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Effects of Rest Period Length on Exercise Volume in Older Adults

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Effects of Rest Period Length on Exercise Volume in Older Adults

A THESIS

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Abstract

Research involving rest periods during resistance training for older adults is limited. Understanding optimal rest periods can help exercise professionals develop efficient and effective training programs for older adults. The purpose of this study was to determine if 1-, 3-, or 5-minute rest periods between sets of the leg press exercise would increase volume (number of repetitions) among older adults 60-90 years of age. Following prescreening, participants completed 1-repetition maximum (1RM) testing to determine maximal leg press strength. In random order, the participants used a 1-, 3-, and 5-minute rest period between two sets of eight repetitions followed by a third set conducted to failure. All participants lifted 80% of their 1RM throughout the study. The number of correct repetitions completed during the third set was recorded for analysis. A one - way repeated measures ANOVA was conducted to compare exercise volume between the three rest periods. The results indicated that the number of repetitions was not significantly different between rest periods, $F(2,42) = .280$, $p = .75$. As for the sex comparison, a 2 x 3 ANOVA with repeated measures was conducted. No significance was found for the interaction or main effects ($p > .05$). Researchers concluded that there is no difference in exercise volume between 1-, 3-, and 5-minute rest periods; however, the study did show trends towards greater exercise volume following the 3-minute rest period. Future research should examine the effects of shorter rest periods on volume in young and older populations.

CHAPTER ONE: Introduction

Significance

One of the main concerns of a proper resistance-training regimen is the rest period taken between sets of exercise (Mirzaei, Arazi, & Saberi, 2008). A rest period is time taken to recuperate between sets and exercises, which are known to have a dramatic effect on the outcome of resistance training (Clark, Lucett, & Corn, 2008). The amount of rest taken between sets of resistance training affects many physiological functions such as metabolic, hormonal, cardiovascular, as well as training adaptations (Ratamess et al., 2009). For instance, maximal strength adaptations depending on a person's fitness level may require 5- minutes of rest between sets and exercises to properly replenish energy sources (Clark et al., 2008; Willardson, 2006).

The National Strength and Conditioning Association (NSCA) refer to this recovery time as an inter-set rest. Factors such as training goals, physical condition, and the amount of weight lifted impacts the amount of time one should rest between sets (Blaechle & Earle, 2008; Ratamess et al., 2009). Also, when training for strength the NSCA recommends rest periods of 2 – 5-minutes, lifting 85% to 100% of one-repetition maximum (1RM) within athletes and younger populations (Blaechle & Earle, 2008; Ratamess et al., 2009). Resting 2 – 5-minutes between sets allows the body to replenish its depleted energy stores (Blaechle & Earle, 2008; Ratamess et al., 2009). For someone who is looking for hypertrophy, 30- seconds – 1 minute of rest between sets seems to be an adequate amount of time while 3-5 minutes of rest is recommended for strength/power gains (Ratamess et al., 2009). In someone who is just beginning to exercise, low levels of energy can lead to fatigue as well as decreased neuromuscular control, force production, and stabilization (Clark et al., 2008). Richmond & Godard (2004) states that the body requires adequate rest so the muscles can recover and restore the capacity to exercise. According to the American College of Sports Medicine (ACSM) and NSCA, individuals should train with rest periods of 2 – 5-minutes for compound exercises such as the squat and bench press while shorter rest periods of 1 – 2-minutes are recommended for assistance exercises (Ratamess et al., 2009; Richmond & Godard, 2004). However, in some studies of untrained individuals short rest periods of 30-seconds – 1 minute have produced substantial increases in strength (Ratamess et al., 2009). Rest periods are extremely important in resistance training because inadequate rest can lead to poor performance, which could eventually lead to serious injury (Clark et al., 2008).

However, these aforementioned recommendations of 2-5 minute rest periods are listed as a category D in the ACSM position stand among older adults. Category D means the recommendation is based expert judgment and panel's synthesis of evidence from experimental research or the consensus of panel members based on clinical experience or knowledge (Ratamess et al., 2009). The amount of rest between sets is important for a proper resistance-training regimen (Mirzaei, Arazi, & Saberi, 2008). In older adults, the rest period between sets of any type of resistance training exercise has not been fully studied (Chodzko-Zajko et al., 2009; Ratamess et al., 2009). Therefore, the lack of evidence regarding the importance of inter-set rest periods in older adults who are seeking to increase muscular strength is what makes this study important and beneficial for the older population (Chodzko-Zajko et al., 2009; Ratamess et al., 2009).

Purpose

The purpose of this study is to determine if 1-, 3-, or 5-minute rest periods between sets of the leg press exercise would increase volume (number of repetitions) among older adults, 60-90 years of age. The independent variable in this study is the rest period (1-, 3-, and 5- minutes), while the dependent variable is volume. This study is significant because after the age of 60 years, structural and functional changes in the neuromuscular system result in loss of muscular strength that can lead to diminished motor skill as well as reduced ability to perform activities of daily living (ADLs). Resistance training has been shown to slow this process by being a reliable means to increase muscle strength in older adults (Rabelo, Oliveira, & Bottaro, 2004). However, very little empirical evidence is available regarding recommendations for rest periods in older adults.

Background

With aging, gradual declines in muscle strength, power, size, and functional abilities are to be anticipated due to factors such as sarcopenia and inactivity in both men and women (Rabelo et al., 2004; Trappe et al., 2001). With sarcopenia, issues such as reduced fiber strength and contractile velocity increase the risks of falls, jeopardize independent living, and cost the health industry millions of dollars a year (Trappe et al., 2001). Most of the decreased strength and reaction time in older adults is due to muscle atrophy of the type 2 muscle fibers (fast-twitch fibers), which in return is replaced with fat and connective tissue (Gauchard, Tessier, Jeandel, & Perrin, 2003). Age-related change in muscle can lead to decreases in strength up to 10%-15% per decade (Gauchard et al., 2003). Recent research has shown that the best way to combat sarcopenia and other aging factors is through resistance training to increase muscular strength and slow the loss of muscle mass (Rabelo et al., 2004; Trappe et al. 2001).

Hypothesis

The researcher has hypothesized, based on the studies of Miranda et al. (2007), Rabelo et al. (2004), Rahimi (2005), and Richmond and Godard (2004), that the volume of exercise completed following a 5-minute rest period would be greater than the volume of exercise completed following the 3- and 1-minute rest periods. It was also expected that the 3-minute rest period would result in a greater volume of exercise than the 1-minute rest period.

Operational Definitions

The following section defines important concepts related to this study.

- One repetition max (1RM) is the maximum weight that can be lifted for one complete repetition of the movement (Heyward, 2010).
- Rest period is time taken to recuperate between sets and exercises (Clark et al., 2008).
- Isometric/static contraction is when the resistance is immovable and there is no visible joint movement (Heyward, 2010).
- Dynamic contraction is where there is visible joint movement, either concentric, eccentric, or isokinetic (Heyward, 2010).
- Concentric contraction occurs when the muscle shortens as it exerts tension (Heyward, 2010).
- Eccentric contraction occurs when the muscle is capable of exerting tension while

lengthening (Heyward, 2010).

- Isokinetic contraction is a maximal contraction of a muscle group at a constant velocity throughout the entire range of joint motion (Heyward, 2010).

Limitations and Delimitations

The primary goal for this study was to determine if 1-, 3-, or 5-minute rest periods between sets of the leg press exercise would increase volume (number of repetitions) among older adults. The limitations to this study include the researcher's ability to recruit a sufficient sample size, participant drop-out rates in this population due to injury or disinterest, and recruiting from a specific location. The delimitations of the study are age (60-90 years old), training status (participating in resistance exercise), and living condition (living independently in the community).

CHAPTER TWO: Literature Review

Several research studies have been written to provide information on the benefits that rest periods between sets may actually have on increasing muscular fitness. However, most of the focus on this particular topic has been placed on younger male adults. It is significant to understand how rest periods affect the human body when trying to increase muscular strength, especially in older adults. Several studies have been presented in order to provide future direction of research in the following literature review.

Rest Periods in Lower Body Exercises

A study by Rahimi (2005) compared the effects of three different rest periods on the squat volume completed during a workout. Twenty college-aged men volunteered to participate in this study. All participants were considered experienced recreational lifters by having consistently performed a minimum of three strength-training workouts per week for the last two years. The warm-up consisted of performing 5-10 repetitions at 40%-60% of maximum exertion, a 3–5-minute rest and stretching period, and the completion of three - five repetitions at 60%-70% of maximum exertion. After the warm-up, three - five lifts were then conducted to determine the one repetition max (1RM) with a 5-minute rest between each lift. Once all the participants' 1RM were determined, the participants then performed three testing sessions with four sets of squats at 85% of their 1RM. During each testing session, the squat was performed with a 1-, 2-, and 5- minute rest period between sets. The results found that the volume completed for the squat was significantly different between the 1- (4.55 ± 2.25 repetitions) and 5-minute (6.17 ± 1.39 repetitions) rest periods and between the 2- (5.10 ± 1.84 repetitions) and 5-minute rest periods ($p < .001$, $p < .002$). However, the results also showed that the volume completed was not significantly different between the 1- and 2-minute rest periods ($p = .90$). The author concluded that a 5-minute rest between sets would allow the highest volume to be completed when training with 85% of a 1RM load (Rahimi, 2005).

However, Willardson and Burkett (2008) compared the squat strength gains and volume components using rest periods of 2- and 4-minutes between sets over multiple mesocycles. Fifteen recreationally trained men with a minimum of four years of experience performing the squat exercise were recruited for this study. The study was split into three four-week mesocycles. Week one of each mesocycle was used to determine the 1RM for each participant so that the proper load could be assigned for the next three weeks. Two squat workouts were performed each week, a light workout and a heavy workout. Each participant was allowed to continue with their regular upper body workout regimen throughout the intervention, but was asked not to perform any lower body exercises without the presence of an experienced strength and conditioning professional present. At the beginning of the intervention, 1RM testing was conducted to determine the appropriate load and match each participant based on initial strength level. Once the 1RM's were determined, the participants were randomly assigned to either a 2-minute (n = 7) or 4-minute (n = 8) rest period group based on their initial strength level. The heavy workouts were performed with two warm-up sets of 10 repetitions with 50% and 75% of their 1RM. Once the warm-up was completed, all sets were performed with 70%-90% of their 1RM to voluntary exhaustion. The light workouts on the other hand were performed with one warm-up set of 10 repetitions with 50% of their 1RM. Once finished with the warm-up set, all sets were performed with 60% of their 1RM for eight repetitions. The purpose for the light workout was to allow added volume but not to hinder the recovery process. Willardson and Burkett (2008) results reported significance within-subject comparison for strength gains in the squat (p = .0001). The 1RM's in the 2-minute group increased from 145.13 ± 24.17 kg in week one to 171.43 ± 25.34 kg in week four. As for the 4-minute group, there 1RM's increased from 150.00 ± 18.54 kg in week one to 182.10 ± 21.44 kg in week four. However, follow-up comparisons found that strength scores were significantly different between all 1RM tests, but the strength gains between-subjects were not significantly different between the 2- and 4-minute rest period groups (p = .47). There was also significance between-subjects total volume per workout in the heavy workout session, but when compared independently it was found not significant. However, the 4-minute rest period group did have higher scores for the load utilized and volume per workout compared to the 2-minute rest period group. The light workout session on the other hand was found not significant between-subjects and like the heavy workout session, the 4-minute rest period group had higher scores for the load utilized and volume per workout compared to the 2-minute rest period group. The authors concluded that large strength gains in the squat exercise can be achieved with a 2-minute rest period between sets and that little to no additional gains are achieved resting 4-minutes compared to the 2-minute. However, athletes looking to achieve a specific volume goal may initially need longer rest periods but as the training proceeds the athlete may adapt to shorter rest periods without excessive fatigue, leaving time for other conditioning priorities (Willardson & Burkett, 2008).

Unlike the previous studies that dealt with multi-joint exercises, a study by Woods, Bridge, Nelson, Risse, and Pincivero (2004) examined the effects that rest period length had on strength and perceived exertion during a single joint exercise, the knee extension. Thirty active men and women were recruited to participate in this study. Participants were required to participate in two testing sessions of three sets of 10 repetitions that were separated by 48-72 hours and were asked to abstain from moderate to heavy physical activity 24 hours before testing. The first day of testing, the participants were tested for their 1RM during a single leg knee extension exercise. On the second day, the participants performed as many repetitions as they possible could to determine their 10RM. After their 1RM and 10RM were calculated the participants were randomly assigned to one of three groups; a short rest period (1-minute), a moderate rest period (2-minutes), and a long rest period (3-minutes). Once the participants were randomly put into the groups, they performed a warm-up on a stationary bike for 5- minutes and stretched their quadriceps for 30-seconds. Once completed, they were asked to perform three sets of 10 repetition knee extensions with their dominant leg using a Pro Leg Extension machine with 70% of their 10RM. The results found that there were no significant differences in strength and perceived exertion when performing three sets of 10 repetition knee extension exercises with rest periods of 1-3 minutes ($p > .05$). The authors' concluded that when using rest periods of 1-3 minutes within sets of the knee extension, there were optimal recovery gains, especially when the three groups increases in perceived exertion were significantly different between sets one and two, and between sets one and three (Woods et al., 2004).

In order to compare the effects of quadriceps strength, Pincivero, Lephart, and Karunakara (1997) examined the effects that rest periods had on hamstring and quadriceps strength/performance during isokinetic training. Fifteen healthy college age individuals with no previous lower extremity injuries and who had not participated in resistance training exercises in the past six months were assigned to one of two groups. Group one received a rest period of 40-seconds and group two received a rest period of 160-seconds. One leg of each participant was randomly assigned to a four week, three day a week isokinetic strength training session. Each participant was tested for functional lower extremity performance by a one-legged hop for distance before and after the study. Before each one-leg hop test the participants were required to complete a dynamic warm-up using a stationary bike for 5-minutes at 60 rpm followed by hamstrings and quadriceps stretching. Isokinetic strength was tested with a Biodex System 2 Isokinetic Dynamometer. Knee extension and flexion was assessed with 60 and 180 degrees/second velocities. For warm-up purposes, the participants had to complete five submaximal and two-three maximal repetitions for each velocity. Once the warm-up was complete, five maximal repetitions were performed with 60 degrees/second, and 30 maximal repetitions with 180 degrees/second. The sequence of the tests was chosen to limit fatigue in later velocities. Once the four week training program was complete, results showed significant quadriceps strength gains in both velocities in-group two (60 degrees/second, $p = .007$; 180 degrees/second, $p = .02$). Also, significant quadriceps strength gains were found between trained and non-trained limbs at the velocity of 60 degrees/second ($p = .03$). In both groups each limb showed a reduction in hamstring peak torque at 60 degrees/second; however the non-trained limbs in-group two showed a 10.9% decrease compared to the trained limbs and the non-trained limbs in-group one. The trained limbs in-group two resulted in a positive 6.0% change in hamstring torque at 180 degrees/second when compared to a -9.3% in the non-trained limbs and in-group one.

Group two had a 17.5% and 20.2% improvement in total hamstring work at 180 degrees/second while the non-trained limbs and both limbs in group one received minimal strength gains. The authors concluded that a longer rest period allowed for greater hamstring strength compared to the shorter rest period (Pincivero et al., 1997).

To provide another basis for comparisons for quadriceps strength, Bottaro et al. (2010) examined the effect of two different rest periods between sets of the isokinetic knee extension exercise on peak torque and total work between untrained younger and older men. Seventeen young men (average age of 24) and 20 older men (average age of 65) were required to perform three sets of 10 isokinetic knee extension repetitions at 60 degrees/second. Rest periods of 1- and 2- minutes between each set were used for this study. The results showed a significant decline in peak torque of 3.2% when the 1- and 2-minute rest periods were used within the younger men ($p = .05$), however when a 2-minute rest period was used within the older men there was no decline. There was also a significant decline of 1.9% in the total work performed when the three sets of 10 repetitions were used with 1- and 2-minute rest periods for the younger men, whereas the decline in the total work performed in the older men occurred between the second and third set. When compared to the second set, peak torque and the total work performed in the third set showed to be significantly greater following a 2-minute rest period in both younger and older men. The authors concluded that young men with no resistance training experience might require longer rest periods for full recovery when compared to older men (Bottaro et al., 2010).

Strengths in these studies include experienced recreational trained participants and the grouping of participants by rest periods used. Limitations would be that the majority of the participants were college age men and the results may not apply to other exercises, especially those for the upper body. Future studies should explore gender differences, older populations, and participants who have no previous experience with exercise.

Rest Periods in Upper Body Exercises

Maintaining or increasing upper body strength is also an important aspect as we age, because, like lower body strength, it to helps with ADLs. A hypothesis introduced by Richmond and Godard (2004) stated that within upper body exercises a 1-minute rest period did not allow adequate amount of recovery time between sets for trained individuals, however the 3 – 5-minute rest period would allow adequate rest between sets. Twenty-eight healthy men each with a minimum of eight weeks of resistance training experience were recruited for this study. Throughout the study, the participants were instructed to continue with their current diets and activity levels. The participants' 1RM was taken after a light warm up on a bench press. Each participant began with a warm-up that consisted of 5-minutes of low-resistance cycling or stretching of the muscles involved. Once the warm-up was complete, each participant was assigned to one of three groups (1-, 3-, or 5-minutes rest periods). Each repetition was performed at 75% of their 1RM. Testing sessions took place for two weeks after the 1RM testing with at least two days of rest, but no more than five days of rest separating the sessions. The results of the training sessions indicate that the participants were able to maintain an 8-12 repetition range with a 3-5-minute rest period, however the repetitions for the 1-minute rest period decreased significantly from 12 repetitions within the first set to 5 ± 1 repetitions for the second set (no p value was given). The authors concluded that the 3-5-

minute rest periods were sufficient in preventing a decrease in the number of repetitions completed whereas the 1-minute rest period was not adequate enough to prevent this decrease (Richmond & Godard, 2004).

A more resent hypothesis tested by Lawton, Cronin, and Lindsell (2006) states that interrepetition rest periods would result in a greater repetition power output when compared to the traditional weight training. This study consisted of 26 elite basketball and soccer players. A week before the study, the participants were tested on two separate days to determine their 6RM. Each participant participated in seven months of supervised resistance-training programs three times a week using the bench press exercise. Before each testing session the participants performed a warm-up that consisted of 10-minutes on the stationary bike and three sets of progressing bench presses at 50%, 75%, and 90% of their 6RM. Once the testing was complete the participants were randomly assigned to one of three (Singles, Doubles, and Triples) groups by sport, test results, and training experiences. The singles group performed six repetitions with a 23-second rest period between each repetition. The doubles group took a 56-second rest period after every two repetitions, and the triples group took a 109-second rest period after every three repetitions. The results found that rest periods between repetitions increased total power output by 21%-25% compared to the continuous 6RM (no p value given). The greatest increases were seen in the Triples Group. However, the increases seen in the Triples Group was not significantly different from the increases seen in both the Doubles and Singles Group (p = .86). The authors concluded that different interreptition rest periods are equally effective in providing increases in repetition power output and total power output (Lawton et al., 2006).

Heavy and light loads of resistance can affect bench press performance if adequate rest is not incorporated into the training program. Willardson and Burkett (2006a) conducted a study to examine the effects of 1-, 2-, and 3-minute rest periods on multiple sets of bench press using heavy and light loads over a four-week training session. Sixteen recreationally trained men with a bodybuilding style of training participated in the study. During weeks two-four the participants performed two training sessions a week, separated by 72 hours. The first training session consisted of a load of 80% of their 1RM and the second session with 50% of their 1RM. For each load five sets were performed to voluntary exhaustion. The participants were allowed to continue with their personal workouts throughout the research period, except they were asked not to perform any bench press type exercises and not to perform any exercises on the day of testing. Before each training session the participants were required to perform a warm-up using 50% and 80% of their 10RM. The results indicate that total repetitions completed were significantly different between each rest period ($p = .000$). The total repetitions completed within 50% of the 1RM for the 1-minute rest were 59.13 reps, 2-minute rest 74.81 reps, and the 3-minute rest 87.69 reps. Within 80% of the 1RM, the total repetitions completed for the 1-minute rest were 18.06 reps, 2-minute rest 23.06 reps, and 3-minute rest 27.06 reps. However, throughout the study there were significant differences between sets ($p = .000$) and between rest periods ($p = .000$) but no significant difference between loads ($p = .849$). As the rest periods between sets increased so did the number of completed repetitions. The authors concluded that the repetitions over five consecutive sets were similar for both the 50% and 80% 1RM loads (Willardson & Burkett, 2006a).

In a similar study comparing heavy and light loads, Mirzaci et al. (2008) compared three different rest periods on the sustainability of the bench press exercise within four sets of heavy vs. light loads. Seventeen recreationally trained college age men with at least three years of experience performing the bench press exercise volunteered to participate in this study. The study consisted of seven sessions in which data was collected each session with at least a 48-hour recovery time between sessions. During the first session, the participant's 1RM were determined. For the remainder of the study, the participants performed four sets of bench press to voluntary exhaustion with 60% or 90% of their 1RM with a 90-, 150-, or 240-second rest period between each set. For the course of the study the participants were allowed to continue with their normal exercise regimen, except each participant was instructed not to perform any bench press exercises and not to workout the day of testing. Prior to each of the six sessions the participants performed a warm-up with the bench press exercise. The 60% 1RM group performed one set of 10 repetitions with 60% of their goal resistance. The 90% 1RM group consisted of one set of 10 repetitions using 50% of their goal resistance and one set of 10 repetitions using 75% of their goal resistance. The results of the study found that the repetitions completed were significantly different between each rest period (p = .00). However, for each of the loads a linear relationship exists between the length of the rest periods and the repetitions completed during each set (p = .00). On the other hand, a significant linear and quadratic contract indicated that a decline (35% for the 240-second rest, 55% for the 150-second rest, and 70% for the 90-second rest within the 60% 1RM; 25% for the 240-second rest, 45% for the 150-second rest, and 69% for the 90-second rest within the 90% 1RM) in completed repetitions occurred between the first and fourth set in both loads (p = .00, p =

.00). The authors found that as the rest periods between sets increased so did the number of completed repetitions. They also recommend when training for maximal strength, a 240-second rest period between sets should be taken to avoid declines in repetitions (Mirzaci et al., 2008).

A study by Ratamess et al. (2007) examined the effects of different rest period lengths on metabolic responses in the bench press exercise. Eight resistance-trained men with a minimum of three years of experience with bench press exercises participated in this study. Each participant took part in the study in a trained state; none of the participants were taking any medications, anabolic steroids, or supplements known to affect energy metabolism or resistance exercise performance. The 1RM bench press was conducted in three-four trials with a 2-3-minute rest period. Warm-up sets for the 1RM testing consisted of 5-10 repetitions using 40%-60% of their perceived 1RM. After a 1-minute rest period, sets of two - three repetitions were performed using 60%-80% of their perceived 1RM. After the 1RM was determined, each participant had to perform a standard warm-up consisting of 3-minutes on a stationary cycle, calisthenics, and two warm-up sets of the bench press using 25%-50% of their 1RM. The study consisted of performing 10 randomized protocols that included five sets of bench presses between 75% and 85% of their 1RM for ten and five repetitions, all using different rest period lengths (30-seconds, 1-, 2-, 3-, or 5-minutes). The results showed that in the 2-minute rest period, performance was maintained during the first two sets but was reduced by 8%–29% during sets three–five. For the 3-minute rest period, a reduction was shown in volume whereas sets four and five were ~21% lower than sets one–three. As for the 5-minute rest period, only a reduction in set five was observed. The largest reductions in performance occurred with a rest period <1-minute, while performance was maintained during the first three–four sets when 3- and 5-minute rest periods were used. The authors concluded that bench press performance is reduced significantly as rest periods are reduced. (Ratamess et al., 2007).

Miranda et al. (2007) studied the effects of 1- and 3-minute rest periods on upper body exercises. Fourteen experienced, well-trained men participated in the study. On days one-five the participant's 8RM for all the exercises were determined, re-tested, and training sessions of two different rest periods were conducted. The same exercises were performed in the same order in both sessions. The exercise order for Sequence 1 (1-minute rest period) and Sequence 3 (3-minute rest period) were lat pull-downs with wide grip (LPD-WG), lat pull-downs with close grip (LPD-CG), machine seated row (SR-M), barbell row lying on a bench (BR-B), dumbbell seated arm curl (SAC-DB), and machine seated arm curl (SAC-M). Exercise technique for each exercise consisted of no pauses between eccentric and concentric phases. Participants were required to perform a warm-up of two sets of 12 repetitions of the LPD-WG with 40% of their 8RM prior to each training session. At the end of the study the results indicate that total training volume in SEQ 3 (107.2 ± 3.28 reps) to be significantly ($p < .05$) higher than SEQ 1 (78.9 ± 3.03 reps). SEQ 1 showed lower values in the number of repetitions completed in all three sets compared to SEQ 3. SEQ 1 also showed a significant decrease in LPD-WG (Set 1: 8.50 ± 0.52 reps and Set 2: 6.00 ± 1.18 reps) and SAC-DB (Set 1: 5.60 ± 1.09 reps and Set 2: 3.90 ± 0.73 reps) in the first and second sets ($p < .05$). However, SEQ 3 and SEQ 1 showed a significant decrease in LPD-WG (SEQ 1 - Set 1: 8.50 ± 0.52 reps, Set 3: 4.60 ± 0.75 reps; SEQ 3- Set 1: 8.50 ± 0.65 reps, Set 3: 6.60 ± 0.75 reps), LPD-CG (SEQ1 – Set

1: 4.30 ± 0.91 reps, Set 3: 3.10 ± 0.47 reps; SEQ3- Set 1: 6.60 ± 1.28 reps, Set 3: 5.20 ± 0.89 reps), SAC-DB (SEQ1- Set 1: 5.60 ± 1.09 reps, Set 3: 3.10 ± 0.86 reps; SEQ3- Set 1: 6.70 ± 0.91 reps, Set 3: 5.00 ± 0.78 reps), and the SAC-M (SEQ1- Set 1: 4.10 ± 1.33 reps, Set 3: 2.80 ± 0.97 reps; SEQ3- Set 1: 5.40 ± 1.01 reps, Set 3: 4.20 ± 0.70 reps) in the first and third sets ($p < .05$). The authors concluded that as the rest periods between sets increased so did the number of completed repetitions (Miranda et al., 2007).

The purpose in the next study by Miranda et al. (2009) was to compare the workout volume completed (sets x resistance x repetitions per set) within 1 – and 3-minute rest periods between sets of upper body resistance training exercises. The study consisted of 12 college age men with two years of experience with resistance training. At the beginning of the study each participant had their 8RM assessed for the barbell bench press (BBP), incline barbell bench press (IBBP), pec deck fly (PDF), barbell lying triceps extension (BLTE), and the triceps push down (TPD) exercises. The 8RM assessment was executed by having each participant perform three 8RM attempts for each of the aforementioned exercises with a 5-minute rest period between each attempt. Each repetition must have been performed throughout the full range of motion and without any pauses in the eccentric or concentric phases. Once the 8RM was determined for a specific exercise, a 10-minute rest period was given before moving on to the next exercise. Now, once the 8RM's were determined for each exercise, two sessions (1- and 3-minute rest periods) for three sets per exercise in randomized order was performed with 48-72 hours of recovery between sessions. Before each session a warm-up of two sets of 12 repetitions using 40% of their 8RM was performed with the first exercise only. When completed with the warm-up, the participants were encouraged to perform three sets to voluntary exhaustion for each exercise. No attempts were made to control repetition velocity, however like the 8RM assessment each repetition must have been performed in the full range of motion with no pauses in the eccentric or concentric phases. Miranda et al. (2009) reported the volume completed for all exercises was significantly greater for the 3-minute rest period when compared to the 1-minute rest period for all exercises ($p < .05$). The authors concluded that the 3-minute rest period allowed for a greater reliability in repetitions within the three sets to voluntary exhaustion, while the 1-minute rest period did not allow adequate recovery time. They also reported that resting 3-minutes between sets and exercises might significantly increase the workout volume completed for upper body exercises (Miranda et al., 2009).

In a more recent study that compared 1- and 3-minute rest periods in upper body exercises, Rodrigues et al. (2012) examined the effects of the 1- and 3-minute rest periods between sets on 1) volume of repetitions in each set of each exercise using 80% of 1RM, 2) total volume of repetitions in each exercise session performed with 80% of 1RM, and 3) the total number of repetitions during each session performed with 80% of 1RM, within six visits. The participants in the study included 12 untrained men who have not participated in any resistance training in the previous six months. The first and second visit consisted of familiarization of the barbell bench press (BP), machine lat pull down (LPD), seated machine shoulder press (SP), machine triceps extension (TE), and the standing free weight straight bar biceps curl (BC) exercises. The third and fourth visit was the testing and re-testing of the participant’s 1RM for each of the aforementioned exercises on nonconsecutive days. The participant’s 1RM were determined within five attempts with a 5-minute rest period between attempts and a 10-minute rest period between exercises. Once the 1RM's for each exercise were established, in visits five (3-minute rest period) and six (1-minute rest period) the participants performed three sets using 80% of their 1RM to concentric failure during each exercise with a 1- or 3-minute rest period between sets and exercises. The results found that the total number of repetitions (1254 reps) for all the exercises in the 3-minute rest period was significantly higher than the total number of repetitions (974 reps) in the 1-minute rest period (p = .02). There was also a significant difference ($p < .0001$) when comparing the total number of repetitions in all exercises within the 1-minute and 3-minute rest periods, except in the SP (p = .263). When Rodrigues et al. (2012) compared the number of repetitions between sets in each of the rest periods; the 1-minute rest period showed a significant difference between the first and second set, and the second and third set in all exercises ($p < .05$). The only significant difference observed in the second and third set was found in the TE exercise ($p < .05$). However, in the 3-minute rest period, significant differences ($p < .05$) were found between the first and second set as well as between the first and third set for all exercises. The only significant difference between the second and third set were in the LPD and BC exercises ($p < .05$). The authors concluded that performing strength training exercises with 1-minute rest periods can reduce the total volume of repetitions compared to a longer rest period such as 3-minutes. They also state that the decreases in volume are highly related to insufficient time of recovery for the energy systems replenishment that in turn causes fatigue (Rodrigues et al., 2012).

Strengths in these studies include that majority of the participants had at least eight weeks of exercise experience, grouping of participants by rest periods used, and the use of multiple exercises. Limitations in these studies include that the majority of the participants were college age men and the order in which some of the exercises were used. For instance in the Rodrigues et al. (2012) study, the TE was performed directly after the SP which is taxing on the elbow extensors. Future studies should explore gender differences, older populations, and participants who have no previous experience with exercise.

Rest Periods in Lower & Upper Body Exercises

The previous studies compared different rest periods on initial strength gains with either lower or upper body exercises. The studies in this section are going to compare both upper and lower body exercises together. Salles et al. (2010) study was conducted to determine the effects that rest periods of 1-, 3- and 5-minutes had on lower and upper body strength. The study consisted of 36 trained men with a minimum of four years of resistance training experience. The participants were randomly divided into three groups by rest periods (G1, G3, and G5). Each participant performed the same exercises and was asked not to perform any additional exercises during the duration of the study. Prior to the study, baseline 1RM for bench press (BP) and leg press (LP) was assessed during three sessions with a minimum of 48-hours of rest between each assessment. During the follow up of week 8 (mid-point) and week 16 (end point) the same strength testing procedures were conducted for the accuracy of the study. The participants were asked to perform four resistance-training sessions a week. Before each training session, the participants performed a warm-up that consisted of two sets of 20 repetitions with 50% of their 1RM; after the warm-up was completed the participants performed three sets of each exercise until exhaustion. The results of the Salles et al. (2010) study showed that there was a high reliability for strength in the BP (baseline = .98, 8 weeks = .96, and 16 weeks = .98) and LP (baseline = .98, 8 weeks = .98, and 16 weeks = .98). The study indicated that there were no significant differences in strength between groups at baseline or 8 weeks ($p > .05$); as for 16 weeks G5 showed a significant increase in both BP strength (4kg) and LP strength (45kg) compared to G1 ($p < 0.05$). However there were indications that significant increases in strength were made in all groups at 8 weeks and 16 weeks compared to baseline ($p < .05$), but only G3 and G5 demonstrated significant increases at 16 weeks compared to 8 weeks ($p < .01$). The authors concluded that longer the rest periods such as 3-5-minutes results in an increase in upper and lower body strength. However, shorter rest periods such as 1-minute can be effective for increasing strength in lesser trained muscles or exercises (Salles et al., 2010).

Resistance training programs were originally designed to increase muscle power, strength, hypertrophy and endurance. The degrees in which these are obtained may be dependent on rest periods (Willardson & Burkett 2006b). Fifteen college age men with a minimum of one-year experience performing squats and bench presses were the participants for this study. The study occurred for four weeks with one testing session each week. During the first testing session, the 15RM for the bench press and squat was calculated for each participant. During the next three testing sessions, each participant was required to perform five sets of squats and bench presses using a 30-second, 1-minute, and 2-minute rest period. All the participants were allowed to continue with their personal workout program except they could not perform any squats or bench presses and were advised not to work out on the day of testing. Before each testing session the participants performed two warm-up sets for each exercise; the first set consisted of 50% of the 15RM for 10 repetitions, the second set 75% of the 15RM for 10 repetitions, and the third set the resistance was raised to the 15RM for five sets to voluntary exhaustion. For the accuracy of the study, all participants were required to move at the same velocity for each repetition, three-second eccentric phase, followed by a one-second concentric phase. Willardson and Burkett's (2006b) results for the squat found that the rest periods had significant differences in the ability to sustain repetitions between the 30-second and the 2-minute rest periods (no *p* value was given). However, the ability to sustain repetitions was not significantly different between the 30-second and 1-minute rest periods and between the 1-minute and 2-minute rest periods. As for the bench press results, there were also significant differences in the sustain repetitions between the 30-second and 2-minute rest periods, and like the squat no significant differences were found between the 30-second and 1-minute rest periods. The results also indicated that the repetitions were not sustainable over five sets using the 15RM. The authors concluded that the squat and bench press repetitions were most sustainable when using the 2-minute rest period (Willardson & Burkett, 2006b).

Rest periods are occasionally over looked within resistance-training programs. Willardson and Burkett (2005) conducted a study to observe the effects that 1-, 2-, and 5-minute rest periods have on four sets of squats and bench presses through a four-week testing period. Fifteen college-age men volunteered to participant in a minimum of three strength-training workout sessions per week. The first week of testing was constructed to determine an 8RM for each participant. For the next three weeks the test sessions consisted of four sets of squats and bench presses with a 1-, 2-, and 5-minute rest period between sets. All participants were allowed to continue their personal workout programs throughout the study except they were not allowed to perform the squat or bench press and they could not workout on testing days. Before each test the participants performed a warm-up with each exercise. The first warm-up was performed at 50% of their 8RM for 10 repetitions and the second warm-up consisted of 75% of their 8RM for five repetitions. Once the warm-ups were completed the participants performed four sets of each exercise using their 8RM until voluntary exhaustion. To ensure that all the participants were moving at the same velocity each set was timed, 3-second eccentric phase followed by a 1-second concentric phase. The results of this study showed that the repetitions completed for the squat were significantly different between the 1- (22.47 ± 4.79 completed reps) and 5-minute (28.80 ± 3.08 completed reps) rest periods and the 2- (25.53 ± 4.29 completed reps) and 5-minute rest periods, but was not significantly different between the 1- and 2-minute rest periods ($p < .05$, $p > .05$). As for the bench press, the results were similar to that of the squat with the repetitions completed significantly different between the 1- (17.13 ± 4.42 completed reps) and 5-minute (25.73 ± 4.23 completed reps) rest periods, the 2- (21.60 ± 4.52 completed reps) and 5-minute rest periods, and the 1- and 2-minute rest periods ($p <. 05$). The authors concluded that in both exercises as the rest periods increased so did the total number of completed repetitions (Willardson & Burkett, 2005).

A study by Tacito et al. (2010) compared the effects of strength and muscle hypertrophy during an 8-week resistance training intervention using constant (2-minute) and decreasing (2-minutes - 30 seconds) rest periods. Participants used in this study consisted of 20 recreationally trained men. For training purposes the 20 participants were divided into two groups, 10 in the constant rest period group (CI) and 10 in the decreasing rest period group (DI). Each participant performed three 1RM sessions separated by 48 hours for two weeks for familiarization. After the familiarization with the 1RM testing (roughly 72 hours) cross-sectional area (CSA) was measured using a magnetic resonance imaging (MRI) followed by an isokinetic peak torque measurement using the Cybex 6000 dynamometer. Pre and post-testing for the bench press and squat 1RM was determined on two occasions separated by 48 hours without participation in any exercise between testing sessions. Knee extensor and flexor isokinetic peak torque was measured by having the participant's warm-up with the two muscle actions at an angular velocity of 60 degrees/second with 50% of their maximum effort. Once warm, each participant performed a concentric action of the knee extensor and knee flexor at an angular velocity of 60 degrees/second for 5RM for both the right and left leg. MRI scans of the right thigh and upper arm were also taken pre and post intervention to compare the CSA for each participant. For the first two weeks of the intervention, both the CI and DI group trained six days a week and used the same exercise program of three sets of 10-12 repetitions with a 2-minute rest period between sets and exercises. The exercises for the first two-weeks consisted of free-weight bench press, free-weight incline bench press, machine wide grip lat pull down, leg extension machine, and leg curl machine on Monday, Wednesday, and Friday. Tuesday, Thursday, and Saturday consisted of free-weight front military press, dumbbell shoulder lateral raises, biceps barbell curls, triceps extension on a pulley machine with a v shaped handle, lying triceps extension with a barbell, and abdominal crunches. After the first two weeks of training, the CI group continued to use the 2-minute rest period for the next six weeks, while the DI group gradually decreased from 2-minutes to 30-seconds. During the next six weeks, different exercises were also used for both groups, Monday and Thursday (free-weight bench press, free-weight incline bench press, machine wide grip front lat pull down, and machine seated row), Tuesday and Friday (free-weight front military press, dumbbell shoulder lateral raises, biceps barbell curl, dumbbell alternating biceps curl, triceps extension on a pulley machine with a v shaped handle, and lying triceps extension with a barbell), and Wednesday and Saturday (free-weight back squat, leg extension/curl machine, and abdominal crunch). The results showed that total training volume (sets x load for all training sessions) for the bench press in the CI (21, 257.9 ± 172.7 kg) group was significantly higher than the DI (19,250.4 ± 343.8 kg) group (p = .043). The squat also showed similar results with the total training volume in the CI (27,248.2 ± 293.8 kg) group being significantly higher than the DI (23,453.6 ± 299.4 kg) group (p = .000). During weeks 6-8, the training volume in the CI group showed to be significantly higher than the DI group in both the squat and bench press. However, the CI and DI group did show significant increases in bench press and squat as well as knee extensor and knee isokinetic peak torque. Increases in strength for the squat were similar between the CI and DI group at 34%. As for the strength increases in the bench press the DI group increased by 38% compared to the CIs 28%. Even though the DI total training volume was lower than the CI, there were no significant differences in strength or CSA due to the different training protocols. Tacito et al. (2010) concluded that similar strength gains and muscle CSA could be achieved with either a constant rest period of 2-minutes or a decreasing rest period of 2-minutes - 30-seconds between sets and exercises over short training periods (Tacito et al., 2010).

Strength training is important for increasing strength, hypertrophy, endurance, muscular potency, and improves quality of life. Simao et al. (2006) examined the effect of a 1- and 3-minute rest period during four weeks of resistance training. Twenty-six men with at least four years of experience with resistance training volunteered for this study. Throughout the four weeks the participants were split into two groups, 1-minute rest period group (G1) and a 3-minute rest period group (G3). Each participant performed the following exercises each week; the horizontal supine, hack squat, bicep curls, leg press, lat pull down, abdominal crunch, and triceps push down for four sets of 8-12 repetitions except the abdominal crunch was performed with15-20 repetitions. Each week consisted of three sessions with 48-72 hour rest between sessions. During week one and week four each participant had their 10RM tested for each exercise with rest period between 2- and 5-minutes between attempts and 20-minutes between exercises. During weeks two - four, G1 performed each exercise three times a week with four sets of 8-12 repetitions for all exercises except for the abdominal crunch, which was performed with 15-20 repetitions. G3 followed the same sequence, but instead of using a 1-minute rest period they used a 3-minute rest period between sets. The results from the study found that there was a significant difference from pre to post between the 1- (Pre: 33.0 kg, Post: 37.0 kg) and 3- (Pre: 31.0, Post: 36.0 kg) minute rest periods (no *p* value given). The authors concluded that over the four-weeks of training, the 3-minute rest period allowed for the greatest strength increases for all exercises when compared to the 1-minute rest period (Simao et al., 2006).

Rahimi, Boroujerdi, Chaeeni, and Noori (2007) examined the effects of 1- 2-, and 5-minute rest periods between sets on the training volume completed over four sets with 85% of a 1RM load. The participants for the study consisted of 11 male bodybuilders who participated in at least three strength training sessions a week in the following; bench press, arm curls, leg press, and military press exercises for the past two years. The length of the study was four weeks, in which data were collected on Saturday, Monday, Wednesday, and Friday of every week. During week one, three to five 1RM attempts were performed with a 4-minute rest period between each attempt. Prior to each session, each participant was required to warm-up with 4-minutes of low intensity exercise on the cycle ergometer. When the participants finished the warm-up on the ergometer, they performed a warm-up of one set of eight repetitions and one set of five repetitions at 50% and 70% of the perceived 1RM for each exercise. During the next three weeks the same warm-up protocol was performed as with the 1RM testing with the addition of four sets to failure using 85% of their 1RM load with a 1-, 2-, or 5-minute rest period between sets. The results found that the volume completed was significantly different between the 1- (Bench Press: 4.90 ± 2.44 total reps completed, Arm Curl: 5.25 ± 1.65 total reps completed, Military Press: 3.95 ± 1.6 total reps completed, Leg Press: 4.52 ± 1.62 total reps completed) and 5-minute (Bench Press: 6.06 ± 1.84 total reps completed, Arm Curls: 5.88 ± 1.12 total reps completed, Military Press: 4.95 ± 1.18 total reps completed, Leg Press: 5.29 ± 0.9 total reps completed) rest periods and between the 2- (Bench Press: 5.25 ± 2.42 total reps completed, Arm Curls: 5.45 ± 1.51 total reps completed, Military Press: 4.29 ± 1.24 total reps completed, Leg Press: 4.81 ± 1.16 total reps completed) and 5-minute rest periods for all exercises ($p < .05$). There was however no significant difference between the 1- and 2-minute rest periods for all exercises ($p = .04$). The authors concluded that the 5-minute rest period showed to have the highest volume of completion with 85% of a 1RM load following descending order with the 2- and 1-

minute rest periods. So as the rest periods increased so did the number of repetitions completed (Rahimi et al., 2007).

Now this study by Senna, Salles, Prestes, Mello, and Simao (2008), looked to examine the effects of 2 - versus 5-minute rest period between sets on repetition completion and total training volume during three sets of 10 repetitions within four sessions for both upper and lower body exercises. This study consisted of 14 recreationally trained men with a minimum of one-year experience with resistance training. The participants had two familiarization sessions to better understand the exercises and equipment that was being used. After the familiarization sessions, the participants performed three 10RM attempts with a 5- minute rest period between attempts to determine their individual 10RM within two nonconsecutive days for the following exercises; leg press (LP), bench press (BP), leg extension (LE), pec-deck (PD), leg curl (LC), and triceps pushdown (TP). Once the load was determined, four sequences were obtained. Sequence A consisted of lower body exercises with a 2-minute rest period and Sequence B was similar to A except with a 5-minute rest period. Sequence C consisted of upper body exercises with a 2 – minute rest period and Sequence D was similar to C except with a 5 – minute rest period. During each sequence the participants were instructed to complete the maximum number of repetitions in each set until concentric failure. Concentric failure for this study was when the participant could no longer produce sufficient force to move the resistance during the concentric phase and if the movement stayed in an isometic contraction for more than two seconds, that repetition was not counted. Before beginning each of these training sequences a warm-up of 12 repetitions using 40% of their 10RM was performed in only the first exercise.

While performing these exercises, the participants were required to utilize a smooth and controlled motion; pauses were not allowed between the concentric and eccentric phases. Senna et al. (2008) results reported that the total number of repetitions for sequence A (66.7 ± 4.9 reps) were significantly smaller than the total number of repetitions for sequence B (80.0 ± 6.9 reps) ($p < .05$). However, sequence C and D reported similar results with the total number of repetitions in sequence C (71.1 ± 4.7 reps) being significantly smaller compared to the total number of repetitions in sequence D (83.7 ± 6.1 reps) ($p < .05$). The authors concluded that the total numbers of repetitions completed were reduced with the shorter rest period. Also, maintaining specific resistance training goals, intensities, and volumes are important variables to be manipulated, and depending on these factors will determine the appropriate rest period (Senna et al., 2008).

Strengths to these studies include combining upper and lower body exercises while utilizing different rest periods. Some limitations to these studies would be the small sample sizes, and the use of bodybuilders and recreationally trained college age men. Future studies should explore gender differences, older populations, and participants who have no previous experience with exercise.

Rest Periods in Women

The bulk of the previous evidence mainly consisted of recreationally trained males. As one might see, there is a vast gap in the literature when trying to determine the appropriate rest periods to increase strength within women.

Unlike the previous studies that primarily used recreationally trained men, Rahimi, Boroujerd, Mozafari, and Faraji (2009) examined the effects of 60-, 90-, and 120- second rest period between sets of the bench press exercise on training volume completed over four sets with a 12RM load in women. Fifteen women with experience performing resistance training volunteered for this study. The study consisted of four sessions in one week's time that took place on Saturday, Monday, Wednesday, and Friday. During each session, each participant was required to warm-up with 4-minutes of low-intensity on a cycle ergometer. Once the 4-minutes were completed on the ergometer, the participants performed one set of 12 repetitions with 50% of their 12RM and another set of five repetitions at 75% of their 12RM. For the next three sessions, four sets using a 12RM load was performed with a 60-, 90-, and 120-second rest period. Each participant was instructed to perform the maximum amount of repetitions in each set. Each attempt was considered successful when the bench press was completed throughout a full range of motion without compromising proper form. To ensure that all the participants were moving at the same velocity of a two-second eccentric phase followed by a one-second concentric phase for each repetition, each set was timed using a handheld stopwatch. The results from this study found a significant difference between training volumes for each of the rest periods ($p < .05$). They found that the training volume completed for the bench press was significantly different between the 120- (8.5 ± 1.29 completed reps) and 60- (7.08 ± 2.11 completed reps) second rest periods and between the 90- (8.16 ± 1.34 completed reps) and 60-second rest periods ($p < .05$). However, there was no significant difference in training volume between the 120- and 90-second rest periods ($p = .18$). The authors concluded that as the rest periods between sets increased so did the number of completed repetitions. The authors also stated that, even though the repetitions decreased from set one - four, a minimum rest period of 120-seconds should be used in the bench press exercise to avoid significant declines in repetitions. Future research is recommended to investigate longer rest periods to detect optimal recovery between sets to prevent decreases in training volume (Rahimi et al., 2009).

Strengths in this study include that majority of the participants had at least eight weeks of resistance training experience, and the use of different rest periods. Limitations in the study include the participants being of college age. With this study being the only one found using only women, future studies should explore rest periods between sets of resistance training exercise among women, older populations and participants who have no previous experience with exercise.

Rest Periods in Older Adults

As previously mentioned in the significance of this study, rest periods between sets of any type of resistance training exercise, either looking to increase strength or power in older adults is listed as a category D meaning it has not been fully studied (Chodzko-Zajko et al., 2009; Ratamess et al., 2009).

In an effort to determine if resistance training helps reduce some of the age related losses in muscle strength and ADLs, Rabelo et al. (2004) examined the effects of two different resistance-training intensities on the muscular strength and performance on ADLs in elderly women. The participants for the study consisted of 61 sedentary women between 60-76 years of age. Prior to the study, the participants were divided into three groups; group one consisted of 21 participants using 50% of their 1RM (G50), group two had 20 participants using 80% of their 1RM (G80), and group three the control group had 20 participants (CG). Each participant had their cardiorespiratory capacity and ADLs measured using the one-mile walk test and the Andreotti-Okuma protocol. One-repetition maximum tests were measured in the leg press, bench press, knee extension, lat pull down, calf raise, arm curl, triceps, and shoulder abduction exercises. Once the 1RMs were determined, the G50 group was instructed to perform three sets of eight repetitions with each exercise using 50% of their 1RM with a 1-minute rest period between each set three times a week for 10-weeks. The G80 group was instructed to perform the same protocol except they used 80% of their 1RM for each exercise. The results from the study found significant differences between the G50 and G80 groups ($p < .001$), G50 and CG groups ($p < .001$), and the G80 and CG groups ($p < .001$). As for the ADLs, there were significant differences found between all groups ($p < .05$), except in the stair-climbing test there was no significant difference ($p > .05$). Although Rabelo et al. (2004) focus for their study was not rest period length and its correlation to strength increases, they did find that resistance training can significantly increase muscular strength and ADLs when using rest periods of 1-minute between sets. The authors concluded that similar improvements in muscular strength and ADLs could occur when using 50% or 80% of 1RM. However, the benefit of using a lighter load especially for beginners is reducing the possibility of injury (Rabelo et al., 2004).

To provide a basis of comparison, a study by Sousa, Mendes, Abrantes, and Sampaio (2011) examined the differences between upper and lower limb maximum strength after a 12-week strength-training program with 3-minute rest periods. Ten healthy men 73 ± 6 years of age with no experience with resistance training participated in this study. The strength-training program consisted of three sessions a week for 14 weeks. The two weeks before the program began was used as a familiarization period for the leg press, leg extension, leg curl, bench press, lat pull down, shoulder press, and arm curl exercises. After the participants were familiar with the exercises, each participant had their 1RM tested. The 1RMs were tested on the first session during weeks one, five, and nine and the last session during week 12. Each 1RM was obtained within three-five attempts with a 3-minute rest period between attempts. Once the 1RMs were calculated, the participants performed two-three sets of 6-12 repetitions with a 30-second rest period between each set while using 50%-80% of their 1RM load. Sousa et al., (2011) results found a significant difference in muscle groups (p = .006), time effects (p = .00), and interactions (p = .01) between the upper and lower limbs. They also found a significant increase between baselines and follow up 1RM testing in weeks five, nine, and 12. However, the biggest increase occurred in the upper limb (81%) compared to the lower limb (66%) over the 14-week program. Like the Rabelo et al. (2004) study, Sousa et al. (2011) focus for their study was not rest period length and its correlation to strength increases, however they did find that resistance training can significantly increase both upper and lower limb strength in older adults over a 14-week training program using 30-seconds of rest between each set. With that being said the authors concluded that the muscles in the lower limbs have a lower trainability due to them being more elicited over time resulting in less strength losses. Strength gains were higher in the upper limbs because they have a greater trainability as well as declines in strength over time, which can lead to losses in balance and postural control. When designing a strength-training program for older adults, special attention should be given to muscle groups located in the trunk and upper limbs (Sousa et al., 2011).

Strengths in these studies include the use of older men and women. A limitation in these studies would be the small sample size. Future studies should explore gender differences using multiple rest periods between sets.

Summary and Conclusion

The purpose of this review was to examine 1-, 3-, and 5-minute rest periods and the effects they had on volume completion during resistance training exercises in older adults 60-90 years of age. Based on the studies reviewed, significant strength increases appear with longer rest periods of 3-5-minutes compared to shorter rest periods of 30-seconds to 1-minute. The studies in this review indicate the most beneficial rest periods for recovery from resistance training exercises are between 3-5-minutes. Salles et al. (2010) suggests that longer rest periods of 3-5-minutes are important for increasing or continuing to increase strength. Shorter rest periods around 1-minute should be performed when the potential for strength increases are high. According to the Richmond and Godard (2004) study, individuals who use as little as 3-minutes of rest between sets were capable of performing in the 8-12 repetition range. As the rest periods between sets increase so does the total number of repetitions completed (Willardson & Burkett, 2005). According to the results from these studies, rest periods greater than 3-minutes seem to be significantly better in increasing muscular strength that could lead to improved exercise performance in younger people.

This literature review will help identify the appropriate rest periods for recreationally trained college age men who are looking to increase muscular strength, however there is not much research identifying the appropriate rest period for older adults and women. Strengths in this review include; that the majority of the studies used recreationally trained college-aged men with at least eight weeks of exercise experience. Some limitations would be the males, college age population, and recreationally trained participants. Future studies need to explore gender differences of all ages, especially female older adults, and a combination of recreationally trained and non-trained participants.

Based on this literature review beginners should start with 1-minute rest periods between sets and exercises. As one becomes more trained, extend the rest period to 3-5-minutes between sets and exercises are recommended for optimal strength gains.

CHAPTER THREE: Methods

Participants

Upon approval from the Institutional Review Board (IRB; Appendix A), 28 men and women between the ages of 60 and 90 years, with a minimum of eight weeks of resistance training experience were recruited from the University of Central Oklahoma’s LIFT resistance training program and by posting fliers in the UCO Wellness Center. Participants who were experienced with resistance training were chosen because this should help minimize the neural effects on initial strength gains (Rodrigues et al., 2012). Of the 28 men and women, three had to be removed from the study due to scheduling conflicts and two dropped out due to soreness in their legs.

Participants were informed of the risks as well as the benefits of participating in the current study. All participants signed an informed consent form (Appendix B) and completed the Exercise Assessment and Screening for You (EASY; Appendix C) before participation. The EASY tool helped the investigator to become more familiar with the individuals participating in this study and determine the need for medical clearance. Any participants whose responses indicate a condition where medical clearance was warranted were not allowed to participate. None of the participants met this criterion. Along with having to obtain medical clearance, participants were not allowed to participant in this study if they were not able to perform the proper leg press technique. One participant was not allowed to participate due to not being able to properly perform the leg press exercise. Participants were allowed to continue with their normal workout routines throughout the duration of the study with the following expectations: (a) participants were instructed not to perform the leg press exercise or squats, lunges, chair stands, or knee extensions in their personal workout and (b) participants were instructed not to work out on the day of their scheduled testing sessions.

Instruments

Stadiometer. A stadiometer is a device that is used to measure height. The particular model that was used for this study consisted of a vertical ruler, mounted to the balance scale with a sliding horizontal platform that adjusts to rest on the top of the head to determine height (Williams & Wilkins, 2009). To insure accurate measurements of height, all participants were instructed to; (a) remove shoes and hat (if worn), (b) stand erect with feet flat on the floor with heels touching each other, (c) the heels, mid-body, and upper-body parts were in line with one another, (d) take a normal breath in and hold it while looking straight ahead (head in a neutral position relative to the chin), and (e) the horizontal platform was then lowered to touch the top of the head (Williams & Wilkins, 2009).

Balance scale. A balance scale is a measuring instrument for determining weight or mass. When weight is applied to the scale, the left end of the beam will drop toward the floor and the right end of the beam will rise until it hits the stopper. The beam is comprised of two rows of numbers with weight that slide along each row. The bottom row contains notches at increments of 50 pounds, along with the larger weight. The top row has a smaller weight, and is marked in two-pound increments. Weight was determined when the beam was parallel to the floor (Williams & Wilkins, 2009). To insure accurate measurements of weight, each participant was instructed ahead of time to (a) wear minimum clothing such as shorts and a t-shirt and (b) void bladder within one hour of the measurement (Williams & Wilkins, 2009).

Hammer Strength leg press machine. The Hammer Strength leg press is a vertical sled type leg press that is used to evaluate lower body strength from the knee joint to the hip (Verdijk, Van Loon, Meijer, & Savelberg, 2009). Weighted plates are attached directly to the sled, which is mounted on rails. The sled itself is what the footplate is located on where the participants placed their feet. The participants sat below the sled and pushed upward using their lower body. This particular machine includes an adjustable safety bracket that prevents the participants from being trapped under the weight. According to Verdijk et al. (2009) the leg press exercise has been shown to be a valid means of measuring lower body strength when compared to isometric/isokinetic peak torques (r = .72-.77, $p < .001$).

Maximal strength testing. The 1 repetition maximum (1RM) test was used to determine maximal strength. Each participant reported to the University of Central Oklahoma's Wellness Center on two nonconsecutive days (separated by at least 7-days; Levinger et al., 2009). The 1RM leg press was assessed before the experimental sessions using a standard protocol (Kraemer, Fry, Ratamess, & French, 2006; Rodrigues et al., 2012). A warm-up set of 5-10 repetitions was performed using 40%-60% of their perceived 1RM on the leg press machine. To ensure the accuracy of the 1RM, each participant sat with their back firmly against the seat and placed their feet flat on the footplate hip width apart. Participant's legs were bent at 90° at the knee joint. The knees were in line with the feet and not bending inward or outwards. Each participant was instructed to exhale as the weight is being pushed up, making sure the knee joints are not locking out at the end of the motion. Next, the participants inhaled while bringing the weight back down in a slow controlled manner. The same spotter was present to provide verbal encouragement and ensure the safety of each participant. To ensure that the participant's moved at the same velocity, each 1RM attempt had the same cadence of 30 beats per minute (BPM) using the Pro Metronome App. The researcher called out a cadence for the eccentric and concentric phases. The velocity consisted of a 2-second eccentric phase followed by a 2-second concentric phase. Attempts not completed in a full range of motion or attempts completed via assistance from the researcher were not counted. Once either of these occurred, the previous load successfully attempt was determined as the participant's 1RM. The 1RM was determined within three attempts with a rest period of 3-minutes between attempts (Rodrigues et al., 2012).

Leg press protocol. Following maximal strength assessment, each participant reported to the University of Central Oklahoma's Wellness Center once a week at a standard time of day (to eliminate potential circadian performance variations) on three occasions with each protocol session separated by at least 7 days. Each protocol consisted of a light warm-up on the leg press machine followed by two sets of eight repetitions at 80% of their 1RM with the third set being conducted to failure. Failure was indicated by the inability to complete a repetition using the correct form. The number of repetitions completed in the failure set was recorded as the volume of exercise performed. Repetitions not completed in a full range of motion or repetitions completed via assistance from the researcher were not counted. The participants performed the same protocol using 1-, 3-, and 5-minute rest periods in a randomized order. To ensure the accuracy of the study, each participant sat with their back firmly against the seat, and placed their feet flat on the footplate hip width apart. Participant's legs were bent at 90° at the knee joints. The knees were in line with the feet and not bending inward or outwards. Each participant was instructed to exhale as the weight is being pushed up, making sure the knee joints are not locking out at the end of the motion. Next, the participants inhaled while bringing the weight back down in a slow controlled manner. The researcher was present to provide verbal encouragement and to ensure the safety of each participant. To ensure that the participant's move at the same velocity for each repetition, each set consisted of the same cadence of 30 BPM using the Pro Metronome App. The researcher called out the cadence for the eccentric and concentric phases. The velocity consisted of a 2-second eccentric phase followed by a 2-second concentric phase.

Experimental Approach to the Problem

- Week 1 consisted of signing the informed consent, conducting the prescreening, measuring height and weight, familiarization of the equipment, and testing the 1RM for each participant.
- Week 2 consisted of re-testing each participant's 1RM to ensure accuracy.
- Week 3-5 (in random order)
    - 1-minute rest period. Following a light warm-up on the leg press machine, the participants completed two sets of eight repetitions at 80% of their 1RM. The rest period between each set was 60 seconds. The third set was conducted to failure. Failure is indicated by the inability to complete a repetition using the correct form. The number of repetitions completed in the failure set was recorded.
    - 3-minute rest period. This session followed the same procedures, as the previous session except the participants rested for 180 seconds between sets.

- 5-minute rest period. This session followed the same procedures, as the last two sessions except the participants rested for 300 seconds between sets.

Design and Analysis

The purpose of this study was to determine if 1-, 3-, or 5-minute rest periods between sets of the leg press exercise would increase volume (number of repetitions) among older adults, 60-90 years of age. The independent variable in this study is the rest period (1-, 3-, and 5- minutes), while the dependent variable is volume. All data were collected on a data collection sheet created by the researcher (Appendix D). A repeated measures ANOVA was conducted to determine whether a significant difference in exercise volume was observed between rest periods. The null hypothesis states that the volume of exercise completed following a 5-minute rest period will not be greater than following the 3- and 1-minute rest periods ($\alpha = .05$).

A secondary analysis of sex differences was conducted using a 2 x 3 ANOVA with repeated measures. The independent variables were rest periods and sex, while the dependent variable was exercise volume.

A dependent *t*-test was conducted to compare differences between the first and second 1RM testing. Sex differences in 1RM were examined using an independent *t* test.

With an alpha level set at .05 and desired power of 0.8, an estimated sample size of 110 participants was recommended to reveal significance according to previous research by Richmond and Godard (2004) which produced an effect size of .22 when assessing volume completed in the lower body. A sample size of a 110 participants for this study is not realistic due to the lack of help and resources. Due to the lack of statistical power in this study, univariate effects sizes were also calculated.

The primary investigator recorded all tests. SPSS Version 18 was utilized to analyze the collected data. An alpha of 0.05 was used to determine significance of all analyses.

CHAPTER FOUR: Results

The purpose of this study was to determine the optimal rest period length for volume of exercise (number of repetitions) completed in the leg press exercise among trained older adults. The researcher hypothesized that the volume of exercise completed following a 5-minute rest period will be greater than the volume of exercise completed following the 3- and 1-minute rest periods. It is also expected that the 3-minute rest period will result in a greater volume of exercise than the 1-minute rest period. The volume of exercise was tested for 1-, 3-, and 5-minute rest period in a random order.

Descriptive Statistics

The descriptive statistics for age, height, weight, results of first 1RM test (max 1), and results of second 1RM test (max 2) are reported in Table 1. Mean age for males was 71.50 ± 6.14 years, while the mean age for females was 70.93 ± 7.03 years, with a range of 60 to 85 years. The mean on the first 1RM was (M = 144.66 ± 94.63 pounds) and the mean on the second 1RM was (M = 217.73 ± 126.75 pounds).

Descriptive statistics for number of repetitions completed following each rest period are reported in Table 2. The 1-minute rest period (M = 21.41 ± 10.02 repetitions) resulted in a minimum score of 5 repetitions and a maximum score of 45 repetitions. Following the 3-minute rest period participants completed a mean of 22.55 ± 9.29 repetitions with a minimum score of 8 repetitions and a maximum score of 42 repetitions. The 5-minute rest period had a minimum score of 10 repetitions and a maximum score of 39 repetitions (M = 22.18 ± 8.45 repetitions).

The descriptive statistics for males and females can be also found in Table 2. Males completed 18.38 ± 8.31 repetitions following the 1-minute rest, 21.75 ± 9.78

repetitions following the 3-minute rest, and 22.38 ± 9.75 repetitions following the 5-minute rest. As the rest periods increased, so did the mean number of repetitions. Contrarily, the exercise volume slightly decreased as rest periods increased among females. For females, the exercise volume following the 1-minute rest period was 23.14 ± 10.77 repetitions. The mean for the 3-minute rest period was 23.00 ± 9.34 repetitions and the mean following the 5-minute rest period was 22.07 ± 8.01 repetitions.

Maximum Testing

One-repetition maximum (1RM) was measured twice in order to account for familiarization of participants. A dependent *t* test was calculated to compare the mean of the first 1RM test to the mean of the second 1RM test. A significant increase was found $t(21) = -7.412$, $p = .000$, between the first 1RM and the second 1RM. The mean on the first 1RM was (M = 144.66 ± 94.63 pounds) and the mean on the second 1RM was (M = 217.73 ± 126.75 pound).

Rest Period Analysis

A one - way repeated measures ANOVA was calculated to compare the exercise volume (number of repetitions) between the three rest periods: 1-, 3-, and 5- minute. The results indicated that the number of repetitions was not significantly different between rest periods $F(2,42) = .280$, $p = .75$. Due to the small sample size, univariate effect sizes were calculated between the 1- and 3-minute rest periods ($d = .11$; 5.32% increase), 3- and 5-minute rest periods ($d = .03$; 1.64% decrease), and 1- and 5-minute rest periods ($d = .07$; 3.59% increase) to examine trends toward a difference in exercise volume. Small effect sizes were noted for all comparisons (Table 3). The most repetitions were observed following the 3-minute rest period (M = 22.55 ± 9.29 repetitions). A bar graph of these results is represented in Figure 1.

Sex Comparison

Descriptive statistics indicated that exercise volume by rest period may be different between males and females, therefore a 2 x 3 ANOVA with repeated measures was conducted with sex as the between subject factor. No significance were found for the rest-by-sex interaction $F(2, 40) = 1.32$, $p = .27$, the main effect for rest $F(2, 40) = 0.62$, $p = .54$, or the main effect for sex $F(1, 20) = 0.26$, $p = .61$. However, for the males there were increases of 18.33% from 1-3 – minutes, 0.02% from 3-5 – minutes, and 21.76% from 1-5 –minutes ($d = .40$; $d = .06$; $d = .48$). As for the females, there were decreases of 0.60% from 1-3 –minutes, 0.04% from 3-5 – minutes, and 4.62% from 1-5 – minutes ($d = .01$; $d = .10$; $d = .09$). A bar graph of these results is represented in Figure 2.

Maximum testing. An independent – samples *t* test was run to compare the means from the second 1RM test between males and females. The test reported a significant difference between the means $t(20) = 3.316$, $p = .003$. The mean of the females was significantly lower (M = 161.96 ± 90.26 pounds) than the mean of the males (M = 315.31 ± 126.36 pounds). Descriptive statistics for the maximum tests are represented in Table 1.

CHAPTER 5: Discussion

Low rates of participation in resistance training and physical impacts of aging has led to a gradual decline in muscle strength, power, size, functional abilities and increases in sarcopenia and inactivity in both men and women (Rabelo et al., 2004; Trappe et al., 2001). Resistance training has been shown to slow the development of sarcopenia by being a reliable means to increase muscle strength in older adults (Rabelo, Oliveira, & Bottaro, 2004). One of the main concerns of a proper resistance-training regimen is the rest period taken between sets of exercise (Mirzaei et al., 2008). A rest period is the time taken to recuperate between sets and exercises, which are known to have a dramatic effect on the outcome of resistance training (Clark et al., 2008). The amount of rest taken between sets affects many physiological functions such as metabolic, hormonal, cardiovascular, as well as training adaptations (Ratamess et al., 2009). ACSM and NSCA recommends 2 – 5-minutes of rest between compound exercises such as the squat and bench press and 1 – 2-minutes of rest between assistance exercises (Ratamess et al., 2009; Richmond & Godard, 2004). Therefore the researcher hypothesized, based on the studies of Miranda et al. (2007), Rabelo et al. (2004), Rahimi (2005), and Richmond and Godard (2004), that the volume of exercise completed following a 5-minute rest period would be greater than the volume of exercise completed following the 3- and 1-minute rest periods. It was also expected that the 3-minute rest period would result in a greater volume of exercise than the 1-minute rest period.

The researchers hypothesis was not supported with no significant differences or trends between rest periods; however, based on effect sizes the 3 -minute rest period showed to be superior over the 1 - and 5 – minute rest period (Table 3, Figure 1). Similar results were found in the Willardson and Burkett (2008) study when they compared 2 - and 4-minute rest periods within squat strength gains in recreationally trained men. Unlike the current study, the participants in Willardson and Burkett (2008) used 70%-90% of their 1RM. They concluded that large strength gains in the squat exercise can be achieved using the 2-minute rest period between sets and that little to no additional gains were achieved using 4-minutes compared to 2-minutes between sets.

In another study using the bench press exercise, Richmond and Godard (2004) studied the effects of 1-, 3-, and 5-minutes of rest with 75% of the 1RM in recreationally trained men. Unlike the current study that found no difference, they found that resting 3-5-minutes between sets allowed more volume whereas the 1-minute rest period reported a lower volume. Willardson and Burkett (2006a) also conducted a study in the bench press exercise examining the effects of 1-, 2-, and 3-minute rest periods with 50% and 80% 1RM. They found that the total repetitions completed were significantly different between each rest period (p = .000). The total repetitions completed within 50% 1RM were 59.13 reps for the 1 – minute rest, 74.81 reps for the 2 – minute rest, and 87.69 reps for the 3 – minute rest. As for the 80% 1RM, the total repetitions completed were 18.06 reps for the 1 – minute rest, 23.06 reps for the 2 – minute rest, and 27.06 reps for the 3 – minute rest. Though significance was found, the 80% 1RM group did not show a large repetition difference between rest periods especially between the 2 – and 3 – minute rest period. In another study using the bench press exercise in recreationally trained men, Mirzaci et al. (2008) compared 90 -, 150 -, and 240 – second rest period within four sets using 60% and 90% 1RM to determine sustainability in the bench press exercise. Like Willardson and Burkett (2006a) they too found that repetitions completed were significantly different between each rest period (*p* = .00). They reported a 35% decline for the 240-second rest, 55% decline for the 150-second rest, and 70% decline for the 90-second rest within the 60% 1RM, as for the 90% 1RM there was a 25% decline for the 240-second rest, 45% decline for the 150-second rest, and 69% decline for the 90-second rest in completed repetitions between the first and fourth set in both loads (*p* = .00, *p* = .00). Their study, like the previous studies, also shows that the 2-5 –minute rest period is best for increasing volume.

Miranda et al. (2007) and Miranda et al. (2009) conducted studies examining the effects of the 1- and 3-minute rest periods on multiple upper body exercises among experience recreationally trained men using 8RM for all exercises. For both studies, they reported that the 3-minute rest period allowed significantly greater volume within three sets to voluntary exhaustion. Rodrigues et al. (2012) found similar results using multiple upper body exercises as well as 1- and 3-minute rest periods between sets. Like the participants in the current study, the participants in the Rodrigues et al. (2012) study also used 80% of their 1RM until repetition failure where they found that the 3-minute rest period produced more repetitions compared to the 1-minute rest period. In another study using the 1- and 3-mintue rest period, Simao et al. (2006) examined the effects of the 1 – and 3 – minute rest period among a variety of upper and lower body exercises including the leg press for 8-12 repetitions. The results from the study found that there was a significant difference from pre to post between the 1- (Pre: 33.0 kg, Post: 37.0 kg) and 3- (Pre: 31.0, Post: 36.0 kg) minute rest periods (no *p* value given). Simao et al. (2006) concluded that over the four-weeks of training, the 3-minute rest period allowed for the greatest strength increases for all exercises when compared to the 1-minute rest period.

The findings in this current study, although not significant, contradict the literature that a rest period of 2 – 5 minutes between sets of exercise is best for maximizing volume and strength (Ratamess et al., 2009; Richmond & Godard, 2004).

When the secondary analysis was conducted to compare males and females, there were still no significant differences or trends between rest periods. Univariate effect sizes indicate that the women showed no change within the rest periods whereas the men slightly increased as the rest periods increased. In a study by Rahimi (2005) the 1-, 2-, and 5-minute rest period was studied within men for squat volume. Each participant used 85% of their 1RM for each session during the squat exercises. Rahimi (2005) found that the volume completed for the squat was significantly different between the 1- minute (4.55 ± 2.25 repetitions) and 5-minute (6.17 ± 1.39 repetitions) rest periods and between the 2-minute (5.10 ± 1.84 repetitions) and 5-minute rest periods ($p < .001$, $p < .002$). Despite significance, the magnitude of the difference between the 1-minute and 5 minute rest period was not large. However, the results also showed that the volume completed was not significantly different between the 1- and 2-minute rest periods ($p = .19$).

In a study using the same variables of 1-, 3-, and 5-minute rest periods between sets of the leg press exercise during 16-weeks of resistance training, Salles et al. (2010) indicated that there were no significant differences in strength between rest periods at baseline or 8 weeks ($p > .05$). As for 16 weeks, the 5-minute rest period showed a significant increase in leg press strength (45kg) compared to the 1-minute rest period ($p < .05$). However there were indications that significant increases in strength were made in all rest periods at 8 weeks and 16 weeks compared to baseline ($p < .05$), but only the 3-mintue and 5-minute rest period demonstrated significant increases at 16 weeks compared to 8 weeks ($p < .01$). Salles et al. (2010) reported that longer rest periods such as the 3- 5-minutes results in increases in lower body strength and that rest periods of 1-minute could be effective in increasing strength among lesser-trained individuals, however that was not the case in this current study.

As for the women, no literature is available to support why the women reported no change within the rest periods. However, Rahimi et al. (2009) examined the effects of 60-, 90-, and 120- second rest period over the volume completed in the bench press exercise. They reported no significant differences between the 120- and 90- second rest period ($p = .18$), but as the rest period increased so did the number of completed repetitions. Future research is needed to examine the effects of rest periods among women of all ages.

Limitations

There were several limitations within this study such as having a small sample size of 23 participants when the initial goal was 25 participants. However, 28 participants were recruited, three were excluded due to scheduling conflicts and two dropped from the study due to soreness in the legs. Having a small sample size decreases the probability of finding significance.

Another limitation would be only recruiting Wellness Center members and not having more diverse participants, but due to the equipment that was used in the study being located in the Wellness Center, each participant had to be a member to enter the facility. This could have affected the results because by recruiting only Wellness Center members there was not much diversity, which also led to a smaller sample size.

The failure of some of the participants to reach their true 1RM during the first two sessions is another major limitation. This could be the result of underestimating their own strength, afraid of being sore or injuring themselves, and not wanting to lift heavier than their spouse as was the case with a few of the participants. This had a large impact on the results because the participants who did not reach their true 1RM were not lifting a true 80% 1RM for each repetition meaning they had more of an advantage for performing increased volume compared to the ones who were lifting 80% of their 1RM.

Future Research

Although the results in this study were not significant, they contradict the literature that the amount of rest needed between resistance training exercises for improving volume seem to be similar when in fact rest period recommendations for older adults may be different than for younger adults and that the recommendations may need to be different for older men and women. While any rest period may be beneficial, resting 2-5- minutes seemed to promote the greatest volume. However, since there is no significant difference between 2-5-mintue rest periods future research should examine the effects of shorter rest periods such as 30 -, 60 -, and 90 – seconds on volume in young and older populations.

Future studies should recruit a larger and more diverse sample of older adults and ensure the participants reach their true 1RM. To have participants reach their true 1RM, the researcher should not underestimate individual strength, further explain that a 1RM is the maximal amount of weight that can only be lifted one time with correct form, and possibly, add a third test of 1RM. By adding another week for 1RM testing the researcher can further examine the participants to determine if they truly are lifting their maximal weight.

Practical Application

The key findings from this study were no significant differences between the 1-, 3-, and 5-minute rest period for increasing volume in the leg press exercise. Non-significance may indicate that rest period recommendations for older adults need to be different than for younger adults. For younger adults, both ACSM and NCSA recommend rest periods of 2-5 minutes (Ratamess et al., 2009; Richmond & Godard, 2004). The results of the current study show that the 1-minute rest period was not different from the 5-minute rest period when measuring exercise volume in older adults. A shorter rest period may augment the ability to sustain volume without sizeable reductions in volume and intensity. If volume and strength increases are similar when resting 1 minute as they are when resting 3 – 5 minutes, more training can be accomplished in a shorter amount of time.

Conclusions

Research involving rest periods in resistance training for older adults is limited, being listed as a Category D by ACSM, which indicates little empirical evidence (Chodzko-Zajko et al., 2009; Ratamess et al., 2009). Although no significance was found between rest periods, this study shows trends towards resting 3 minutes between sets promotes the greatest volume completion. Further research with a larger sample size is necessary to evaluate the effects of these rest periods among older adults more fully.

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Table 1

Descriptive Statistics of Total Group, Males, and Females

Total Group				
Variable	M	SD	Min	Max
Age	71.14	6.66	60	85
Height	64.64	3.19	58	72
Weight	165.33	32.87	113	246
Max 1	144.66	94.63	40	385
Max 2	217.73*	126.75	75	520
Males				
Variable	M	SD	Min	Max
Age	71.50	6.41	60	82
Height	67.75	2.37	64	72
Weight	197.79	28.13	165	246
Max 1	221.25	95.00	120	385
Max 2	315.31*	126.36	190	520
Females				
Variable	M	SD	Min	Max
Age	70.93	7.03	61	85
Height	62.86	2.02	58	66
Weight	146.79	17.33	113	175
Max 1	100.89	62.72	40	280
Max 2	161.96*	90.26	75	445

Note. Max 1 = First One-Repetition Maximum Test; Max 2 = Second One-Repetition Maximum Test
*Indicates significant difference from Max 1(p<. 05).

Table 2

Descriptive Statistics of Completed Repetitions

Total Group				
Variable	M	SD	Min	Max
RP-1	21.41	10.02	5	45
RP-3	22.55	9.29	8	42
RP-5	22.18	8.45	10	39
Males				
Variable	M	SD	Min	Max
RP-1	18.38	8.31	9	31
RP-3	21.75	9.78	11	39
RP-5	22.38	9.75	12	35
Females				
Variable	M	SD	Min	Max
RP-1	23.14	10.77	5	45
RP-3	23.00	9.34	8	42
RP-5	22.07	8.01	10	39

Note. RP-1 = 1-Minute Rest Period; RP-3 = 3-Minute Rest Period; RP-5 = 5-Minute Rest Period

Table 3

Effect Sizes for Differences Between Rest Periods

	Total		Males		Females	
Rest Periods	% Change	*d*	% Change	*d*	% Change	*d*
1- and 3- minute	5.32	-0.11	18.33	-0.40	-0.60	0.01
3- and 5-minute	-1.64	0.03	0.02	-0.06	-0.04	0.10
1- and 5-minute	3.59	-0.07	21.76	-0.48	-4.62	0.09

Note. d = Univariate effect size.

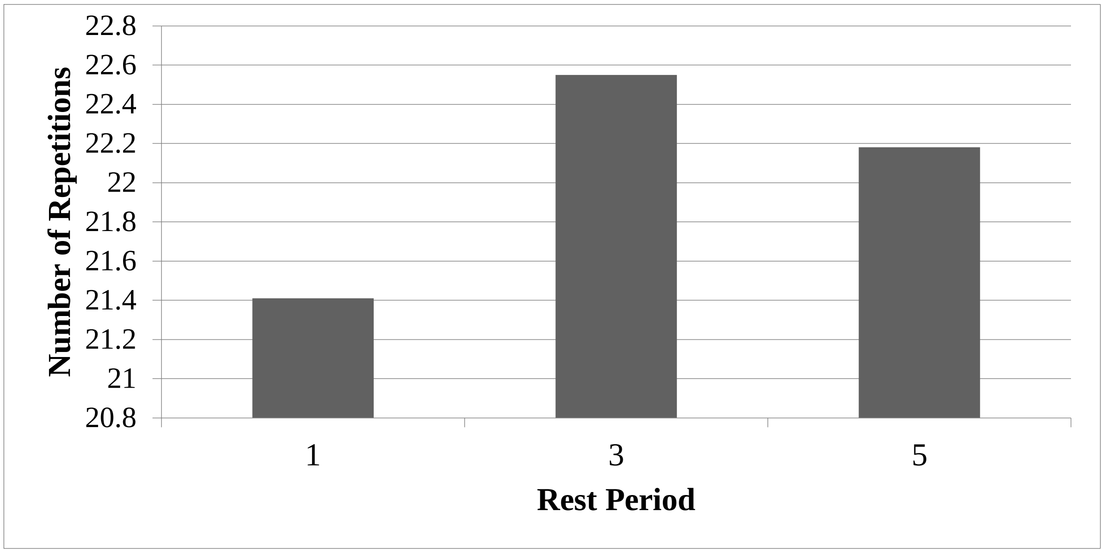

Figure 1. A bar graph of the differences in exercise volume between 1-, 3-, and 5-minute rest periods. The 1-minute rest period resulted in 21.55 ± 10.02 repetitions during the failure set. The 3-minute rest period resulted in 22.55 ± 9.29 repetitions and the 5-mintue rest period resulted in 22.18 ± 8.45 repetitions during the failure set.

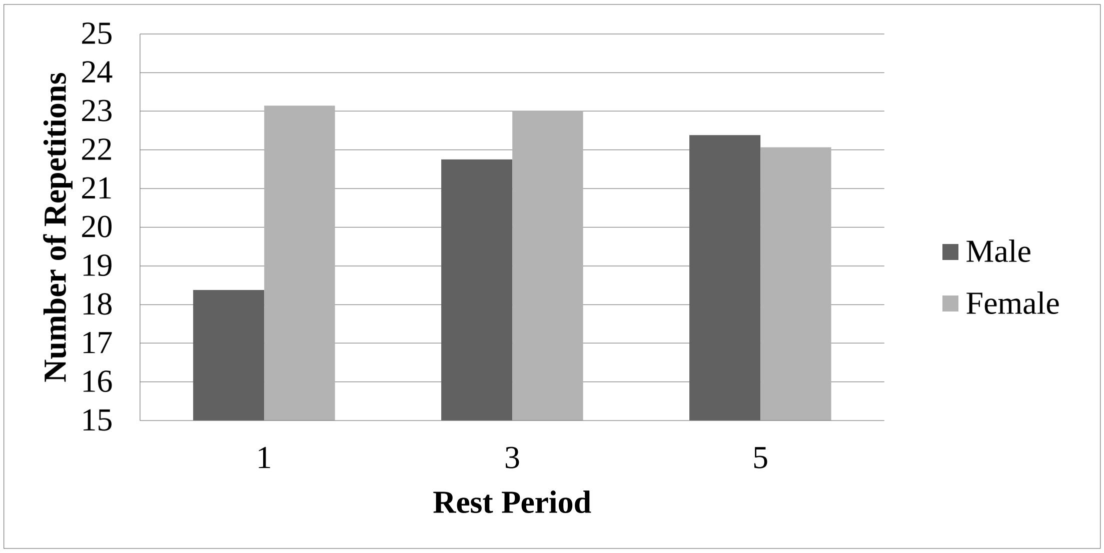

Figure 2. A bar graph of the differences in exercise volume between male and female participants following 1-, 3-, and 5-minute rest periods. Men reported 18.38 ± 8.31 repetitions in the 1-minute rest period, 21.75 ± 9.78 repetitions in the 3-minute rest period, and 22.38 ± 9.75 repetitions in the 5 – minute rest periods. The women reported 23.14 ± 10.77 repetitions in the 1 -minute rest period, 23.00 ± 9.34 repetitions in the 3 – minute rest period, and 22.07 ± 8.01 repetitions in the 5 – minute rest period.

Appendix A

IRB Application Approval

UNIVERSITY OF Central Oklahoma

October 3, 2013

IRB Application #: 13155

Proposal Title: Effects of Rest Periods on Exercise Volume Among Older Adults

Type of Review: Initial-Expedited

Investigators:

Mr. Brandon Hamill
Dr. Melissa Powers
Department of Kinesiology and Health Studies
College of Education and Professional Studies
Campus Box 189
University of Central Oklahoma
Edmond, OK 73034

Dear Mr. Hamill and Dr. Powers:

Re: Application for IRB Review of Research Involving Human Subjects

We have received your materials for your application. The UCO IRB has determined that the above named application is APPROVED BY EXPEDITED REVIEW. The Board has provided expedited review under 45 CFR 46.110, for research involving no more that minimal risk and research category 7.

Date of Approval: 10/3/2013
Date of Approval Expiration: 10/2/2014

If applicable, informed consent (and HIPAA authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. A stamped, approved copy of the informed consent form will be sent to you via campus mail. The IRB-approved consent form and process must be used. While this project is approved for the period noted above, any modification to the procedures and/or consent form must be approved prior to incorporation into the study. A written request is needed to initiate the amendment process. You will be contacted in writing prior to the approval expiration to determine if a continuing review is needed, which must be obtained before the anniversary date. Notification of the completion of the project must be sent to the IRB office in writing and all records must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of the investigators to promptly report to the IRB any serious or unexpected adverse events or unanticipated problems that may be a risk to the subjects.

On behalf of the UCO IRB, I wish you the best of luck with your research project. If our office can be of any further assistance, please do not hesitate to contact us.

Sincerely,

Rashi Shukla, Ph.D.
Assistant Chair, Institutional Review Board
Campus Box 159
University of Central Oklahoma
Edmond, OK 73034
405-974-5497
irb@uco.edu

Office of Research Compliance, Academic Affairs
100 North University Drive · Edmond, Oklahoma 73034 · Phone (405) 974-5497 · Fax (405) 974-3825 · www.uco.edu

Appendix B

Informed Consent Form

UNIVERSITY OF CENTRAL OKLAHOMA

INFORMED CONSENT FORM

Research Project Title: Effects of Rest Periods on Exercise Volume Among Older Adults

Researcher (s): Brandon Blake Hamill

A. Purpose of this research: The purpose of this study is to determine if 1-, 3-, or 5-minute rest periods between sets of the leg press exercise will increase volume (# of repetitions) among older adults 60-90 years of age.

B. Procedures/treatments involved:

Procedures

Pre-screening. After signing this form, you will be asked to answer questions about your health status to determine if you qualify for participation. We will also ask you to complete a Participant Information Form with your personal and emergency contact information.

Testing

You will be asked to perform the following:

- Week 1 will consists of measuring height and weight, familiarization of the equipment, and testing the maximal amount of weight that can be lifted one time on the leg press machine (1repetition max).
- Week 2 will consist of re-testing the 1RM to ensure accuracy.
- Week 3-5 (in random order)

o 1-minute rest period. Following a light warm-up on the leg press machine, you will complete two sets of eight repetitions at 80% of your 1RM. The rest period between each set will be 60 seconds. The third set will be conducted to failure. Failure is indicated by the inability to complete a repetition using the correct form. The number of repetitions completed in the failure set will be recorded.

o 3-minute rest period. This session will follow the same procedures, as the previous session except you will rest for 180 seconds between sets.

o 5-minute rest period. This session will follow the same procedures, as the last two sessions except you will rest for 300 seconds between sets.

C. Expected length of participation: Five Weeks

D. Potential benefits: Increases in lower body muscular strength.

Weight lifting exercises have been shown to be safe for all adults. Risks associated with testing and exercise training include muscle soreness, muscle tiredness, and rarely muscle or joint injury. These injuries usually occur when

E. Potential risks or discomforts; exercises are not performed correctly. You will be supervised by the researcher who is highly qualified to recognize signs and symptoms that increase your risk of injury. If these signs are reported or observed, you may be asked to rest or reduce your training intensity. The research may remove any participant from the study at any time, if needed, due to injury or any other reason. If you are injured, you will be responsible for all cost associated with the treatment of the injury. By signing this form, you indicate that you understand that UCO is no liable for any injuries that may occur during your participation in this study.

F. Medical/mental health contact information (if required):

G. Contact information for researchers: **Blake Hamill Phone: 580-775-3581; Email: bhamill1@uco.edu**
Dr. Powers Phone: 405-974-5309; Email: mpowers3@uco.edu

H. Contact information for UCO IRB: Dr. Richard Sneed Phone: 405-974-5497; Email: irb@uco.edu

I. Explanation of confidentiality and privacy:

J. Assurance of voluntary participation:

AFFIRMATION BY RESEARCH SUBJECT

I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep.

Research Subject's Name: ______________________

Signature: ______________________

Date: ____________

APPROVED
OCT -3 2013
UCO IRB

APPROVAL
[illegible] -2 [illegible]
EXPIRES

Appendix C

EASY Screening Tool

www.easyforyou.info

Answering the Six Easy Questions:

EASY QUESTIONS (Circle Response):

1) Do you have pains, tightness or pressure in your chest during physical activity (walking, climbing stairs, household chores, similar activities)?	**Yes No**
2) Do you currently experience dizziness or lightheadedness?	**Yes No**
3) Have you ever been told you have high blood pressure?	**Yes No**
4) Do you have pain, stiffness or swelling that limits or prevents you from doing what you want or need to do?	**Yes No**
5) Do you fall, feel unsteady, or use assistive device device while standing or walking?	**Yes No**
6) Is there a health reason not mentioned why you would be concerned about starting an exercise program?	**Yes No**

Appendix D

Data Collection Sheet

Participant #			
	80% of 1RM =		
AGE:			
Length of Time (RT)			
Ht.	Wt.		
1RM (1):	Date:	1RM (2):	Date:
1-Minute RP	Date:		
Set 1:	Set 2:	Set 3:	
3-Minute RP	Date:		
Set 1:	Set 2:	Set 3:	
5-Minute RP	Date:		
Set 1:	Set 2:	Set 3:	
Additional Notes:			
Date:			
Date:			
Date:			
Date:			
Date:			