes between baseline and post-intervention. To the authors knowledge, this is the first study to have investigated the effects of a full-body resistance training program in female collegiate cheerleaders.

Similar effects have been observed between cheerleaders who follow an anaerobic resistance training program consisting of primarily weightlifting and plyometrics compared to those who perform a “mixed” program of anaerobic and aerobic training (15). Routman et al. (2023) found that cheerleaders who participate in anaerobic resistance training programs performed significantly ($p = 0.038$) better on maximal lower body strength measures compared to the cheerleaders who perform in a mixed approach program (15). Similar to our analysis, values were expressed by %BW (15). When interpreting these results, it is noteworthy that Routman et al. (2023) measured maximal strength for lower body through 3RM (15), while our study examined the maximal lower body strength through 1RM, the gold-standard of measuring maximal strength, according to the NSCA (7).

Upper body relative strength improvements between baseline and post-intervention for the RT group was found to be statistically significant (p = 0.012), however, the post-intervention differences between the RT group and CON group were not statistically significant. The use of the 1RM shoulder press to measure upper body relative strength was selected considering its strong translation to sport-specific skills of cheerleading. This method to measure upper body strength was also used by Davis et al. (2004), who investigated the fitness profiles of collegiate cheerleaders, due to its specificity in sport of tossing and pressing motions (1). However, Davis et al. (2004) explored the fitness profiles of cheerleaders and did not examine any effects of training (1).

Our study observed a within-group improvement of 10.34% in mean upper body relative strength in the RT group from baseline to post-intervention. These results can be compared to a similar study by Dinyer et al. (2019), who investigated maximal strength change after a 9-week resistance training intervention (2). This study found that untrained females significantly improved their relative 1RM seated military press by 17±14% (2). The percent change from baseline to post-intervention is larger than what was observed in our RT group (2). A larger improvement in upper body relative strength of our RT group would have led to a statistically significant difference between groups at post-intervention.

Similarly, both Dinyer et al. (2019) and our study's sample population were untrained females, described as individuals who do not participate in a structured resistance training program, hence leading to an expectation of comparable improvements (2). Although the participants in our study were not resistance trained, they are athletes who participate in a sport that has a high demand for upper body strength and lower body power (1, 15, 18). This may explain the trivial improvements observed in upper body relative strength. Cheerleaders are required to perform skills that share almost the same movement pattern as a standing shoulder press (1). During these actions, they repeatedly lift a flyer, mimicking a standing shoulder press. Although this activity is not formal resistance training, its specificity in movement, the muscle action, loading, and volume share the same principles as resistance training, contributing to muscular strength (25). This suggests that although our study's population was not trained according to resistance training experience, the participation of cheerleading our participants endure has a large enough stimulus to elicit strength adaptations similar to those of a trained individual.

Muscular strength is the ability to generate force due to neuromuscular adaptations, increased muscle cross-sectional area, and connective tissue stiffness (8). As individuals continue to undergo these adaptations, the progression of improvements in strength, neuromuscular adaptations, and muscle mass slows (25). Alternatively, physiological adaptations to resistance training programs occur quicker in untrained individuals (25). The observed differences in strength from baseline to post between our study and Dinyer et al. (2019) may be attributed to participants' baseline ability to produce force, rather than their training history. The lack of statistically significant differences between groups post-intervention may be due to the demanding nature of cheerleading, which elicits substantial stimuli for enhanced strength, neurological function, and muscular adaptations. However, the RT group experienced a statistically significant difference ($p < 0.001$) in lower body strength compared to the control group. Despite the concept previously mentioned, the significance in lower body strength is driven by the properties of larger muscle groups, in comparison to smaller muscle groups (7), as observed in the shoulder press 1RM assessment. If an alternative upper body strength exercise was employed, for example, 1RM bench press that utilizes overall more muscle mass, our results may have differed and elicited statistically significant differences between groups.

No statistically significant differences were found between baseline and post-intervention or between groups for muscular power and sport-specific skills. The plyometric demand of cheerleading translates to the same neurological adaptations as mentioned above (25). This concept is further supported by a study investigating the longitudinal changes in total body power as a result of resistance training in female collegiate gymnasts (5). The gymnasts in this study were similar to the cheerleaders in our study in the sense that they did not participate in resistance training prior to the study.

Considering the population of this study were collegiate gymnasts, the imposed demand of their sport elicits similar strength, neurological and muscular adaptations to our study's population (5).

This study investigated the change in peak power output (W) during the CMJ following resistance training (5). While our study did not directly measure peak power output, since force * velocity = power (7), and our study explored the changes in take-off velocity and peak propulsive force, comparisons can be made between studies. French et al. (2004) investigated the muscular power adaptations to a resistance training program over the course of 3 years (5). Researchers measured both CMJ and squat jump biannually over the time of intervention (5). Similarly to our study, participants continued with their typical practice regimen concurrently with an appropriately periodized resistance training program (5).

Similar to our findings, neither French et al. (2004) nor our study found statistical significance in short-term improvements of muscular power (5). Over the three years of intervention durations, longitudinal improvements were observed from baseline to post-intervention, demonstrating a statistically significant ($p \leq 0.05$) 46% increase in peak power output (5). This finding gives insight that female collegiate cheerleaders may endure statistically significant improvements in muscular power with continuing with a resistance training program for a longer period of time.

Our results revealed no statistically significant changes, either independently or as an interaction between time and group, in the performance of sport-specific skills such as basket toss and toe pitch. This study is the first, to the best of our knowledge, to have evaluated sport-specific skills of all-girl cheerleading. Optimal performance of these skills relies heavily on achieving maximal height during mid-air flight, making acceleration of flyers a relevant measure. Our results revealed no statistically significant changes, either independently or as an interaction between time and group, in the performance of sport-specific skills such as basket toss and toe pitch.

During these skills, the flyer is propelled into the air by the combined effort of bases and a backspot. The acceleration experienced by the flyer reflects how effectively power is transferred from the bases and backspot. Moreover, the ability of the flyer to generate power through this transfer is exhibited in the acceleration observed. Flight occurs when the combined force generated by the athletes surpasses the gravitational forces acting upon the flyer. Consequently, as the cumulative force exerted by the group against gravity increases, so does acceleration. This improved rate of velocity for the flyer translates into increased flight height.

It's important to note that participants were randomly assigned to stunt groups specifically for the purpose of these assessments, which differed from the groups they typically practice or compete with. This could have contributed to the lack of change both between and within groups. Had the intervention included practice of these skills with the assigned stunt groups, we might have observed different results.

The collection of dietary intakes was intended to demonstrate differences in eating habits among the RT group and CON group. A lack of complete records from baseline to post-intervention did not allow the authors to make valid and reliable conclusions regarding the impact of the intervention on dietary habits.

It is worth noting that two participants (n = 2) voluntarily dropped out of the study. The reason for discontinuation was due to schedule conflicts, which occurred in the first few weeks of the intervention, and illness, which occurred immediately prior to post-intervention assessments. Importantly, these instances of dropout were unrelated to injury. These participants' data was not included in the final analysis. A notable limitation of this study is the lack of complete data on participants' dietary intake. Despite the importance of understanding the influence of the resistance training intervention on diet, participants were not compliant with completing dietary records at both baseline and post-intervention. Additionally, the researchers were not blind to the participants of each group, both during the training sessions and the post-assessments, contributing to the limitations of this study. Another limitation was the duration of the resistance training intervention, which may have been too short to induce significant improvements in strength, power, performance, and skeletal muscle characteristics, including CLM and SMM. A longer intervention period might have provided adequate time to induce these adaptations, as suggested by the NSCA's statement that such changes can take up to 24 weeks in a trained population (7). Upon reviewing our data, we discovered that our participants are indeed trained, contrary to our initial assumption. Additionally, the lack of practice between stunt groups outside of the assessment sessions may have influenced the study results and is a limitation of the study. Integrating the practice of sport-specific skills within the assigned stunt groups designated for the study could provide familiarity to the participants working with another and better simulate cheerleading performances and competitions. These limitations should be considered when interpreting the study's findings.

In conclusion, this study represents the first investigation into the effects of a resistance training intervention on sport-specific skills, muscular power, and strength in female collegiate cheerleaders. Statistical analyses revealed significant increases in lower body relative strength following the resistance training program compared to the CON group. Additionally, significant improvements were observed in upper body relative strength in response to the resistance training program. Despite the observed improvements in strength, this study did not detect significant changes in weight or body composition. This finding is particularly relevant in the context of cheerleading, where alterations in weight may impact skill performance, and aesthetics is considered an aspect within the sport. In the future, further research should explore these physiological changes over an extended training period of up to 24 weeks. Investigating the long-term effects of resistance training on sport performance, strength, and power in female collegiate cheerleaders could provide valuable insights for optimizing training protocols and enhancing athletic performance in this population.

APPENDICES

Appendix I

THE UNIVERSITY OF RHODE ISLAND

Consent Form for Research

STUDY TITLE
Effect of Resistance Training on Power, Strength and Performance in Collegiate Cheerleaders

STUDENT RESEARCHER & PRINCIPAL INVESTIGATOR

Amanda Stors	Phone: 774-210-0189	Email: amanda_stors@uri.edu
Dr. Disa Hatfield	Phone: 401-874-5183	Email: doch@uri.edu

KEY INFORMATION

- This research project will be conducted at the University of Rhode Island.
- The purpose of this study is to examine sport-specific performance, muscular power and strength in female collegiate cheerleaders who participate in a ten (10) week resistance training program versus those who do not.
- You will need to come to the Health and Fitness Laboratory in Independence Square at URI for a baseline fitness assessment at the start of the study.
- During Week 1 and Week 10 (at the time of pre-intervention and post-intervention, respectively), you will use a computer program or paper log to record your dietary intake for two (2) weekdays and one (1) weekend day.
- After the initial fitness assessment, you will be assigned to one of two groups: 1) Resistance training or 2) control.
- If assigned to the resistance training group, weeks 1-10 will require you to attend three (3) strength training sessions per week. Each session will last for approximately 1 hour.
- If assigned to the control group, you will be asked to continue participating in all of your normal daily activities, including your typical cheerleading training.
- During Week 5, all participants will complete a 1-hour midpoint fitness assessment, similar to the assessment completed during Week 1.
- At the end of the intervention, all participants will complete a follow up fitness assessment.
- There is no compensation for participation in this study.
- Risks or discomforts from this research are expected to be minimal, but include muscle soreness.
- The study will help investigators better understand how resistance training programs affect female collegiate cheerleaders and if the effects translate to sport performance.
- You will be provided a copy of this consent form.

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INVITATION

You are invited to take part in this research study. The information in this form is meant to help you decide whether or not you want to participate. As you read the document and have questions, please ask.

Why are you being asked to be in this research study?

You are being asked to be in this study because you are a member of the University of Rhode Island's Cheerleading team, who is aged 18-23 years old. You are able to perform a standing back tuck, toe pitch in your designated position, and a straight-ride basket toss in your designated position. You have not participated in a program of regular resistance training (3 or more days per week of total body strength training) for the past 6 months. You do not take any medications or supplements that affect your ability to perform exercise. You do not have any acute or chronic condition affecting cardiovascular, respiratory, endocrine and/or muscular function. You do not have any condition that may limit the ability to perform resistance training and testing. You can secure transportation to URI for all measurement visits and training sessions. You are able to read and communicate in English, and you are not currently pregnant or planning to become pregnant during the duration of the intervention.

What is the reason for doing this research study?

The purpose of this study is to examine how female collegiate cheerleaders' execution of sport-specific skills, and levels of muscular strength and power respond to a three (3) day per week full-body power and strength focused resistance training program compared to female collegiate cheerleaders who do not participate in the resistance training program. Understanding these responses will give insight into how training adaptations to resistance training translates to the performance of sport-specific skills. The results of this study will help strength and conditioning coaches and team coaches when designing resistance training programs for cheerleading athletes.

What will be done during this research study?

As a part of this study, you will be asked to complete baseline, midpoint (Week 5), and follow up assessment visits, and if assigned to the training group, you'll also complete three (3) in-person resistance training sessions for ten (10) weeks. All in-person visits and training sessions will take place at the University of Rhode Island's Department of Kinesiology Health and Fitness Laboratory located at 25 Independence Way and in Keaney Gymnasium located at 85 Keaney Road. Sport-specific measurements including tuck, toe pitch and straight-ride basket toss and power measurements including countermovement jump will be performed in Keaney Gymnasium. All other measurements and training sessions will be performed in the University of Rhode Island's Department of Kinesiology Health and Fitness Laboratory.

First, you will complete a baseline fitness assessment, including the measurement of body composition, bone density of the heel, muscular power, and muscular strength, along with tuck, toe pitch, straight-ride basket toss performance. You will also complete questionnaires about your health history, your nutrition history, and your physical activity history during your baseline visit. All assessment visits will take ~1 hour. We will also ask you to track your dietary intake for two (2) weekdays and one (1) weekend day. The time to report your dietary intake will take ~30 min. Then, you will be randomly assigned to one of two groups and based on this assignment, you will complete a full body resistance training program in addition to your usual cheerleading duties, or continue your normal activity level in addition to your usual cheerleading duties. All participants in the resistance training group will be supervised and coached by a trained exercise professional during their training sessions. Each session will last ~1 hour.

During the midpoint assessment, we will only measure body composition and muscular strength. At the follow up assessment visit, we will measure body composition, bone density of the heel, muscular power, and muscular strength, along with tuck, toe pitch, straight-ride basket toss performance. We will also ask you to track your dietary intake for two (2) weekdays and one (1) weekend day. The time to report your dietary intake will take ~30 min. Total time required between all visits and dietary reporting is approximately 33 hours for participants in the resistance training group and approximately 4 hours for the control group.

Visit 1 and Follow Up (Baseline – Pre-Intervention and Follow-Up – Post-Intervention)

1. We will review this consent form and answer any questions that you may have. Then, you will sign the consent form upon your decision to participate in the study.
2. We will have you complete a health history questionnaire to ensure your safety during the course of the study, a nutritional history questionnaire, and a physical activity questionnaire.
3. We will measure your height, weight, body composition, bone density of the heel, and take your heart rate and blood pressure. If you have a pacemaker device you will not have your body composition assessed using bioelectrical impedance analysis, which sends a weak electrical current through the body, but you will still be able to participate in the study.
4. Next, we will have you complete several sport-specific skills including tuck, toe pitch, and straight-ride basket toss. These assessments will measure how much force you produce throughout these skills and how much height you achieve during these skills through the use of Loadsol insoles in your shoe and Opal Wireless Sensors. Bases and Back Spots will have Loadsols inserted in their shoes during tuck, toe pitch, and straight-ride basket toss. Top girls will have Loadsols inserted in their shoes only for tuck, then will have an Opal Wireless Sensor on an elastic belt placed at their sacrum (tailbone) by a researcher for toe pitch and straight-ride basket toss. The Opal Wireless Sensor is a small electronic device that is used to measure the speed at which the "top girl" travels throughout the skills.
5. Then, we will have you complete a muscular power assessment to assess how much force you are able to produce in a single jump with an arm swing. The Loadsols will be inserted into your shoes for this measurement.
6. Next, we will have you complete several strength assessments for the muscles in your upper and lower body. These assessments will measure how much force and how fast you can exert force through a typical shoulder, hip, knee and ankle range of motion. These measurements will consist of you lifting weights through a squat and a shoulder press motion.
7. Finally, we will have you record your dietary intake over the course of 2 non-consecutive weekdays and 1 weekend day. We will provide you with information about how to use the dietary intake reporting computer program or paper log.

Training Sessions – Weeks 1-10 (Resistance Training Sessions)

Upon randomization of groups, the resistance training group will follow the procedures below

1. We will measure your heart rate and blood pressure at the start of each session. You will also perform a dynamic warm up.
2. During each resistance training session, you will be asked to complete the prescribed program incorporating movements which offer resistance against extending and flexing your arms, legs, and trunk region. The program is designed with light (<65% of your maximal strength), moderate (65-85% of your maximal strength), and heavy intensity (>85% of your maximal strength) training sessions. The resistances will be gradually increased based on individual progress. The resistance will always be adjusted so that you are exercising at the appropriate intensity for that specific training day.
3. Your overall progress will be monitored by a trained exercise professional so that you are able to tolerate the exercise and ask for assistance if necessary. Each session will end with a cool down.
4. If you have to miss a session of testing due to a scheduling conflict or acute illness, the research team will do their best to reschedule your visit at a mutually convenient time.

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Mid-point (Week 5)

1. We will measure your body composition and take your heart rate and blood pressure. If you have a pacemaker device you will not have your body composition assessed using bioelectrical impedance analysis, which sends a weak electrical current through the body, but you will still be able to participate in the study.
2. Then, we will have you complete several strength assessments for the muscles in your upper and lower body. These assessments will measure how much force and how fast you can exert force through a typical shoulder, hip, knee and ankle range of motion. These measurements will consist of you lifting weight though a squat and a shoulder press motion.

What are the possible risks of being in this research study?

Risks or discomforts from this research are expected to be minimal. You may experience some temporary muscular soreness from testing, and heart or blood vessel problems could arise during your participation in the study. These risks are highly unusual, and we will take precautions to minimize these risks including measuring your resting heart rate and blood pressure prior to beginning testing and having a spotter assisting you when completing the strength assessments and resistance training programs to reduce your chance of injury and assist with steadiness and safety. You are also allowed to rest whenever you want during the testing session. If you have a pacemaker, you will not be able to complete a body composition analysis via bioelectrical impedance, although you may still participate in the study. None of the exercises programmed throughout the study require the participant to make direct contact with the chest that may interfere or make contact with the area typically associated with a pacemaker. Measurements of cheerleading skills may impose minimal risk. The sport-specific skills being measured throughout the study are basic level skills and will always be performed and measured in a high-clearance gymnasium with a trained spotter. In addition, your participation in this study will not interfere or affect your position and status as a member of the University of Rhode Island Cheerleading team. The use of the Opal Wireless Sensors imposes minimal risk. The investigators of the study believe that the risk of study participation is relatively small.

What are the possible benefits to you?

Participants may improve their physical fitness as a result of participating in the study. This includes increasing their muscular strength and power and performance of sport-specific skills and improving their body composition by increasing their lean muscle mass.

What are the possible benefits to other people?

Participants in the intervention group may improve their physical fitness as a result of participating in the study. This includes increasing their muscular strength and power and performance of sport-specific skills and improving their body composition by increasing their lean muscle mass. Participants in the control group may not receive any benefit.

What will being in this research study cost you?

There is no cost to you to be in this research study.

Will you be compensated for being in this research study?

You will not be compensated for participating in this study.

What should you do if you have a problem during this research study?

If you have a problem or experience harm as a direct result of being in this study, you should immediately contact the person listed at the beginning of this consent form. If needed, seek immediate emergency care for this problem. Please note, it is the policy of URI not to pay for any required care. Agreeing to this does not mean you have given up any of your legal rights.

How will information about you be protected?

Reasonable steps will be taken to protect your privacy and the confidentiality of your study data.

All information collected in this study is confidential, and your name will not be identified and linked to any study data at any time to anyone other than the principal investigators of the study. Your data will be coded with an ID number only, which will be linked back to you only by the investigators of the study. Any electronic data will be stored on computers protected with passwords.

None of the information will identify you by name. All study data, including this consent form, will be locked in a file cabinet and also stored in a study computer with a password secured in the Principal Investigator's locked office (Independence Square Building, Suite P, room 205).

The data will be stored electronically through a secure server and will only be seen by the research team during the study and for 5 years after the study is complete. In any publications that result from this research, no personally identifying information will be used.

The only persons who will have access to your research records are the study personnel, the Institutional Review Board (IRB), and any other person, agency, or sponsor as required by law. The information from this study may be published in scientific journals or presented at scientific meetings but the data will be reported as group or summarized data and your identity will be kept strictly confidential.

What are your rights as a research subject?

You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study. For study related questions, please contact the investigator(s) listed at the beginning of this form. For questions concerning your rights or complaints about the research contact the Institutional Review Board (IRB) or Vice President for Research and Economic Development:

• IRB: (401) 874-4328 / researchintegrity@etal.uri.edu.
• Vice President for Research and Economic Development: at (401) 874-4576

What will happen if you decide not to be in this research study or decide to stop participating once you start?

You can decide not to be in this research study, or you can stop being in this research study ("withdraw') at any time before, during, or after the research begins for any reason. Deciding not to be in this research study or deciding to withdraw will not affect your relationship with the investigator or with the University of Rhode Island. You will not lose any benefits to which you are entitled.

DOCUMENTATION OF INFORMED CONSENT

You are voluntarily making a decision whether or not to be in this research study. Signing this form means that (1) you have read and understood this consent form, (2) you have had the consent form explained to you, (3) you have had your questions answered and (4) you have decided to be in the research study. You will be given a copy of this consent form to keep.

Participant Name:

____

Name of Participant: Please print

Participant Signature:

____

Signature of Participant

____

Date

Investigator certification: signature certifies that all elements of informed consent described on this consent form have been explained fully to the subject. In my judgment, the participant possesses the capacity to give informed consent to participate in this research and is voluntarily and knowingly giving informed consent to participate.

____

Signature of Researcher Obtaining Consent

____

Date

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Appendix II

Collegiate Cheerleading Strength Assessment

Participant #: ________ Date: ________ Time: _________

Researcher Initials: _______ Circle one: Pre / Post

What did you eat and/or drink before today's session?

Borg CR10 pre RPE: _________

Dynamic Warm-up

1RM Squat

Warm-Ups:	Attempts:	Borg CR10:
1. ________ lbs (5-10 reps @ 50%)	1. _______ lbs	1. __________
2.__________ lbs (3-5 reps @ 60-70%)	2. _______ lbs	2. __________
3. _________ lbs (2-3 reps @ 80-90%)	3. _______ lbs	3. __________
(4.) ________ lbs (2-3 reps @ 85-95%)	4. _______ lbs	4. __________
	5. _______ lbs	5. __________

Notes:

1RM Military Press

Warm-Ups:	Attempts:	Borg CR10:
1. ________ lbs (5-10 reps @ ~25%)	1. _______ lbs	1. __________
2.__________ lbs (3-5 reps @ 30-35%)	2. _______ lbs	2. __________
3. _________ lbs (2-3 rep @ 40-45%)	3. _______ lbs	3. __________
(4.) ________ lbs (2-3 rep @ 50-55%)	4. _______ lbs	4. __________
	5. _______ lbs	5. __________

Notes:

Appendix III

DATE	3/10/2023							
Day 1	Recommended load (lbs)		8-10 reps		120 sec rest (2 min)			Notes:
		set 1		set 2		set 3		
		load (lbs)	# of reps	load (lbs)	# of reps	load (lbs)	# of reps	
Squat								
Walking lunge								
Bench								
Pulldown								
Upright row								
Standing Calf Raise								
Dead bug		---		---		---		

Appendix IV

Day 5	Recommended load (lbs)		6-7 reps		180 sec rest (3 min)		Notes:
		set 1		set 2		set 3	
		load (lbs)	# of reps	load (lbs)	# of reps	load (lbs)	# of reps
Barbell lunge							
Sliding leg curl							
Incline bench							
Seated row							
Shoulder press							
Bicep Curl							
Seated calf raise							
Plank shoulder taps		---		---		---	

Appendix V

DATE	3/22/2023							
Day 7	Recommended load (lbs)			12 reps		60s rest (1 min)		Notes:
		set 1		set 2		set 3		
		load (lbs)	# of reps	load (lbs)	# of reps	load (lbs)	# of reps	
Squat (3s down, 1s iso)								
Bench								
Walking Lunge								
Bentover Row								
DB RDL								
Dead Bug		---		---		---		

Appendix VI

M	H	M
M	H	M
L	M	H
M	L	M
H	M	L
H	M	H
H	M	L
H	H	M
M	L	H
H	M	L

- *While exercising we want you to rate your perception of exertion, i.e., how heavy, and strenuous the exercise feels to you.*

- *The perception of exertion depends mainly on the strain and fatigue in you muscles and on your feeling of breathlessness or aches in the chest.*

- *Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is.*

- *In addition, this scale has no anchor.*
    - *That is, if after giving a "10" on a previous rating, you decide that the current exercise is more strenuous, you may give a higher number (i.e., "11")*

- *Look at the scale and the expressions and then give a number.*

Borg CR-10 Scale of Perceived Exertion

0	Nothing at all	
0.3		
0.5	Extremely weak	Just noticeable
0.7		
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	Extremely strong	"Maximal"
11		
•	Absolute Maximum	Highest possible

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