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The effect of Hatha yoga on muscular strength in healthy, young adults

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THE EFFECT OF HATHA YOGA ON MUSCULAR STRENGTH IN HEALTHY, YOUNG ADULTS

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Chapter One: Introduction

Yoga is an ancient Indian exercise focused on connecting body and mind through slow and controlled movements (Douglass, 2007). Although it started with a spiritual foundation, the focus of yoga shifted as it spread outside of India. During the late 1800's yoga began gaining popularity in the United States (Laycock, 2013). As it grew in popularity, it became less about spirituality and more about improving physical fitness and health (Laycock, 2013). Thus, yoga has been implemented into a variety of different settings (i.e., fitness facilities, collegiate athletics, and professional sports) with intentions of improving health or physical performance abilities (Toland, 2014). Over 52 unique styles of yoga exist, but the most common are Iyengar, Integrated, Pranayama, and Hatha (Cramer, Lauche, Langhorst, & Dobos, 2016). Hatha yoga is unique from the other major types as it is the most physically oriented style of yoga (Cramer et al., 2016). While Iyengar, Integrated, and Pranayama yoga styles all include elements of physicality, the main focuses are based around improving separate components of health (i.e., bodily alignment, overall wellness, and breathing efficiency), respectively. Thus, although Hatha yoga addresses the same components of health (to a lesser extent), it has a predominately physical orientation.

The effects of yoga on various components of health and fitness are relatively new to the field of research. The majority of recent studies have focused on the effect of yoga on injury rehabilitation (Curtis, Hitzig, Leong, Wicks, Ditor, & Katz, 2015) and prevention (Gura, 2002), as well as chronic pain (Tekur, Singphow, Nagendra, & Raghuram, 2008). Research into yoga as a possible exercise to enhance both health and skill related components of fitness may be limited due to its low mechanical load

(Hagins, Moore, & Rundle, 2007). Thus, equivocal opinions exist on yoga's potential to improve overall athleticism (Hagins et al., 2007). Still, many major fitness centers (Gold's Gym® and LA Fitness®) and professional teams (Dallas Mavericks®, Los Angeles Clippers®, and Seattle Seahawks®) implement yoga into their training protocols (Toland, 2014).

Yoga has been found to increase multiple skill-related components of fitness, including agility (Kanniyan, 2014), balance (Polsgrove, Eggleston, & Lockyer, 2016), power (Bera & Rajapurkar, 1993; Saha, Tomer, Halder, & Pathak, 2010), and speed (Yadav, Rao, & Amarnath, 2012) in both sedentary and active populations. Furthermore, yoga has also significantly improved several health-related components of fitness including cardiorespiratory endurance (Hewett, Ransdell, Yong, Petlichkoff, & Lucas, 2011), flexibility (Amin & Goodman, 2014), and muscular strength (Singh, Singh, & Singh, 2014; Tran, Holly, Lashbrook, & Amsterdam, 2001). However, previous research examining the effect of yoga on muscular strength has resulted in considerable methodological limitations, such as lack of testing specificity (Bhavanani, 2003).

If yoga is found to have a positive effect on muscular strength in this study, it will act as a preliminary step to show its potential applicability in non-athletic populations to professional sport. For individuals who exercise on a regular basis, yoga could be an activity for them to add to their training to supplement the results from their workouts. For collegiate or professional sports, yoga could be an exercise added to training regimens to help further improve muscular strength capabilities. Thus, this study will help fill a current gap in the literature while also offering preliminary implications to the fields of fitness and athletics.

Need for the Study

Although research investigating the effects of yoga on muscular strength have found significant improvements, the methodologies used have been limited. Testing protocols have included sit up tests (Singh, Singh, & Gaurav, 2011), push up and curl up tests (Lau, Yu, & Woo, 2015), and most commonly, a hand-grip strength test (Bhavanani, 2003). Each of these tests, excluding the hand-grip strength test, are considered measures of muscular endurance and therefore, these studies are unable to make inferences about improvements in muscular strength. One study, however, used a more holistic methodology with leg extension, leg flexion, elbow flexion, and elbow extension activities performed to measure muscular strength (Tran et al., 2001). Although this study provided a clearer picture of overall strength improvements from yoga, only four muscle groups were tested and all exercises were single-joint movements.

Furthermore, Hatha yoga performed independently from other exercise is unlikely to promote maximal muscular strength gains (Hagins et al., 2007). However, maximal muscular strength may be improved from Hatha yoga when paired with a resistance training program. Improvements to maximal muscular strength would likely occur from multiple mechanisms. Primary mechanisms are likely due to improved motor unit activation, yet other secondary mechanisms (i.e., motor skill coordination, stability, breath control, non-maximal isometric muscular strength, power lifting technique, and intra-abdominal pressure) may assist in muscular strength improvements (Hart & Tracy, 2008; Madan et al., 1992; Omkar & Vishwas, 2009; Pauline & Rintaugu, 2011; Tran et al., 2001). Therefore, current literature would benefit from a study analyzing the effects of Hatha yoga on muscular strength through the three main powerlifts i.e., bench press, squat, and deadlift as research has tested muscular endurance, handgrip strength, and single-joint movements, rather than total body muscular strength.

Objective and Purpose Statement

The purpose of the current study is to investigate the effects of a six-week Hatha yoga intervention on upper and lower body muscular strength in healthy, young adults.

Research Questions

1. Does six weeks of yoga improve muscular strength in healthy, young adults?
2. Are there differences in post-test scores between the yoga intervention and control groups?

Null Hypotheses

1. There will be no significant difference in muscular strength in the bench press, squat, or deadlift due to the condition (i.e., yoga versus no yoga intervention).
2. There will be no significant difference in muscular strength in the bench press, squat, and deadlift due to time (i.e., pre-test versus post-test scores).
3. There will be no significant interaction between condition (i.e., yoga versus no yoga intervention) and time (i.e., pre-test versus post-test scores).

Alternative Hypotheses

1. There will be a significant difference in muscular strength in bench press, squat, or deadlift due to the condition (i.e., yoga versus no yoga intervention).
2. There will be a significant difference in muscular strength in the bench press, squat, and deadlift due to time (i.e., pre-test versus post test scores).
3. There will be a significant interaction between condition (i.e., yoga versus no yoga intervention) and time (i.e., pre-test versus post-test scores).

Independent and Dependent Variables

The independent variables were the treatment (i.e., yoga group or control group) and time (i.e., pre versus post). The dependent variables were the one repetition maximum (1-RM) of the bench, squat, and deadlift.

Delimitations and Limitations

The delimitations of this study required all participants to be healthy, young adults (18-25 years old) meeting the American College of Sports Medicine's (ACSM) guidelines for resistance training of working each major muscle group two to three times a week with a minimum of 48 hours between muscle groups (American College of Sport Medicine, 2013), since studying a healthy population would provide more practical implications for yoga in fitness and athletics. Furthermore, pregnant participants were not included in the study as maximal muscular training (i.e., 1-RM) is not recommended for pregnant individuals (Artal & O'Toole, 2003).

The limitations of this study included time, as six weeks is a shorter intervention length than used in similar research (Lau et al., 2015; Pauline & Rintaugu, 2011; Tran et al., 2001), which used interventions ranging from eight to twelve weeks. Secondly, 1-RM testing was performed in a pre-determined order, since fatigue may have influenced the testing results if done randomly. Research suggests that muscles can take up to 48 hours to recover (Grobler, Collins, & Lambert, 2004). As one week was allotted for pre- and post-testing and tests were conducted every other day, there was the potential that participants could perform two maximal lower body exercises before the 48-hour recovery period had finished. Thus, to control for fatigue, lifts were performed in a pre-determined order (i.e., squat, bench press, and then deadlift) to ensure that adequate time was provided for recovery.

Hatha yoga involves static stretches, which may improve flexibility and decrease acute muscular strength if performed directly before resistance training (Fowles, Sale, & MacDougall, 2000). Thus, any flexibility improvements obtained from yoga may have had a negative effect on muscular strength. However, since no yoga was performed directly before 1-RM testing, it is unlikely that the acute negative effects of static stretching impacted testing. Like closely related studies, participants must not have participated in yoga for six months prior to the starting date so that yoga was a new intervention to all participants (Tran et al., 2001; Pauline & Rintaugu, 2011).

Social desirability bias is the tendency for individuals to present themselves in the most favorable way possible rather than reporting the truth (King & Bruner, 2000). Since participants self-reported their activity levels, there was the potential for inaccurate reporting, as they may have over-reported physical activity levels. Thus, it is possible that not all participants in this study met the physical activity requirements. Additionally, this study did not take place in a controlled setting. The materials needed for testing exceeded the capabilities of the on-campus exercise science laboratory, as multiple weight stations were needed at one time. Therefore, testing took place in the University Recreation Center at Eastern Washington to allow for three lifting platforms to be utilized at once.

Moreover, participants in both groups did not follow a specific exercise plan; rather, they were asked to perform resistance training two to three times a week with a minimum of 48 hours separating the exercise training sessions for the same muscle groups. This was done in accordance with the ACSM's guidelines for resistance training

(American College of Sport Medicine, 2013). Research by Grabara (2016) suggested that Hatha yoga met the ACSM's guidelines for general physical activity, but Hagins et al. (2007) found with high reliability that Hatha yoga does not satisfy ACSM's guidelines. Thus, the intervention group performed the yoga routines in addition to their resistance training workouts. Participants in both groups filled out activity logs reporting each workout (see Appendix F) so results could be better understood upon completion of testing. Lastly, nutrition was not controlled for, as the participants may have had strict diets to adhere to in accordance with their training goals. Participants were asked to keep nutrition consistent throughout testing and a nutrition log for the eight weeks (see Appendix G), so results could be compared later.

Assumptions

Firstly, it was assumed that participants honestly and accurately reported on their nutrition and activity logs for the entire duration of testing. It was also assumed that participants performed resistance training at least two to three times a week in accordance with the ACSM guidelines. In addition, it was assumed that participants put forth maximal effort during all phases of testing. Furthermore, it was assumed that all participants answered questionnaires honestly and to the best of their knowledge. It is also assumed that participants adhered to the instructions given throughout testing.

Chapter Two: Literature Review

Yoga is a low-impact physical activity that dates back to 500 BC, designed to connect the mind and body through movement (Basavaraddi, 2015). Yoga spread to the United States largely due to two individuals, named Pierre Bernard and Blanche DeVries (Laycock, 2013). Prior to Bernard and DeVries coming to the United States, yoga was of little interest to most of the American population, as it was an ancient practice with strong religious ties to Hinduism. To make yoga more marketable in the United States, Bernard and Devries, both of whom practiced yoga in India, developed a Westernized version of yoga. The new, Western yoga format had no ties to Hinduism or Indian culture. Rather, it was marketed as an exercise that would produce stronger, more vigorous men and graceful, independent women. After this shift in focus occurred, yoga quickly spread across the country (Laycock, 2013).

Yoga has gained popularity in many gym and personal training settings in recent years as well as in the field of exercise science. The majority of research surrounding yoga has investigated it as a light physical activity that may have beneficial effects on cardiometabolic disease risk factors such as blood pressure (Murugesan, Govindarajulu, & Bera, 2000), total cholesterol (Damodaran, Malathi, Patil, Shah, & Marathe, 2002), and blood glucose (Malhotra, Singh, Tandon, & Sharma, 2005). Furthermore, research has studied the role of yoga in rehabilitation settings particularly related to chronic pain (Tekur et al., 2008), injury prevention (Gura, 2002), and injury recovery (Curtis et al., 2015). However, there is currently a paucity of research investigating yoga as a beneficial addition to training regimes in the athletic setting or how it relates to fitness components, such as muscular strength.

Physical fitness can be sub-divided into two main categories: skill-related and health-related components (American College of Sports Medicine, 2013). Skill-related components of physical fitness include agility, balance, coordination, power, reaction time, and speed (American College of Sports Medicine, 2013) with several of these components being studied in the literature for their relationship with yoga participation (Amin & Goodman, 2014; Bal & Kaur, 2009; Kanniyan, 2014; Polsgrove et al., 2016; Singh et al., 2011; Yadav et al., 2012). Health-related components of fitness include cardiorespiratory endurance, muscular endurance, body composition, flexibility, and muscular strength (American College of Sports Medicine, 2013). Multiple components of health-related fitness have also been researched to determine their relationship with yoga-interventions (Bhavanani, 2003; Hewett et al., 2011; Lau et al., 2015; Madan et al., 1992; Mahadevan, Balakrishnan, Gopalakrishnan, & Prakash, 2007; McCarthy, Brazil, Greene, Rendell, & Rohr, 2013; Pauline & Rintaugu, 2011; Tran et al., 2001). However, due to a lack of available research, coordination, reaction time, muscular endurance, and body composition will not be included in this review.

Relationships between Yoga and Skill-Related Components of Fitness

In recent years, researchers have investigated the possible benefits of yoga interventions on agility in a range of populations. Agility is defined as the ability to quickly change direction (Sheppard & Young, 2006) and plays an integral role in an array of different sports, such as basketball, volleyball, and soccer (Horicka, Hianik, & Simonek, 2014). Research has shown that 12-weeks of yoga in sedentary males (Kanniyan, 2014), 6-weeks of asana yoga in physical education students (Singh et al., 2011), and 8-weeks of daily yoga in college males (Yadav et al., 2012) all resulted in significantly faster shuttle run test times, a common measure of agility. Research using alternative measures of agility, i.e., a hexagonal obstacle test, have also seen beneficial results from 6-weeks of daily yoga in college males (Bal & Kaur, 2009). Although the research seems to indicate that participation in at least 6-weeks of yoga can be beneficial to agility performance, the research is currently limited to male participants and an array of different interventions, i.e., 90-minute sessions versus 60-minute sessions or three times a week versus six times a week. However, from the current literature, it appears yoga may positively impact agility.

Another skill-related component of fitness is speed, i.e., the amount of time it takes to move across a given distance (Haff & Triplett, 2015). Research surrounding yoga and speed is somewhat scarce. In a study of sedentary males (n=40), it was found that 12 weeks of yoga performed three times a week significantly improved speed in the 50-meter sprint (Kanniyan, 2014). Additionally, a study of male physical education undergraduate students (n=30) found that eight weeks of yoga significantly improved speed in the 50-yard dash test (Yadav et al., 2012). Although current research has found improvements in speed from a yoga intervention, there are limited data. Thus, more research is needed to develop a better understanding of the effect of yoga on speed, but these findings may contribute to why some of the collegiate and professional teams are starting to implement yoga into their training regimens.

Although research suggests speed and agility may be improved by yoga, findings are more equivocal surrounding the effect on balance and power. Balance, the ability to maintain control and uprightness during movements, is a key component of motor control (Davlin, 2004), while power is the rate of doing mechanical work (Vanhatalo, Jones, &

Burnley, 2011). Power and balance play an important role in physical performance (Abernethy, Wilson, & Logan, 1995). Performance in explosive sports such as basketball, volleyball, wrestling and boxing are heavily influenced by the athlete's power capacity (Gacesa et al., 2009), yet little research has explored the relationships between yoga and power. However, one study found that sedentary males can obtain significant power improvements from a 12-week yoga intervention in a standing broad jump test (Kanniyan, 2014).

Furthermore, minimal research has been conducted to see how balance is impacted by a yoga intervention in healthy participants. Significant improvements in balance were found from a 10-week yoga intervention on Division II male soccer players in the stork stand test (Polsgrove et al., 2016). However, a separate study of healthy, young males and females found no significant improvements in balance from a six-week yoga intervention (Silver & Mokha, 2008). Significant improvements to balance from yoga have been found more widespread in diseased or deconditioned populations, such as those who are obese (Chaiyong, Jutaluk, Chiraprapa, Boontiwa, & Phatchari, 2015), elderly (Schmid, Puymbroeck, & Koceja, 2010), or with chronic diseases such as multiple sclerosis (Guner & Inanici, 2015).

Relationships between Yoga and Health-Related Components of Fitness

Cardiorespiratory endurance is the extent to which the circulatory and respiratory systems can supply energy over a sustained duration (Percia, Davis, & Dwyer, 2016). VO_2max, an aspect of cardiorespiratory fitness often used to display cardiorespiratory capabilities, is the ability of the human body to transport and utilize oxygen during maximal intensity exercise (Hill, Long, & Lupton, 1924). Cardiorespiratory fitness is associated with reduced morbidity and premature death (Warburton, Nicol, & Bredin, 2006). Multiple studies have found relationships between yoga and VO_2max. Current research suggests that 8-weeks of yoga may improve VO_2max levels in healthy male and female adults (Hewett et al., 2011) as well as in healthy, untrained male and female adult participants (Tran et al., 2001).

Many other elements of cardiorespiratory fitness have shown to improve from a yoga intervention. In a study of male medical students (n=27) it was found that 12-weeks of yoga significantly increased maximum expiratory pressure, maximum inspiratory pressure, 40-mmHg test performance, breath holding time after expiration, and breath holding time after inspiration (Madan et al., 1992). Furthermore, a second study observing performance of the 40-mmHg test found significant improvements from a yoga intervention in young male and female participants (Mahadevan, Balakrishnan, Gopalakrishnan, & Prakash, 2007). This shows an increase in performance of the respiratory muscles, which would extend to an improvement in overall cardiorespiratory fitness (Madan et al., 1992). Lastly, a study of male and female students (n=20) found that six months of yoga significantly improved maximum expiratory pressure, maximum inspiratory pressure, forced expiratory volume, first expiratory volume in the first second, and peak expiratory flow rate (Bhavanani, 2003). Overall, the current literature suggests that yoga has a positive effect on cardiorespiratory endurance in a myriad of groups.

Flexibility is the maximal range of motion at any given joint (Pollock et al., 1998), and is one of the most commonly recognized benefits of yoga. Yoga consists primarily of isometric exercises and stretches focused on improving range of motion. Therefore, since flexibility may be improved by static stretching (Bacura et al., 2009;

Bandy, Irion, & Briggler, 1997), yoga is likely to also improve flexibility. Researchers have obtained data from multiple studies showing positive associations between yoga and flexibility (Amin & Goodman, 2014; McCarthy, Brazil, Greene, Rendell, & Rohr, 2013; Singh et al., 2014). Significant improvements in the sit-and-reach test, a measure of lower back and hamstring flexibility, were found in a six-week yoga study of moderately active females (Amin & Goodman, 2014) and a six-week study of adult females (Singh et al., 2014). Furthermore, there were significant improvements in both upper and lower body flexibility in moderately active adults from four weeks of 20-minute Wii Fit™ yoga, a movement-based video game developed by Nintendo® (McCarthy et al., 2013). Most of the literature has involved rehabilitation populations, which is outside the scope of the current study, and research has focused less on apparently-healthy individuals. However, there currently seems to be no contradictory evidence regarding the benefit of yoga on flexibility in healthy populations.

Lastly, muscular strength, a health-related component of fitness, has been investigated to understand the relationships with yoga participation. In a recent study of healthy, young, adult females (n=30), it was found that six weeks of daily yoga significantly improved muscular strength (Singh et al., 2014). However, the testing protocol used to measure muscular strength was not reflective of total body muscular strength. Similar results were elucidated by Singh et al. (2011) who determined the benefit of yoga on muscular strength in young adult males. The conclusions by Singh et al. (2014) and Singh et al. (2011) were somewhat limited by using the curl-up test as the outcome measure, which is a measure of abdominal muscular endurance rather than total body muscular strength (Percia et al., 2016). Therefore, it may have been more appropriate for the researchers to have concluded that yoga was beneficial to abdominal muscular endurance. It is not sound to say that overall muscular strength increased since performance in a curl-up test improved.

Another study observed men and women (n=173) and found that 12, weekly, 60-minute yoga sessions significantly improved muscular endurance in the curl-up test and push up test (Lau et al., 2015). This research adds strength to the literature in this area due to its large sample size, duration of intervention, and strong experimental design; however, it remains limited in its measurement methodology. Both the push-up and curl-up test are considered measures of muscular endurance (American College of Sports Medicine, 2017), rather than muscular strength as the authors conclude. However, research in a smaller cohort of male and female participants (n=10) has shown beneficial effects of yoga on total body isokinetic strength (Tran et al., 2001). Significant improvements were reported for elbow extension, elbow flexion, and knee extension; yet, isokinetic testing is expensive and not available to many populations. Future research would benefit from determining the true effects of yoga participation on muscular strength.

Additional research is also limited in its measurement methodology, when investigating the effects of 12 weeks of 30-minute yoga sessions on muscular strength by means of the handgrip dynamometer test (Madan et al., 1992). Handgrip dynamometers are widely used instruments due to their simplicity and inexpensive cost and results have recently shown to be prognostic of cardiovascular morbidity and mortality (Leong et al., 2015). However, they are unable to provide a total body measure of muscular strength, which may limit findings with regard to whole body yoga exercises.

Due to the simplicity of use, a considerable amount of research has investigated the effects of yoga on hand grip strength. A study of teenage students (n=40) found that six months of yoga significantly improved handgrip strength (Bhavanani, 2003). Moreover, in a study of healthy adults (n=46), it was found that six weeks of 90-minute yoga sessions performed six days a week significantly improved respiratory muscular strength but not hand grip strength (Mahadevan et al., 2007). This finding contradicts the results found from similar studies potentially due to the use of a different yoga protocol, as the yoga style was not specified, but the poses within the yoga routines were focused on breathing techniques (Mahadevan et al., 2007).

Lastly, in a study by Pauline & Rintaugu (2011), the efficacy of yoga on improving muscular strength and decreasing bilateral strength differences was investigated. Twenty-one female participants (24-38 years of age) were recruited and were placed into the experimental (n=9) or the control group (n=12). Significant improvements were found in the right and left legs in the 1-RM on leg press from pre- (right: 36.26±3.75 kg; left: 33.83±4.29 kg) to post-test (right: 58.60±4.92 kg, $p<0.05$; left: 36.21±5.43 kg, $p<0.05$), respectively. Each arm improved significantly in the chest press from pre- (right: 8.57±2.80 kg; left: 7.71±2.51 kg) to post-test (right: 8.83±2.66 kg, $p<0.05$; left: 7.98±2.45 kg, $p<0.05$), respectively. However, significant improvements were not found on either arm for the shoulder press. Although significant muscular strength improvements were found in both the upper and lower body, no differences in bilateral differences were found. The researchers hypothesized that the slight increases in strength were due to increases in motor unit activation and motor skill coordination. This study provided a unique addition to current literature, as it analyzed bilateral strength.

However, it did not provide a clear picture of how total-body maximal strength can improve. Research has suggested that the squat involves greater muscle activity than the leg press, in both the hamstring and quadriceps muscle groups (Escamilla, 2001). Furthermore, the study only analyzed females, so it is still unknown whether the muscular strength of men and women are differently affected from a Hatha yoga intervention.

Although most of these studies did find that yoga could improve muscular strength, other research suggests that physiological adaptations from participating in yoga may have a negative impact on muscular strength. One of the most commonly recognized benefits from yoga is improvements in flexibility, as yoga consists of many poses that involve static stretches (Amin & Goodman, 2014; Singh et al., 2014). Research has shown that static stretching has either no effect, or more commonly, a negative effect on muscular strength (Fowles et al., 2000; Kokkonen, Nelson, & Cornwell, 1998; Rodrigues et al., 2017; Su, Chang, Wu, Guo, & Chu, 2017). However, research surrounding how chronic stretching affects muscular strength have found inconsistent results (Joke, Nelson, Carol, & Winchester, 2007; Morton, Whitehead, Brinkert, & Caine, 2011; Ryan et al., 2011).

Some studies have found that regular static stretching can significantly improve muscular strength (Joke et al., 2007; Ryan et al., 2011) whereas other research has suggested it may be more beneficial to focus solely on resistance training (Morton et al., 2011). Moreover, Morten et al. (2011) suggested that lifters would improve flexibility while participating in resistance training permitting that the lifter achieved the appropriate range of motion for each lift. The authors did not conclude that static stretching had a negative effect on strength and therefore it should be avoided. Rather, it was concluded that flexibility can be improved during the lifts, so it is not necessary to perform static stretching in addition to a resistance training program (Morton et al., 2011). Thus, it seems that improvements in flexibility may improve maximal strength, likely due to increased muscle length, allowing for greater force development (Lieber, 2002). Furthermore, stretching may stimulate hypertrophic mechanisms (Joke et al., 2007) which are a foundational element of strength (Schoenfeld, 2010). Overall, most research has found a negative effect to muscular strength with acute static stretching prior to exercise, but the research surrounding chronic static stretching suggests muscular strength may be improved from static stretching.

Reasons for increases in muscular strength due to yoga participation are largely unknown. To directly improve maximal muscular strength, it is best to train the type II muscle fibers by utilizing heavy resistance with fewer repetitions paired with multiple sets (Campos et al., 2002). Since Hatha yoga does not involve load-bearing activities nor maximal muscle contractions, it is unlikely that it will directly increase maximal muscular strength (Hagins et al., 2007). Furthermore, it is well-known that acute static stretching has a negative effect on muscular strength, likely due to viscoelastic stress relaxation that occurs during static stretching as it decreases muscle viscosity and thus, maximal joint torque decreases (Bacurau et al., 2009).

Therefore, it seems that changes to muscular strength may occur from multiple primary, secondary, and tertiary mechanisms. The primary mechanism is likely due to improvements in motor unit activation, as it is a primary construct of maximal muscular strength that research has shown to improve from yoga interventions (Hart & Tracy, 2008; Pauline & Rintaugu, 2011). Secondary mechanisms include improvements to stability (Omkar & Vishwas, 2009), breath control (Tran et al., 2001), and non-maximal isometric muscular strength due to the isometric muscle contractions that occur in yoga poses (Madan et al., 1992). As Schoenfeld (2010) discussed, hypertrophic and muscular strength mechanisms occur separately from one another, but hypertrophic increases provide a foundation for muscular strength improvement. Furthermore, tertiary mechanisms may include improved power output, lifting velocity, and power lifting technique that occur from increased stability during exercises in stable environments, as yoga is performed on a stable surface (Drinkwater, Pritchett, & Behm, 2007). Moreover, improvements to breath control improve intra-abdominal pressure, which may improve maximal force production (Hagins, Pietrek, Sheikhzadeh, & Nordin, 2006). In addition, muscle activation occurs faster and more powerfully with improvements to motor control, which may increase immediate weight lifting capacity and muscular strength as a byproduct (Sale, 2008).

Skeletal muscle damage still occurs during isometric contractions (Mackey et al., 2008), which is foundational to strength increases but not directly stimulating of strength increases (Schoenfeld, 2010). Therefore, important foundational elements of total body muscular strength enhancements may occur from a yoga intervention due to hypertrophic improvements (Schoenfeld, 2010). Thus, the overall effect of the combined mechanisms (i.e., stability, breath control, motor control, and intra-abdominal pressure) may indirectly improve maximal strength capabilities in maximal lifting. Overall, the current mechanisms regarding yoga's ability to increase strength are hypothesized and more research is needed to understand this phenomenon.

Hatha yoga specifically may have a strong influence on muscular strength as compared to other types of yoga. As previously discussed, Hatha yoga is the most physically oriented style of yoga, whereas other types of yoga are focused on separate constructs (Cramer et al., 2016). For example, Iyengar yoga focuses on bodily alignment and Pranayama yoga focuses on breathing techniques. Hatha yoga sessions still include similar constructs to other types of yoga (i.e., bodily alignment and breathing techniques), but the predominate focus is based around improving muscular strength and athleticism (Cramer et al., 2016). Overall, Hatha yoga is both the most physically oriented style of yoga and the most practical for implementing into gym or athletic settings due to its focus on improving health and skill related components of fitness.

As research has suggested that yoga can significantly improve multiple components of fitness (i.e., agility, speed, cardiorespiratory endurance, and muscular endurance), there is already justification to implement yoga into the training protocols of sports and activities that have high demands for these biomotor abilities. If muscular strength is also found to be improved from yoga, trainers and coaches may have even greater reason to add yoga to the training regimen. However, it should be noted that implementing Hatha yoga into sports would not replace the training protocols already in place, as fitness constructs such as maximal muscular strength, speed, and cardiorespiratory endurance are predominately improved through other training methods; rather, Hatha yoga could be used to help enhance the improvements to health- and skill-related components of fitness.

Current research has primarily concluded that there may be beneficial effects of yoga on muscular strength through handgrip, as well as curl up and push up tests, which should be more accurately regarded as measures of muscular endurance, thereby limiting our knowledge in this area due to methodological limitations. Overall, there is a paucity of research investigating the impact of yoga on total body muscular strength. Therefore, research investigating the possible relationships between yoga and muscular strength utilizing multiple compound exercises, such as 1-RM bench press, squat, and deadlift, which may be more generalizable to an active population, is necessary.

Chapter Three: Methods

Participants

Male and female participants between the ages of 18 and 25 years who were active in accordance with ACSM's resistance training guidelines of at least two to three resistance training sessions per week were recruited for this study (American College of Sport Medicine, 2013). The Physical Activity Readiness Questionnaire (PAR-Q+) and a tester-created questionnaire (see Appendix A) were distributed to participants to determine whether they met all inclusion criteria. Exclusion criteria included pregnancy, any chronic injury or risk factors for injury from power lifts (i.e., osteoporosis, osteopenia, etc.), disease (i.e., autoimmune, cardiovascular, metabolic, etc.), any yoga practice within three months prior to the start of the intervention, as well as any injury occurrence within six months prior to the start date of the intervention. Lastly, since these lifts have been determined to be a safe activity with professional supervision, participants did not need to have experience with the power lifts (Hamill, 1994). Rather, their experience with power lifting was reported in a pre-testing questionnaire to better understand results.

Participants were recruited through convenience sampling methods and were randomly stratified by sex to either the intervention group (yoga group) or control group (non-yoga group) by drawing numbers from a hat. All odd numbers were placed in the intervention group and even numbers were placed into the control group. Control group participants were offered 18 free yoga sessions after the completion of the study. All participants provided their informed consent prior to data collection. The study protocols were submitted and approved by the University's Institution Review Board (IRB) for ethical testing prior to any data collection in accordance with the Declaration of Helsinki. Participants were recruited by word-of-mouth and flyers placed throughout the Eastern Washington University (EWU) campus. Permission was obtained from the IRB before any flyers were posted. As recruitment incentives, 18 free yoga sessions and two free BOD POD® tests were offered to participants.

Instrumentation/Apparatus

Anthropometric measures, i.e., height and weight, were measured using a stadiometer (Health-O-Meter, Continental Scale Corporation®, Bridgeview, IL) and scale (Health-O-Meter, Continental Scale Corporation®, Bridgeview, IL), respectively. Body composition was estimated using air displacement plethysmography with predicted thoracic gas volume (BOD POD®, COSMED, Rome, Italy). 1-RM testing was conducted at power racks (Power Rack®, Power Lift & Conner Athletics Products Inc, Jefferson, Iowa) with standard barbells for each lift (Iron Grip Standard Barbell, Iron Grip®, Santa Ana, CA). For the bench press, Power Lift® adjustable benches were used (Lever Action Bench®, Power Lift & Conner Athletics Products Inc, Jefferson, Iowa). For the deadlift, 1-RM testing was conducted on Olympic lifting platforms (Power Lift Olympic Platform®, Power Lift & Conner Athletics Products Inc, Jefferson, Iowa).

Pre- and Post- Testing Protocol

Participants were asked to refrain from exercise and alcohol or caffeine consumption for at least 12 hours prior to each testing session. Participants were also encouraged to get a restful night of sleep the night before testing. Pre- and post-testing followed the same format and each were completed over a one-week period. Anthropometric measures were taken on the first testing day along with estimations of body composition. Height and weight were measured to the nearest 0.1 cm and 0.5 kg, respectively. Body composition was estimated via air displacement plethysmography using standard procedures from the manufacturer.

Following the first day, participants performed their 1-RM for the squat. Two days later, 1-RM were tested for the bench press. Lastly, two days after the bench press test, 1-RM for the deadlift was tested (Figure 1). Specific warm-ups were not included due to the gradual progression used for testing 1-RM in accordance with the National Strength and Conditioning Association (NSCA) testing protocol (Haff & Triplett, 2015). Thus, progression through the 1-RM test began with lighter weights and higher repetitions as a warm-up procedure. Participants provided an estimation of their 1-RM which was then be applied to the NSCA's 1-RM chart (see Appendix B) for participants to work through accordingly. All testing on a given day was completed within a 30-minute period.

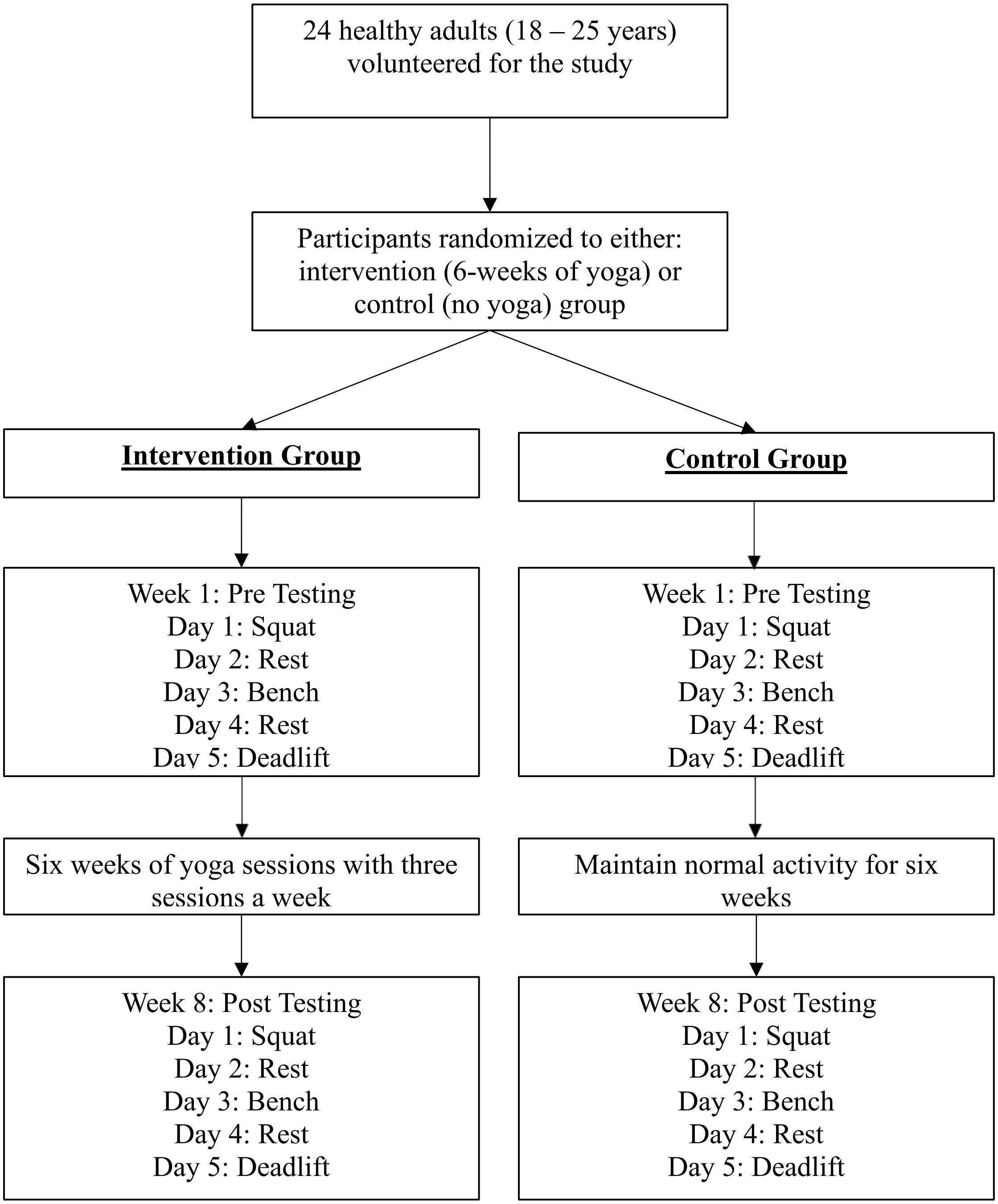

Figure 1: *Testing Protocol*

Bench Press Testing

For bench press testing, one spotter was at each lift to ensure the safety of the participant. In accordance with USA Powerlifting™ guidelines, lifters had a grip with no more than 81 centimeters between the fore fingers (USA Powerlifting, 2016). The head, shoulders, and buttocks were required to stay in contact with the bench and the feet had to stay flat on the floor. Once the participant was set in their position, spotters verbally confirmed that they were ready for the lift. Upon the participant's confirmation, a lift off was given by the spotter. The participant then lowered the bar to their chest or upper abdominal area and paused in this position until the referee of the lift said, "press." The spotter then tracked the bar (without making contact) as the participant pressed the bar upwards. Once the lifter fully locked their elbows, the referee said, "rack," and the spotter grabbed the bar and helped the participant rack the weight. During the ascent phase, the spotter immediately grabbed the bar and re-racked the weight if any negative motion occurred.

Squat Testing

For squat testing, one spotter was at each lift along with one referee to the side of the rack to ensure proper depth was reached. The lifter removed the bar from the rack and prepared for the lift. Once they were in position, the spotter said "squat" to verbally cue the lifter to start the descent phase. In accordance with USA Powerlifting™ guidelines, lifters achieved proper depth once the top surface of the legs at the hip joint were lower than the top of the knees (USA Powerlifting, 2016). Once the referee determined that proper depth was achieved, they said, "up" and the lifter began the ascent phase. The lift was counted as complete once the lifter returned to an upright position with knees locked. Once the lifter completed the lift, the referee said, "rack" and the spotter assisted the bar back to the racks. If negative motion occurred at any point during the lift, the spotter immediately helped the lifter return the weight to the racks and the lift was not counted.

Deadlift Testing

For the deadlift testing, there was no spotter as it is not necessary for the deadlift. However, there was a referee evaluating the lift to ensure the knees locked out with the shoulders back. Lifters chose to use their preferred grip (i.e., conventional or mixed) and their preferred stance (conventional or sumo) but had to use the same grip and stance for pre- and post-testing. This is in accordance with the USA Powerlifting™ protocol (USA Powerlifting, 2016). Once the lifter was in a ready position, the referee gave the verbal cue, “lift,” and the lifter began the ascent phase. Once the lifter fully locked out the knees and hip with shoulders back, they were given the cue, “down.” Lifters then lowered the bar back to the ground and the lift was completed. If the lifter failed to reach the full upright position or if the bar was dropped rather than lowered, the lift was not counted.

Testing protocol

For each of the 1-RM tests, participants were shown an example lift prior to performing any repetitions. Participants were then asked if they had any questions before testing began. Familiarization lifts occurred during the warm-up sets. Participants were not allowed any wrist straps, belts, knee wraps, or knee sleeves during testing. Lastly, participants were clearly instructed to let the spotters do all weight and platform rack adjustments.

Intervention Group

Participants within the intervention group received 18 sessions of yoga over a six-week period with three sessions a week. Each session lasted 50 minutes and was conducted by a Registered Yoga Trainer who led all 18 sessions. Alternatives to more challenging postures were offered to account for differences in ability. Each yoga session was held at the same time of the day and were conducted as a Hatha yoga session following a three-mountain format (Shaw, 2016). Yoga sessions were held in the EWU Group Exercise Room (Physical Education Activities 270). After the first and last session, the Registered Yoga Trainer filled out a tester-created questionnaire (see Appendix C) describing how the class went. Participants were checked in by their assigned participant number at each session they attended. Therefore, if participants missed a session, it was recorded and adherence was discussed in the results. Attendance rate was recorded to help explain results upon completion of testing.

Control Group

Participants within the control group did not receive any form of treatment during the six-week period of the yoga intervention. Participants were asked to continue their regular routine, physical activity levels, and nutrition. Furthermore, they were asked to fulfill the ACSM's guidelines for resistance training of working each major muscle group twice a week, similarly to the intervention group. Participants in the control group were offered the 18 yoga sessions following the conclusion of the study.

Sample Size Estimates

Sample size estimates were generated for a 2x2 factorial analysis of covariance (ANCOVA) research design using GPower version 3.1.9.2 (Universitat Kiel, Germany). The primary outcome variable was maximal 1-RM on the three main power lifts. When running a sample size calculation with a .13 partial eta squared (moderate effect size), a power of .80 and an alpha level set at 0.05, it was calculated that 16 participants would be needed for this study. Furthermore, when comparing different ends of the spectrum, similar studies had found significant differences with sample sizes ranging from 30

(Singh et al., 2014) to 173 (Lau et al., 2015) participants. However, for practical purposes, 36 participants was the maximum recruited for the current study, as that was the highest number of BODPOD tests able to be performed in the one day allotted for pre- and post-testing. Lastly, with a longitudinal study, attrition should be accounted for. Therefore, it was beneficial to recruit more participants than required to achieve 80% power to account for attrition rates. Overall, 36 was the target sample size, as it left room for attrition and still exceeded the mathematical sample size calculation of 16.

Statistical Analysis

Data were analyzed using SPSS Statistical Software (IBM SPSS Statistics for Windows 24.0, Armonk, NY, USA). Data were checked for normality using the Kolmogorov-Smirnov test and any necessary transformations were made. Data were represented as means, and a 2 (group) x 2 (time) factorial ANCOVA was used to determine differences between treatment and control groups and differences in pre- and post-values, with sex as a covariate. Tukey's post hoc analysis was used to determine differences if main effects were significant. Alpha level was set at 0.05.

Chapter Four: Results

Participant Characteristics

Eighteen resistance trained, young adults volunteered for the current study and were randomized to either the control (n=8) or yoga (n=10) group. Twenty-four participants began the study but five discontinued for unspecified reasons and one outlier was removed from the data set. Participants were predominantly female within the current study (61%) and had just over two years of resistance training experience (25.5 ± 28.6 months). Participant characteristics are reported in Table 1.

Table 1: Descriptive statistics of participants

Group	Sex			Age (years)	Height (cm)	Weight (kg)	Experience (months)
Yoga	Male	(n=4)	Mean	24.0	173.0	79.5	33.0
			Std. Deviation	2.0	5.8	12.3	26.6
	Female	(n=6)	Mean	22.0	161.2	69.3	26.2
			Std. Deviation	2.1	8.4	6.0	24.6
	Total	(n=10)	Mean	22.8	165.9	73.4	28.9
			Std. Deviation	2.2	9.3	10.0	24.2
Control	Male	(n=3)	Mean	24.0	176.1	89.5	35.7
			Std. Deviation	1.7	3.9	15.5	52.3
	Female	(n=5)	Mean	23.2	165.3	66.8	14.0
			Std. Deviation	2.0	7.3	8.5	17.6
	Total	(n=8)	Mean	23.5	169.3	75.3	22.1
			Std. Deviation	1.9	8.1	15.8	32.9

Differences in 1-RM Squat

The yoga and control group improved their squat 1-RM scores from pre- to post-test (see Figure 2). There was no significant interaction between condition (i.e., yoga versus control) and time (i.e., pre versus post) (p=0.69). Although, there was no significant interaction, there was a significant difference between groups (p=0.043) but no difference due to time (p=0.053).

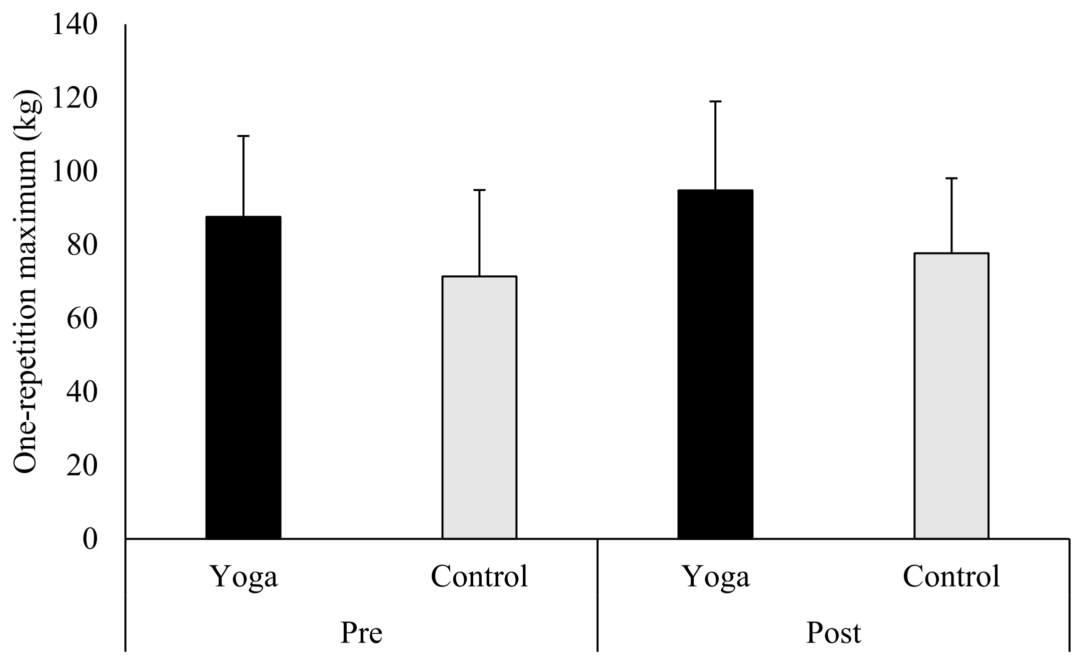

Figure 2: Differences in 1-RM squat performance across the two conditions (i.e., yoga = black and control = grey) and the two times (i.e., pre and post).

Differences in 1-RM Bench Press

1-RM bench press results are reported in Figure 3. There was no significant interaction between condition and time (p=0.789), nor were there significant main effects for condition (p=0.078) or time (p=0.904) for 1-RM bench press test.

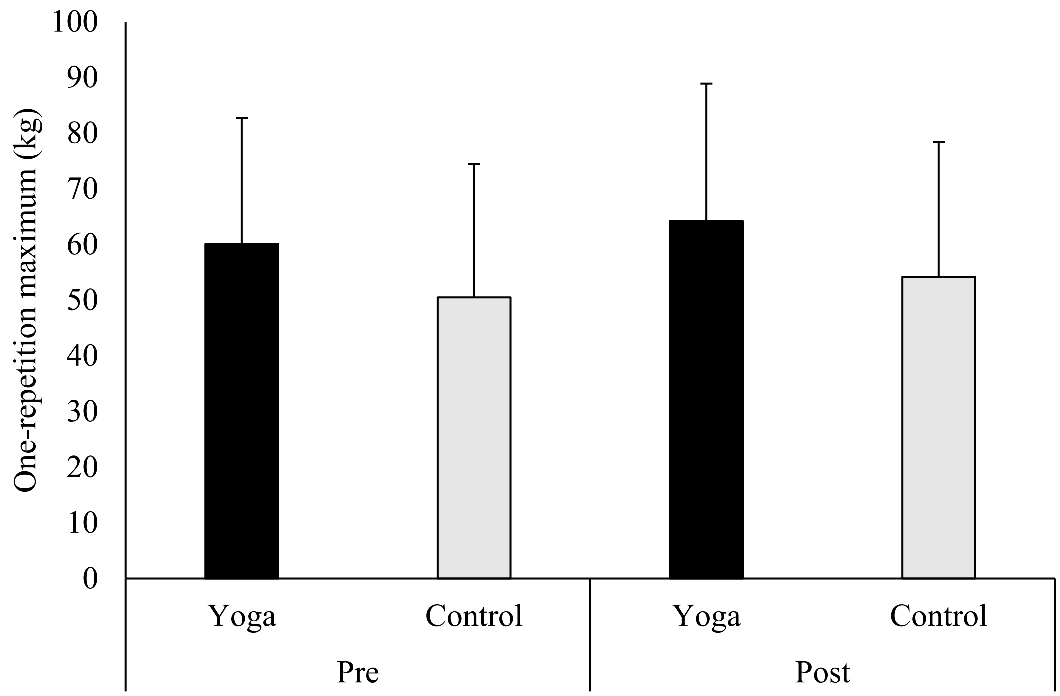

Figure 3: Differences in 1-RM bench press performance across the two conditions (i.e., yoga = black and control = grey) and the two times (i.e., pre and post).

Differences in 1-RM Deadlift

All 1-RM deadlift scores for both conditions and times are displayed in Figure 4. There was no significant interaction between condition and time for the 1-RM deadlift (p=0.177). There were no significant differences for the main effect of group (p=0.291) or the main effect of time (0.967).

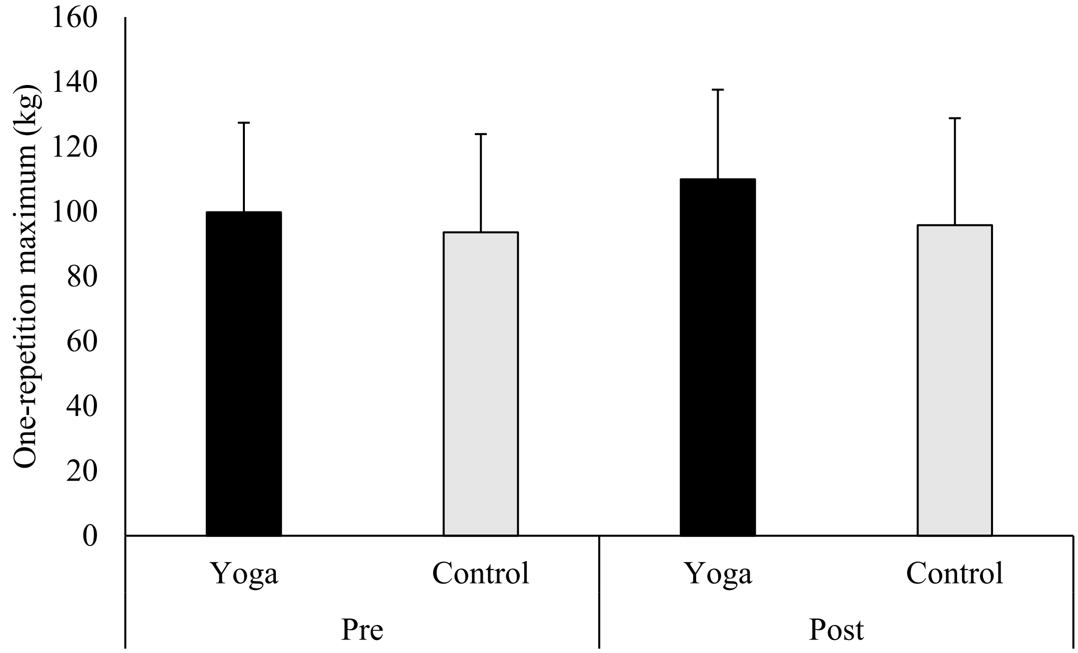

Figure 4: Differences in 1-RM deadlift performance across the two conditions (i.e., yoga = black and control = grey) and the two times (i.e., pre and post).

Chapter 5: Discussion

Hatha yoga is an activity practiced all around the world; however, many of its benefits are still unknown. This study aimed to determine if six weeks of Hatha yoga in addition to regular resistance training improved maximal muscular strength in healthy, young adults. It was hypothesized that participants who engaged in six weeks of Hatha yoga in addition to their regular resistance training would have greater increases in muscular strength across the deadlift, bench press, and squat, compared to those who did not engage in yoga training. Previous research has investigated the role of yoga on muscular strength (Bhavanani, 2003; Lau et al., 2015; Madan et al., 1992; Mahadevan et al., 2007; Pauline & Rintaugu, 2011; Singh et al., 2011; Singh et al., 2014; Tran et al., 2001); however, much of this research was limited by poor methodology and measurement of muscular strength.

Our research indicated that six weeks of yoga did not improve muscular strength across the deadlift, bench press, and squat when compared to a regular resistance training program. There was a significant difference in squat 1-RM ($p=0.043$) between the two conditions but no difference over time. There were no other significant differences noted in the analysis for 1-RM deadlift or bench press. It is worth noting that the yoga group saw an improvement of 8.2 kilograms more than the control group on the deadlift, but the results were not statistically significant.

Interpretations of the findings

While there are multiple mechanisms (i.e., motor unit activation [Hart & Tracy, 2008; Pauline & Rintaugu, 2011], motor skill coordination [Pauline & Rintaugu, 2011], stability [Omkar & Vishwas, 2009], breath control [Tran et al., 2001], and intra-abdominal pressure [Hagins et al., 2006]) that suggest yoga could improve muscular strength, there are other mechanisms that imply yoga may be detrimental to muscular strength (i.e., flexibility [Amin & Goodman, 2014] and training of type I muscle fibers [Lau et al., 2015]). From the results of this study, it is unclear if the benefits of Hatha yoga to muscular strength outweigh the disadvantages. However, this study presents a new perspective on how yoga may benefit muscular strength depending on the experience level of participants.

Participants within the yoga group were stronger on average from the beginning of testing, which is reflected in the higher number of average months of experience in the yoga group *(M=28.9, SD=24.2)* over the control group *(M=22.1, SD=32.9)*. This variable was anticipated prior to the start of testing, so power lifting experience was tracked as an effort to account for potential differences. While there was a statistically significant effect due to power lifting experience in bench ($p=.02$), there were no statistically significant effects observed in the squat ($p=.719$) or deadlift ($p=.334$).

Although a significant effect was only observed in the bench press, it is still possible that results on all three lifts were influenced by differentiating levels of power lifting experience among participants (Mulligan et al., 1996; Tesch, 1988). Neuromuscular strength is the first construct of strength to improve when performing a resistance program (Mulligan et al., 1996). As the main hypothesized mechanism behind yoga improving muscular strength is related to this phase of strength development (Drinkwater et al., 2007; Hart & Tracy, 2008; Omkar & Vishwas, 2009; Pauline & Rintaugu, 2011), regularly trained participants would likely see less improvement to strength from a yoga routine than non-trained participants due to already having developed such improvements, which may contribute to the findings of this study (Schoenfeld, 2010).

It is possible that prior research studies were able to find strength improvements not only due to limited methodologies such as handgrip strength (Bhavanani, 2003; Mahadevan et al., 2007), push up tests (Lau et al., 2015), and curl-up tests (Singh et al., 2011), but also from a stronger adaptation to neuromuscular functionality. Since all the participants in this study were regularly trained, the lack of significant differences between groups may be related to already having improved foundational neuromuscular functions. If so, the effect of Hatha yoga on strength may decrease as neuromuscular functions increase.

Previous research has concluded that Hatha yoga does improve maximal strength (Bhavanani, 2003; Lau et al., 2015; Mahadevan et al., 2007; Pauline & Rintaugu, 2011; Singh et al., 2011; Singh et al., 2014; Tran et al., 2001), which conflicts with the results of this study. As previously mentioned, this confliction in results may be due to testing trained participants over non-trained participants. Another factor that may influence results of previous research is that different styles of yoga have been used to test muscular strength. Hatha yoga was used in this study as it is the most physically oriented style of yoga (Cramer et al., 2016), while other research has utilized styles such as Bikram (Hewett et al., 2011), Iyengar (Amin & Goodman, 2014), and Pranayama (Kanniyan, 2014). With each of these having unique characteristics, it is difficult to compare the different conclusions as they train different constructs of fitness. Without more research investigating how muscular strength is affected by Hatha yoga specifically, making strong conclusions on the topic would be premature.

Lastly, as this study is the first known research to have measured total body strength improvements from a yoga intervention, it is difficult to compare results with studies that technically measured different constructs of fitness (i.e., handgrip strength and muscular endurance). Moreover, Pauline & Rintaugu (2011) and Tran et al. (2001) did measure upper and lower body muscular strength, but participants were untrained in both studies. As this study measured muscular strength changes in trained participants, it would be unsound to make comparisons with studies that did not measure strength in a trained population. Therefore, due to limitations in testing methodologies and the populations being tested, it may not be appropriate to compare the results from this study to the currently available research. The paucity of research on this topic limits the implications that can be drawn from this study. Still, these findings offer a preliminary insight to the effects of Hatha yoga on muscular strength in healthy adults, but more research is needed before more confident conclusions can be made.

Strengths and Limitations

This study was the first to measure whether Hatha yoga improves total body muscular strength. Yoga classes were instructed by a 200-hour Registered Yoga Trainer, which ensured participants received professional guidance. It was also the first to implement a questionnaire to measure yoga improvement from pre- to post-testing (Appendix C). From the results of the perceived yoga session questionnaire, it seems that the overall quality of the class improved from pre- to post-testing. The same music playlist was used each session and the instructor utilized similar coaching cues during each meeting. Although the results from the questionnaire only offer a handful of insights into the yoga class, it seems that yoga became more comfortable to the participants, but no technique improvements were observed.

The current study had high ecological validity, as all participants adhered to their own exercise routines (Appendix H) and diets (Appendix I). However, these two factors may have also impacted the results of this study. Some participants performed a greater number of resistance training sessions than others, leading to a higher volume of training. With different volumes of training, some participants may have experienced greater strength improvements than others regardless of yoga participation (Schoenfeld et al., 2015).

Diet was not controlled for but was tracked so it could be discussed with the results. With diet being controlled by the individual, it is possible that nutrition may have caused different adaptations to occur within the participants. Calories were not tracked but meal choices and daily snacks were. The goal of the nutrition trackers was to monitor eating frequency rather than specifically tracking daily caloric intake. If any participants skipped meals, results for their tests may not have been accurate. Some participants did not specify if a meal was skipped or if they forgot to track for the given day, so it is possible that the nutrition log (Appendix I) does not perfectly display the eating habits of all participants throughout testing. Due to the frequency of some reports, it seems adherence to the nutrition tracker may have been limited so it is difficult to draw conclusions from the gathered information.

Furthermore, participants were recruited through convenience sampling methods which may increase the likelihood of selection bias and sampling error. Sample size was also limited (n=18), which limits the strength of the statistical analysis. Participants were predominately female (56%) which may have impacted results. The interventions for the control and yoga groups were both 6 weeks long, which is shorter than similar studies have utilized (Bhavanani, 2003; Lau et al., 2015; Pauline & Rintaugu, 2011; Singh et al., 2011). However, a six-week intervention was chosen to help minimize attrition rates while ensuring enough time was provided for strength improvements to take place (Schoenfeld, 2010).

Yoga class attendance was another limitation, as the average attendance for yoga sessions was 62% (SD = 15%). With the varied yoga attendance, it is possible that participants within the intervention group were affected differently due to the different experienced volumes of the yoga intervention. Furthermore, when comparing the Hatha yoga group to the control group, the yoga group was subjected to a greater training volume overall. Therefore, increased strength changes may have occurred due to the greater volume of exercise to the yoga group (Schoenfeld et al., 2015).

Implications for Practice

As previously discussed, yoga is implemented into the training regimens of collegiate and professional sport teams across the world. However, in sports where maximal strength is the main training goal, it may be unnecessary to add Hatha yoga to a training routine. It may be more beneficial to spend the extra training time focused on training styles that have been found to produce more meaningful improvements to maximal strength. Sports and activities dependent on constructs related to more proven benefits of yoga, such as flexibility or balance, would seem to be more beneficial.

For the general population, yoga may make more practical sense for implementation into training routines. Even though yoga did not result in a significant improvement over the control group, both groups still improved. If an individual enjoys yoga or feels it helps improve their strength, the results of this study suggest that it at least will not have a negative effect on maximal strength. Overall, it seems implementing yoga into the programs of trained participants may be a matter of preference rather than necessity.

One population in which yoga could be a more meaningful addition to a training routine is with new lifters. During the first phase of a resistance training routine, the primary adaptations that occur are in neuromuscular functions (Schoenfeld, 2010). As balance, coordination, and motor unit activation are elements of this component of strength, adding yoga to the foundational strength program could help accelerate the results or help promote better technique. Once motor unit activation and neuromuscular control is enhanced, it may benefit participants to switch to a heavier focus on resistance training than yoga, as there is more research supporting the effects of resistance training on maximal strength.

Recent Research

There seems to be no further research on the effect of Hatha yoga on muscular strength since completion of the review of literature. There have been recent studies that analyzed yoga as a rehabilitative mechanism in care givers (Martin & Candow, 2019) and multiple sclerosis patients (Hosseini et al., 2018). Both studies found significant improvements to maximal handgrip strength and 1-RM on the leg press, respectively. However, the populations studied were not trained, further contributing to the potential of using yoga to assist in training non-athletic individuals.

Future Research

This study helped fill a gap in understanding as to how Hatha yoga effects muscular strength in healthy, young adults. However, it would be beneficial for a study to analyze these effects while following a consistent exercise and diet plan between both groups. Although the ecological validity may be lower with this approach, the number of uncontrolled variables would decrease, strengthening the study. Equating total volume between groups to ensure that both yoga and non-yoga groups were performing the same amount of exercise would be another beneficial study, as performing a higher volume of exercise can lead to improved results (Schoenfeld et al., 2015).

Currently, most research on this topic has only looked at how muscular strength was affected by one type of yoga. It would also be beneficial to compare multiple styles of yoga to see how muscular strength is affected differently from the type of yoga being practiced. Although Hatha yoga was found to be the most physical, other styles of yoga may be equally, if not more beneficial to muscular strength. When using yoga as a supplementary exercise method to resistance training, yoga styles that focus heavily on constructs of strength (i.e., motor unit activation, balance, coordination) may help accelerate results.

Analyzing the effects of strength improvements from a yoga intervention due to sex would be another study to help improve this field of research. Due to the small amount of available literature that has been conducted on this topic, it is difficult to tell if yoga is of equal importance to male and female participants. If males and females respond differently to a Hatha yoga intervention, implementation of yoga into training programs may differ based off sex.

Conclusion

Overall, it seems that Hatha yoga with resistance training may not improve muscular strength differently than resistance training alone as prior research has suggested. While both the intervention and control group improved from pre- to post-tests on strength averages, the findings were not statistically significant. Based off the literature currently available, it is still unknown whether Hatha yoga improves muscular strength in healthy, young adults and athletic populations. Thus, individuals and coaches need to choose based on sport-specificity and training preference until more research is conducted. However, it seems that there may be more efficient methods to increasing maximal strength than implementing a Hatha yoga routine. Athletes and individuals may benefit from focusing on strategies that have been found to improve maximal strength more meaningfully until more research is done on the relationship between Hatha yoga and muscular strength.

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Appendix A: Pre-Participation Questionnaire

Pre-participation questionnaire

The secondary effects on muscular strength from a Hatha yoga intervention in healthy adults

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Thank you for your interest in participating in this study. Below are a series of questions regarding your activity history, current health, and current fitness levels. Please answer all questions to the best of your knowledge. Your answers will be completely confidential and will not be shared with anyone. Only the lead investigator will have access to your answers. The information given in this questionnaire will be used to determine your eligibility for this study. If you have any further questions or concerns, please contact the lead investigator listed above.

1. Age: _____
2. Sex: _____
3. Do you currently perform resistance training two to three times per week? (Circle one)

   Yes No
4. Are you currently pregnant? (Circle one)

   Yes No
5. Do you currently have any chronic disease? (i.e., autoimmune, cardiovascular, metabolic, etc.) (Circle one)

   Yes No
6. Do you currently have any chronic injury/injuries? (Circle one)

   Yes No
7. Have you obtained any injury within the last 6 months? (Circle one)

   Yes No
8. Within the last 6 months, have you attended a yoga class? (Circle one)

   Yes No
9. How many months of experience do you have with the three powerlifts (i.e., bench, squat, and deadlift)?

Appendix B: One Repetition Max Protocol

1. Instruct the athlete to warm up with a light resistance that easily allows for 5-10 repetitions
2. Provide a 1-minute rest period
3. Estimate a warm-up load that will allow the athlete to complete 3-5 repetitions by adding
    a. 10-20 pounds (4-9kg) or 5% to 10% for upper body exercise or
    b. 30-40 pounds (14-18kg) or 10% to 20% for lower body exercise
4. Provide a 2-minute rest period
5. Estimate a conservative, near maximal load, that will allow the athlete to complete two or three repetitions by adding
    a. 10-20 pounds (4-9kg) or 5% to 10% for upper body exercise or
    b. 30-40 pounds (14-18kg) or 10% to 20% for lower body exercise
6. Provide a 2 – 4-minute rest period
7. Make a load increase
    a. 10-20 pounds (4-9kg) or 5 to 10% for upper body exercise or
    b. 30-40 pounds (14-18kg) or 10% to 20% for lower body exercise
8. Instruct the athlete to attempt a 1RM
9. If the athlete was successful, provide a 2-4 minute rest period and go back to step 7. If the athlete failed, provide a 2-4 minute rest period: then decrease the load by subtracting
    a. 5-10 pounds (2-4kg) or 2.5% to 5% for upper body exercise or
    b. 15-20 pounds (7-9kg) or 5% to 10% for lower body exercise.

Appendix C: Perceived Success of Yoga Session

Registered Yoga Trainer

Perceived Success of Yoga Session

Please answer the following questions based off the following scale:

1 = Strongly Disagree

2 = Slightly Disagree

3 = Neither

4 = Slightly Agree

5 = Strongly Agree

1. **The yoga session went according to plan:**

   1 2 3 4 5

2. **Participants seemed engaged throughout the session**

   1 2 3 4 5

3. **Participants seemed confident with the routine**

   1 2 3 4 5

4. **Participants performed poses with proper form**

   1 2 3 4 5

5. **The class seemed to understand all instructions given**

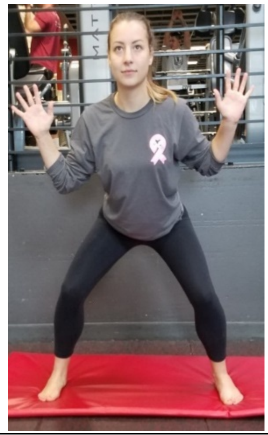
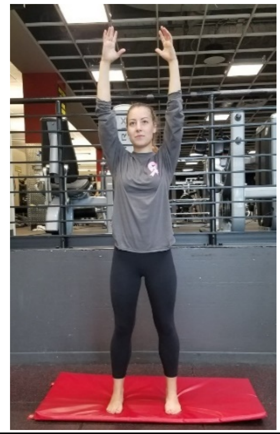
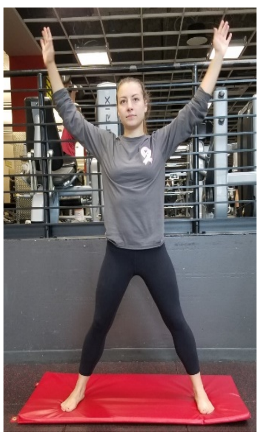
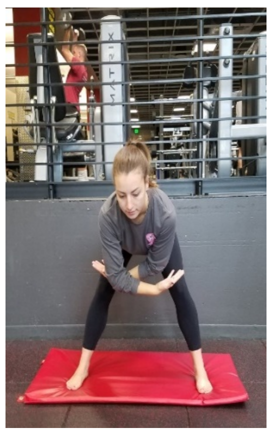
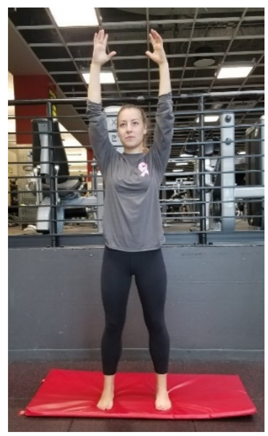
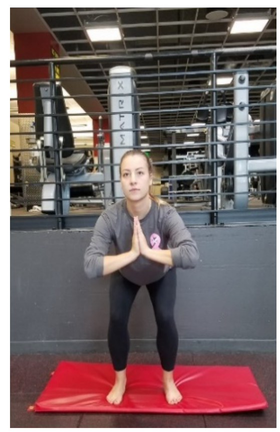
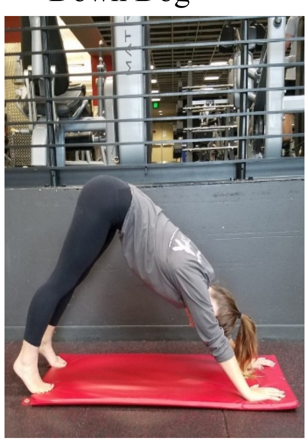
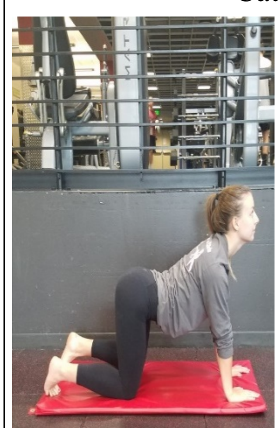
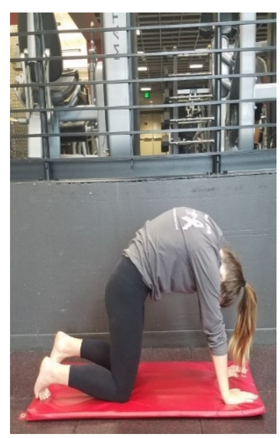
   1 2 3 4 5

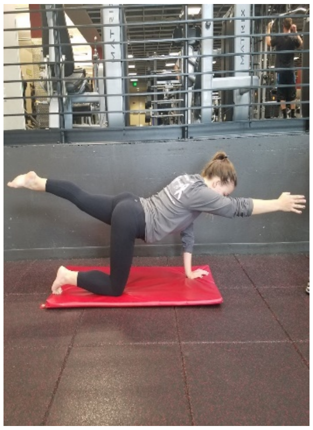
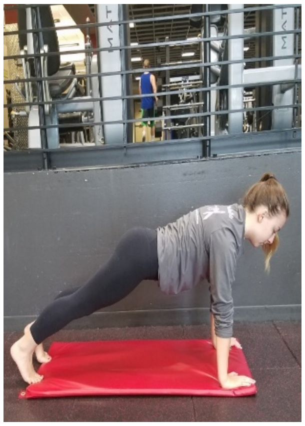
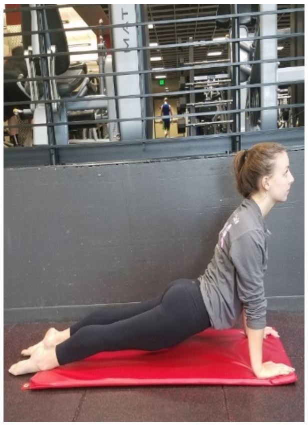
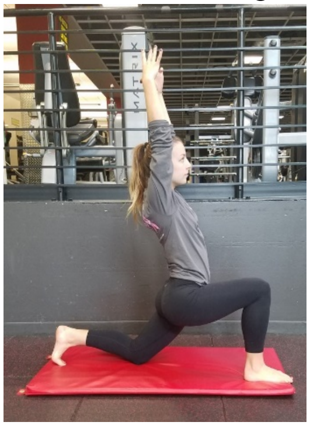
Appendix D: Yoga Program Exercise Order

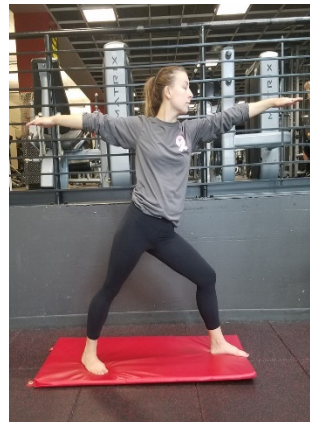
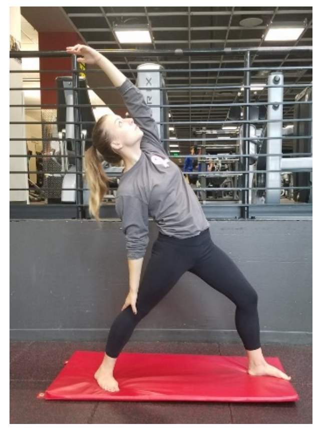
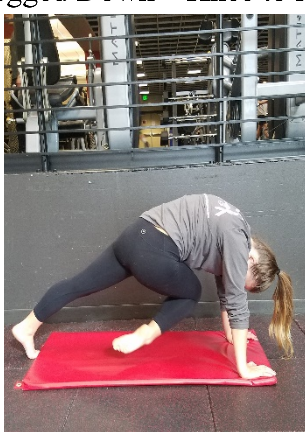
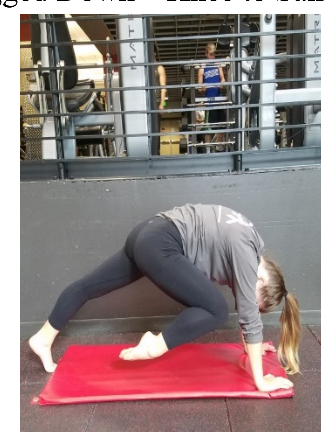
Mountain
Moonflowers
Sunflowers
Chair Flow
Down Dog
Cat-Cow
Spinal Balance
Half Series
Sun Salutations – three rounds
Warrior I
Warrior II
Triangle
Reverse Warrior
Half Series
Repeat on opposite side
Down Dog
Three-legged down dog, knee to nose x3
Three-legged down dog, knee to same elbow
Three-legged down dog, knee to opposite elbow
Crescent lunge
Twisting lunge
Kneeling hamstring stretch

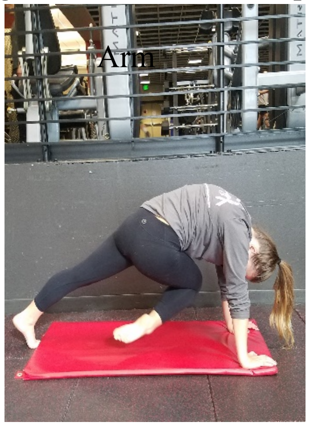
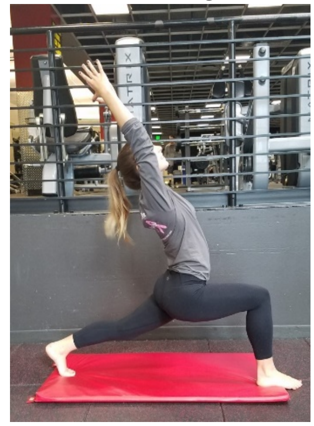
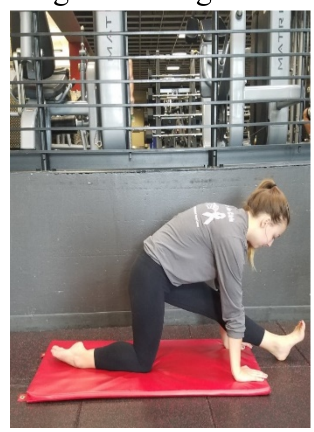
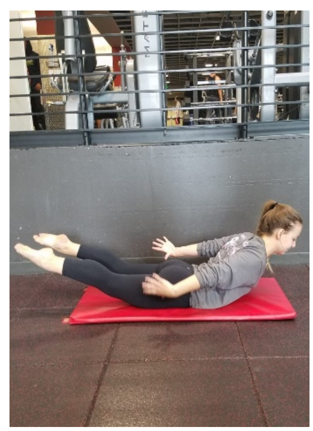
Lizard
Down dog
Repeat opposite side
Locust
Boat
Spinal twist to each side
Legs up the wall – five minutes

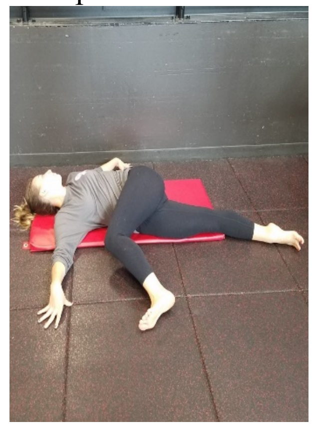
Appendix E: Yoga Poses

Mountain Pose	Moonflower
	 
Sunflower	Chair Flow
 	 
Down Dog	Cat-Cow
	 

Spinal Balance 	Half Series - Forward Fold 
Half Series - Plank 	Half Series - Crocodile 
Half Series - Upward Dog 	Sun Salutations - Lunge 

Warrior I	Warrior II
	
Triangle	Reverse Warrior
	
Three Legged Down – Knee to Nose	Three Legged Down – Knee to Same Arm
	

Three Legged Down – Knee to Opposite Arm 	Crescent Lunge 
Twisting Lunge 	Kneeling Hamstring Stretch 
Lizard 	Locust 

Boat 	Spinal Twist 
Legs Up the Wall Pose 	

Appendix F: Exercise Log

Date	Exercises Performed (Exercise Name: Sets/Repetitions)	Workout Duration	Recovery Time

Appendix G: Nutrition Log

Date	Breakfast	Lunch	Dinner	Snacks

Appendix H: Summary of Exercise Logs

Participant #	RTSP	Mean Length	Full-body	Split	Mixed
1	12	90	x		
2	19	45	x		
3	27	60			x
5	23	30			x
6	14	60	x		
7	12	30		x	
8	12	60	x		
9	15	45	x		
10	22	45	x		
13	14	45	x		
14	13	30	x		
15	13	45	x		
19	20	30			x
20	16	60		x	
21	17	60	x		
22	28	30			x
23	22	60		x	
24	12	60	x		

**Odd numbers represent participants in the intervention group and even numbers represent participants in the control group*

**RTSP: Resistance Training Sessions Performed*

**Length of workouts is reported in minutes*

Appendix I: Summary of Nutrition Logs

Participant #	Breakfast	Lunch	Dinner	Snack
1	37	40	42	40
2	15	25	38	20
3	35	35	35	19
5	38	38	38	38
6	23	30	30	31
7	42	42	42	42
8	29	29	34	40
9	30	30	30	30
10	42	42	42	37
13	40	42	42	31
14	7	22	30	30
15	29	29	29	29
19	12	33	33	33
20	17	27	32	14
21	39	39	39	39
22	34	37	37	22
23	25	29	31	27
24	36	42	42	38

**Numbers are reported amount of each meal consumed during the 6-week intervention*

Appendix J: Perceived Success of Yoga Sessions Results

Pre-test Score	Post-test Score
1. The yoga session went according to plan:	
5	5
2. Participants seemed engaged throughout the session	
5	5
3. Participants seemed confident with the routine	
4	5
4. Participants performed poses with proper form	
4	4
5. The class seemed to understand all instructions given	
4	5

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