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The Effect of Resistance Training on Strength and Total Physical Activity in Postpartum Females

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A thesis submitted to the faculty of
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Master of Science

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ABSTRACT

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The purpose of this study was to compare strength and physical activity (PA) changes in postpartum women randomly assigned to either a four-month progressive resistance training (RT) program or a four month flexibility program. Sixty healthy women between six weeks and eight months postpartum initiated the study and 43 completed the entire study. The women tended to be overweight, were all non-smokers, and most were breastfeeding (97%) at the beginning of the study. Both groups (RT and flexibility) completed training exercises twice weekly. Both groups improved in all measures of strength (RT group: leg press, $P < 0.001$; bench press, $P < 0.001$; curl-ups, $P < 0.001$. Flexibility group: leg press, $P = 0.009$; bench press, $P < 0.001$; curl-ups, $P = 0.005$); however, the RT group had higher strength gains compared to the flexibility group over time (leg press, $P < 0.005$; bench press, $P < 0.001$; curl-ups, $P < 0.007$). In addition, both groups increased in low back flexibility but the group*period interaction did not reach significance ($P = 0.096$). Light-intensity PA increased in the RT group but not the flexibility group ($P < 0.05$). A group*period interaction was significant for light-intensity PA time ($P = 0.031$) and borderline significant for sedentary time ($P = 0.054$). However, controlling for the number of months postpartum and weight gain during the previous pregnancy resulted in a significant interaction for sedentary time ($P < 0.05$). No changes were found in moderate, vigorous, or moderate to vigorous PA within or between groups over time. In conclusion, twice-weekly RT increases strength and is associated with improvements in several PA outcomes in postpartum women; however, the mechanisms for this are unclear. The training sessions and/or increased spontaneous activity may have contributed.

Keywords: postpartum, resistance training, physical activity

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Introduction

Obesity continues to be a significant concern in the United States and worldwide due to its high prevalence, contribution to health care costs, and its role in the progression of many chronic diseases. A recent study conducted by the National Health and Nutrition Examination Survey (NHANES) found that in the United States, nearly 36% of adult women and 32% of adult men were classified as obese (1). In addition, Rashad and Grossman reported that in the year 2000, more people died from obesity and sedentary lifestyles than those who died from alcohol or drug abuse (2). Further, in 2008, estimates showed that the medical costs of obesity were nearly 10% of total health care costs in the United States (3). While the rate of obesity in the United States appears to be stabilizing for women and possibly for men in more recent years (1), the large number of those affected by obesity and related diseases, has made the prevention and treatment of obesity a top national priority.

Though obesity is a concern for both men and women, women have higher rates of obesity than men (1) making them an important population of focus. The reasons for increased obesity rates in women may be partially attributed, but not limited to, excessive energy intake, cessation of smoking (4), and lifestyle changes that often occur during pregnancy and postpartum (5). Specific to the postpartum period, weight retention beyond six months increases the likelihood of long term weight retention and obesity (6-8). Weight retained postpartum has also been shown to be a good indicator of increased weight gain in the second pregnancy (9). Accordingly, one study showed that obesity rates among elderly women increased as their number of childbirths increased (8).

Moreover, the postpartum period has been associated with decreased levels of physical activity (PA) (5, 10-14). One study has shown that the percentage of women who can be categorized as insufficiently active increases significantly from pre-pregnancy to postpartum and that total leisure-time PA levels decline from pre-pregnancy to six months postpartum by approximately 1.4 hours per week (12). Another study has shown that approximately 50% of the women in their sample reported being less physically active than normal at six weeks postpartum (11).

There is evidence that decreased levels of PA during the postpartum period is related to greater long-term weight gain (13). Furthermore, increasing PA has been suggested as a means of decreasing the risk of postpartum weight retention and later obesity in childbearing women. For example, Rooney found that women who reported participating in aerobic activity postpartum experienced less weight gain five to eight years later than those who did not report participation in aerobic activity (15). Unfortunately, less is known regarding the role of postpartum PA obtained through resistance training (RT) for weight retention and risk of obesity. Only one previous study has been published examining the role of RT in postpartum women; however, this study focused on hip bone density, not PA, as the primary outcome, though body weight and composition outcomes were reported (16).

Studies have shown that RT increases spontaneous PA levels in older adults and in cardiac rehabilitation patients (17-18). As physical strength increases, activities of daily life may be performed with less effort, potentially resulting in increased PA levels (17). Due to this mechanism, RT may also increase PA in postpartum women and, if true, may be effective in decreasing postpartum weight retention and risk of future obesity. Unfortunately, there are no known studies that have investigated the relationship between RT and subsequent PA. This study sought to fill this gap in the literature. Therefore, the purpose of this study was to compare strength and PA changes in postpartum women randomly assigned to either a four-month progressive RT program or a four-month flexibility training program. Physical activity outcomes assessed included: sedentary time, low-intensity PA time, moderate-intensity PA time, vigorous-intensity PA time, and moderate-to-vigorous PA (MVPA) time.

Methods

Design & Intervention

Sixty postpartum women were recruited to participate in this randomized trial that compared resistance and flexibility training in postpartum women over a four month period. The RT group engaged in a RT exercise protocol that included: 9 different exercises that worked all major muscle groups, 1-3 sets per training session, and 8-10 repetition maximums (RM) per set performed on two nonconsecutive days per week. During the first month, all training sessions were supervised and thereafter, participants received one supervised training session per week. The flexibility training group acted as the control group and subjects engaged in a flexibility program that consisted of two training sessions each week, four different stretches (sets) per muscle group, holding each stretch for 10-30 seconds. Flexibility sessions were not supervised, but flexibility group subjects had the option of participating in a group stretching session once per week. To avoid confounding the study, the flexibility training group was advised not to perform RT exercises over the course of the study.

Subjects

Sixty postpartum women were recruited for this study from the university community and surrounding areas. Institutional Review Board approval at BYU was obtained prior to beginning the study and all subjects signed an informed consent before participating. Subjects included in the study were healthy according to the Physical Activity Readiness Questionnaire (PAR-Q) (19) and each subject provided a signed physician's release form stating that she was healthy and could safely participate in the study. In addition, all subjects were between six weeks and eight months postpartum and at least five pounds over their pre-pregnancy weight at baseline. Subjects were not planning to become pregnant within the next year, nonsmokers, and had a social support network that allowed them to break away from their mothering responsibilities to perform the prescribed twice weekly training sessions. Subjects were also not planning to leave the area for the year following the initiation of the study and were willing to be randomized into either group. Subjects were excluded from the study if they were unable to perform RT or moderate-intensity exercise, had engaged in RT or flexibility training twice or more per week within the last six months, or were participating or planning to participate in a commercial diet or weight- loss program. All subjects in the RT group were given a four month membership to a local physical therapy clinic to ensure access to RT equipment, but were instructed not to use the aerobic exercise equipment to prevent unequal access between the groups.

Procedures

Baseline, Two, and Four Month Testing

At baseline, two, and four months, all subjects were tested for strength, flexibility, and PA level. Each testing period included two visits separated by at least seven days to allow for PA to be assessed for a full week. During the first visit at baseline, all subjects completed an informed consent, PAR-Q, and health history and demographic questionnaire. After a five-minute warm-up of walking on a treadmill at moderate intensity and brief preliminary stretching, subjects performed a standard sit-and-reach test (20) to assess flexibility. In order to prepare for strength assessments on the second visit, all subjects were subsequently instructed on the proper lifting techniques for the leg press, bench press, and for the partial abdominal curl-up test. Each participant was allowed to practice these exercises to minimize any possible learning effects that could weaken the results of the official strength tests that occurred on the second visit. Also on the first visit, each subject was given an Actigraph GT1M accelerometer (Actigraph LLC, Walkton Beach, FL). Subjects were instructed to wear the accelerometer on their right hip continuously, except when in the water, for seven consecutive days.

On the second visit, accelerometers were collected and the information downloaded. Subjects were asked to change into a standardized, one-piece, polyester and lycra swimming suit and asked to use the bathroom before height and weight data were collected. After each subject was assessed for height using a wall-mounted stadiometer and weight using a digital scale, subjects changed back into athletic clothes and performed a five minute warm up and light stretching. Subsequently, a supervised 3-5 RM for the bench press and leg press were performed. Information from the RM tests was used to estimate each subject’s 1RM. Finally, subjects completed the ACSM partial curl-up test (21) with one modification (exclusion of a time limit), to assess abdominal strength and endurance. The elimination of a time limit was necessary to accurately assess changes in abdominal muscular strength and endurance. This is due to the fact that the standard partial curl-up test allows for a maximum of 25 curl-up’s given the one minute time limit. There would be no way to determine changes in strength if the subject could perform more than 20 curl-ups at baseline or subsequent testing periods without the modification. The subjects performed as many curl-ups as possible until they either stopped, or could not stay in rhythm with a cadence set at 40 beats per minute. The same measurements and protocol were used for follow-up testing at two and four months. After baseline testing the subjects were randomized into either the flexibility or the RT group using a random numbers generator from the PC-SAS statistical software package (version 9.1, SAS Institute, Inc., Cary, NC).

Resistance Training Protocol

After baseline testing, subjects randomized to the RT group were prescribed a RT program adapted from the recommendations of the American Heart Association and the American College of Sports Medicine (22). During the first month, each RT session was supervised to ensure proper lifting techniques. RT sessions consisted of one set of at least 8-10 repetitions for nine different exercises that worked all major muscle groups. Intensity for each exercise was approximately 60-70% of the subjects estimated 1RM, or the highest weight that could be lifted for 8-10 repetitions. The subjects were instructed to rest at least 90 seconds between sets.

The RT program was progressive. When subjects could perform two or more repetitions over the prescribed amount (≥12) for any given exercise, the weight was increased by one machine increment or~ 2-10% (23). The RT exercises included leg extensions, seated leg curl, leg press, biceps curl, shoulder press, chest press, lat pull-down, seated row, and abdominal curl-ups (24). All RT exercises were performed via machines except the shoulder press which was performed using free weight dumbbells.

During the second month, the subject completed the same nine exercises, the same number of repetitions (8-10 per set), and the same number of training sessions (two per week). However, unlike the first month, two sets of each exercise were performed. The first set of each exercise consisted of 10 repetitions and were performed using the highest weight obtained from the previous resistance training session for that exercise. The same weight was used for the second set but the subject was asked to perform as many repetitions as possible. Furthermore, when subjects were able to complete the second set of each exercise with two or more repetitions over the prescribed amount, the weight for each set was increased at the following training session by ~2-10% or one machine increment. However, if the subject was unable to complete the second set of each exercise with at least eight repetitions, she decreased the weight at the following training session by ~2-10% or one machine increment.

During months three and four, the same protocol was followed as months one and two with the main difference being that three sets per exercise were completed during each session. For each participant, the first and second sets consisted of 10 repetitions and were performed using the highest weight obtained from the previous resistance training session for that exercise. Similar to the previous months, when the number of repetitions completed met or exceeded the prescribed number of repetitions by two or more on the third set, each set was increased by 2-10% or one machine increment on the following training session.

During months 2-4, at least one session was supervised each week. For the non-supervised RT sessions, subjects received an exercise record and were asked to record the exercise, sets, repetitions, and weights lifted, and reported that information at the following supervised session.

Subjects were instructed not to engage in any additional RT outside of the prescribed protocol and location. Participants were also instructed to stop any exercise immediately if they experienced any acute, persistent, or out of the ordinary joint pain and to reduce the resistance (weight) at the next exercise session to a weight that they could lift with little pain. If the pain persisted after adjustments were made, participants were instructed to discontinue that exercise.

If subjects went out of town and were unable to perform their prescribed RT protocol, they were instructed to perform a modified exercise routine twice per week. The exercises included: lunges; crunches; and push-up's to fatigue for 1-3 sets depending on the month (one set during month one, two sets during month two, and three sets during months 3-4). A completion rate of 75% of the prescribed RT sessions was necessary for subjects to remain in the study.

Flexibility Protocol

After baseline testing, subjects who were randomized to the flexibility group were prescribed a flexibility program adapted from guidelines by the American College of Sports Medicine (four exercises per muscle group, holding each stretch for 10-30 seconds per exercise, twice each week) (25) and provided with a flexibility record to record their stretching sessions. Flexibility training was chosen for the control group as flexibility changes would not likely affect the major outcomes of this study and would likely keep these subjects engaged in the study. Subjects were asked to verify weekly flexibility sessions by e-mail. Subjects were also invited to attend an optional weekly group flexibility session held on the BYU campus where they had the opportunity to receive additional instruction on stretching exercises and ask any questions they had regarding flexibility training. The prescribed stretches included four stretches (sets) for each of the following muscle groups: hamstrings and low back, calves, quadriceps, neck, shoulders and arms, and torso (20).

Measurements

Strength Assessment

Strength was assessed for both the RT and flexibility groups at baseline, two, and four months. Strength tests were performed for the legs and buttocks (leg press) (21), chest and triceps (chest press) (21), and abdomen (modified ACSM partial curl-up test) (26). A 3-5 RM, in place of a 1RM, was used for both the leg press and bench press assessments to reduce the risk of injury. The strength assessment protocol at each data collection period consisted of a five minute aerobic warm up (walking on a treadmill at moderate intensity) to increase muscle temperature and reduce the risk of injury and was followed by a brief, lower-body, sit-and-reach stretch to allow for muscle relaxation and lengthening before performing the strength tests. To ensure accurate measurements, a goniometer was used to position the knee at a 90 degree angle from the foot plate for the leg press, and handles were positioned at chest and nipple level for the chest press. The position of the equipment was recorded via hole number on each machine to ensure consistent positioning for follow-up tests. Each subject subsequently performed 10-20 sub-maximal warm-up repetitions for both the leg press and bench press. A starting weight was selected that was within 50%-70% of the subjects estimated capacity to be lifted three to five times. Weight was then progressively increased by no less than five pounds until the subject could no longer lift the weight more than five times. Each successful set of lifting the weight was followed by a three minute rest period (25). The greatest amount of weight lifted successfully three to five times was used in the Brzycki equation (Weight lifted (lb) ÷ (1.0278 - (reps to fatigue X 0.0278)) to estimate 1RM (21). The Brzycki equation has been shown to be valid and reliable (within an average of two percent) at predicting 1RM when 10 or fewer repetitions were used (27).

To perform the modified partial curl-up test the subject lay supine on the mat with her legs shoulder-width apart, arms straight down by her sides, feet flat on the mat, and knees at a 90 degree angle. A piece of tape marked the zero point at which the subject's middle finger on each hand was to touch before beginning the test. Another piece of tape was placed 10 cm beyond the zero mark and the metronome was set to 40 bpm. The subject was asked to lift her shoulders off the mat and touch the 10 cm tape with her fingers on every beat of the metronome. The subject's palms and feet were required to stay in contact with the mat and her shoulders and head had to touch the floor with every curl-up. The subjects fingers were also required to touch the zero mark between each curl-up. Crunches were not counted when the subject's feet or hands came off the floor, she was not in rhythm with the metronome, or she lost proper form. The number of curl-ups performed successfully were recorded to assess abdominal strength.

Physical Activity Assessment

Physical activity was assessed using an Actigraph GT1M accelerometer worn over the right hip for seven consecutive days set at 60-second epochs at baseline, two and four months. Each 60-second epoch resulted in a total count number that represented the number of times the subject moved or accelerated during that time period. The greater the number of counts per epoch, the greater the intensity of activity that occurred during that 60-second period. Physical activity outcomes of interest for this study included: total PA, sedentary time, light-intensity activity time, moderate-intensity activity time, vigorous-intensity activity time, and moderate-vigorous physical activity (MVPA) time. Epoch cut-points used to determine the above PA outcomes were utilized from Troiano et al. and included the following: sedentary time = 249 counts or less per minute; light-intensity activity time = 250-2019 counts per minute; moderate-intensity time = 2020-5998 counts per minute; vigorous-intensity activity = 5999 or greater counts per minute; and MVPA was a sum of the moderate-intensity and vigorous-intensity time (28). Data treatment and analysis procedures are outlined in the statistics section. Accelerometers have been used in previous research and have been shown to be valid and reliable (29-31). Subjects were instructed to wear the accelerometer day and night (including while sleeping) and not to remove it except when in water (ie. swimming or bathing).

Flexibility Assessment

Flexibility was assessed at baseline, two, and four months using the standard sit-and-reach test (21). A light five-minute aerobic warm-up and light stretching of the upper and lower body were performed prior to flexibility testing. The standard sit-and-reach test was performed three times and the average score was used to represent the subject's performance. This flexibility test was chosen because it is a nationally standardized test and has been found to be valid (interclass correlation = 0.96; CI = 0.94-0.97) (32) and reliable for both inter-trial ($r = 0.98$) and intercession ($r = 0.79$) assessments (33).

Data Treatment and Analysis

The data were analyzed using the statistical software package PC-SAS (SAS Institute, Inc., Cary, NC) with statistical significance set at $P < 0.05$. Standard deviations and means were used to summarize the descriptive and outcome data (demographics, strength, PA, BMI, and body weight). Independent T tests were utilized to determine differences between groups at baseline for descriptive data, strength, PA, and body weight. Mixed effects models were utilized to determine differences in strength, flexibility, body weight, and PA outcomes across time within groups, and to test for the presence of a group*time interaction. Mixed models were used to analyze these data as it is a robust method of accounting for individual variation. Nevertheless, the baseline score was statistically controlled for each outcome to further account for baseline differences in each variable of interest. Additionally, several control variables were added to the model to examine their effect on the relationship between RT and PA, including: number of months postpartum, the amount of weight retained postpartum, weight gain during the last pregnancy, and number of children.

As this study was an efficacy study of the effect of RT on PA outcomes, completers-only analysis is primarily reported in the results below. Treatment of the accelerometer data utilized previous studies in the literature as models and included the following criteria. First, non-wear time was set as 20 minutes or more of continuous strings of zero counts (34). Second, a valid week was considered to be at least four days of at least 80% of the time between 7am and 11pm as wear time (34). In other words, there were 960 minutes or 16 hours of potential wear time each day. At least 768 minutes of wear time per day was required for at least four days to be a valid week. As a result of not meeting these criteria, 10 weeks of PA data were removed from the analysis (five at baseline, four at two months, and one at four months).

Results

Subjects were Caucasian (90%) and Hispanic (10%). Subjects tended to be overweight, were non-smokers, and most were breastfeeding at the initiation of the study (97%). Characteristics for all subjects at baseline are outlined in Table 1. Except for height, there were no significant differences in baseline characteristics between the flexibility and RT groups. Of the 60 participants that initiated the study, 72% completed all aspects of the study. Reasons for withdrawal from the study are outlined in Table 2. Characteristics for the 43 subjects that completed the study are outlined in Table 3. There was no difference at baseline between the participants who completed the study and those who did not for sedentary time, light-intensity time, moderate-intensity time, vigorous-activity time, or MVPA ($P > 0.05$). However, body weight, bench press, and weight retained postpartum, were significantly different between the completers and non-completers.

Completion of flexibility sessions by the flexibility group averaged ~84%. Flexibility scores improved for the sit-and-reach in both groups (flexibility $F = 14.52$, $P < 0.001$; RT $F = 9.70$, $P < 0.001$). However, there was not a significant group*period interaction ($F = 2.90$, $P = 0.096$) (Table 4).

Completion of training sessions for the RT group averaged ~94%. Strength improved in both groups for the leg press (flexibility $F = 5.30$, $P = 0.009$; RT $F = 31.89$, $P < 0.001$); bench press (flexibility $F = 8.79$; $P < 0.001$; RT $F = 58.15$, $P < 0.001$); and curl-ups (flexibility $F = 6.12$, $P = 0.005$; RT $F = 16.07$, $P < 0.001$). There was a significant group*period interaction for each strength test indicating that the RT group improved strength to a greater extent over time than the flexibility group ($P < 0.05$) (Table 5).

For BMI, there were significant changes within both groups from baseline to four months (flexibility $F = 7.73$, $P = 0.001$; RT $F = 22.89$, $P < 0.001$) as outlined in Table 6. After controlling for BMI at baseline, BMI was not different between the flexibility and RT groups over time ($F = 2.41$, $P = 0.128$). Both groups showed significant weight loss over the course of the study (flexibility F = 7.85, P = 0.001; RT F = 23.7, P < 0.001); however, there was not a significant difference in body weight between the two groups from baseline to four months (F = 2.78, P = 0.103), though there tended to be more weight loss in the RT group.

Neither group significantly changed their total PA counts over time, though there was an increasing trend for the RT group (F = 3.29, P = 0.079) and a decreasing trend for the Flexibility group (F = 2.17, P = 0.128). With control of baseline activity, there was not a significant group*period interaction for total activity (F = 2.35, P = 0.134) as shown in Table 7. In addition, after controlling for number of months postpartum, the amount of weight retained postpartum, weight gain during the last pregnancy, and number of children individually or combined, the lack of a significant group*period interaction remained (P > 0.05).

Sedentary time did not change in the flexibility group over time (F = 2.16, P = 0.129) and was on the borderline for a significant decrease in sedentary time in the RT group (RT F = 3.26, P = 0.051). With control of baseline sedentary time, there was not a significant group*period interaction (F = 3.98, P = 0.054). However, after also controlling for the number of months postpartum or the amount of weight gained during the previous pregnancy the group*period interaction became statistically significant (P < 0.05). Further, controlling for the number of months postpartum, the amount of weight retained postpartum, weight gain during the last pregnancy, and number of children combined a group*period interaction was observed for sedentary time (P < 0.05).

Light-intensity activity time did not change significantly in the flexibility group over the course of the study (F = 1.76, P = 0.186), but did increase in the RT group (F = 3.85, P = 0.031). When comparing the two groups over time (group*period interaction), the RT group showed significantly higher light-intensity activity time than the flexibility group (F = 5.09. P = 0.030). Further, after controlling for number of months postpartum, the amount of weight retained postpartum, weight gain during the last pregnancy, and number of children individually or combined, the group*period interaction remained. Specifically, controlling for the number of months postpartum most strengthened the relationship (P = 0.013).

There was no significant difference in moderate-intensity or vigorous-intensity PA time within either group or a significant group*period interaction for either outcome (P > 0.05). Likewise, MVPA did not change significantly within the groups (P > 0.05) or between the groups over time (F = 0.56, P = 0.458). The group*interaction for moderate- intensity, vigorous-intensity, or MVPA was not affected by controlling for number of months postpartum, the amount of weight retained postpartum, weight gain during the last pregnancy, and number of children individually or combined (P > 0.05).

Discussion

Childbearing has been identified as a possible contributor to excess weight gain and obesity in childbearing women (7, 9, 35). The purpose of this study was to determine the extent that RT influences strength and PA in postpartum women.

Strength increased in both the flexibility and RT groups; however, the RT group had significantly greater increases in all measurements of strength at four months. This is consistent with current evidence that RT increases strength in both men and women (36-37). In the only other study of the effect of RT in postpartum women, Lovelady et al. found that RT increased strength similar to the present study (16). In addition, the present study showed that sedentary time significantly decreased and light-intensity activity time significantly increased.

Interestingly, Pereira et al. showed that decreases in PA postpartum were partly a result of decreased light/moderate PA (12). It is noteworthy that in the present study there was a trend toward more total and vigorous-intensity PA.

The lack of statistical significance found in some of the PA outcomes measured (total and vigorous-intensity PA) could be due to a lack of power. This study was originally powered based on a variable that is not reported in this thesis as there was no other PA data to base power on. With greater power some of the variables in this study may have reached significance.

Increasing light and/or moderate-intensity activity may increase total PA and help improve weight loss postpartum. When the flexibility and RT groups were compared, there was a trend toward greater total activity in the RT group, but the results did not reach statistical significance ($P = 0.134$). Interestingly, a similar trend was shown for weight change. The RT group lost approximately 1 more kg of weight than the flexibility group, but the results did not quite reach statistical significance ($P = 0.103$). When intent to treat analysis was completed for all participants who completed at least two months of the study, there was an even stronger trend for weight change ($P = 0.060$). The RT group increased their light-intensity activity time by an average of 15 minutes per day and decreased their sedentary time by an average of 16 minutes per day. When the MET equivalent for intensity as outlined by Rothney (38) was used, it was found that the average increase in energy expenditure within the RT group (as a result of the increase in light activity time and decrease in sedentary time) could contribute to as much as 24.3 kcal/day or an average of 1.0 kg of weight loss a year. This is significant because it has been reported that the average amounts of weight retained postpartum are between -0.27-3.0 kg for each pregnancy (39). Had the women continued RT for a year, is possible that the changes in sedentary and light-intensity PA would have resulted in greater total PA and weight loss than the flexibility group; however, this is speculative.

There are several possible mechanisms that explain why sedentary time decreased and light-intensity PA increased in the RT group. It is possible that improvements in some aspects of PA in the RT group were primarily a result of the extra activity required by the intervention itself; however, even if this were the case, simply engaging in a RT program would improve some PA outcomes in postpartum women and would therefore, be a beneficial intervention.

Schmitz et al. recently reported the results of a study investigating the effect of twice weekly RT in middle-aged but non-pregnant or postpartum women over two years (40). These investigators reported that body composition decrements, specifically abdominal obesity, were attenuated by participation in RT compared to controls (40). They suggested, but did not measure, that RT may increase women's confidence to become more physically active (40). It is possible that this is a mechanism in the present study. In other words, RT may have acted as a motivator to become more generally active postpartum and may have contributed to the positive change in light-intensity and potentially sedentary time in the RT group of the present study. It is also possible, as previously mentioned, that the increase in strength allowed the women of the present study to have greater ease of movement resulting in more spontaneous light activity.

Furthermore, the finding that sedentary time tended to decrease significantly more in the RT group compared to the flexibility group is interesting and deserves additional attention. It is well-documented that a sedentary lifestyle is associated with increased risk for all-cause mortality as well as cardiovascular disease and some cancers (41-43). It is noteworthy that the number of months postpartum partially influenced the group*period interaction causing it to become statistically significant. This may indicate that decreasing sedentary time, particularly in the earlier postpartum months, may be especially important. Given that the postpartum period increases the likelihood of being sedentary, interventions that reduce sedentary activities through increasing either planned or spontaneous activity have important implications health beyond weight management.

Although there were significant strengths to this study, there were also limitations. First, the intervention was limited to four months. A longer duration may have allowed for observed trends to reach statistical significance. Second, RT sessions were only twice per week. This frequency was incorporated to match current recommendations from the AHA and ACSM and because it is likely a feasible frequency for busy mothers. It is certainly likely that greater increases in strength may have resulted from three sessions per week and that this would have resulted in greater improvements in the PA outcomes measured. Third, only women who had a social support network that would allow them to perform RT or flexibility training were allowed to participate in the study. It is important to recognize the potential difficulty that may exist for postpartum women to consistently obtain twice weekly RT who have less support or that have significant time barriers, such as single mothers or mothers with special needs children.

In conclusion, the results of the present study suggest that RT in postpartum women increases strength and may also increase light-intensity PA and may decrease sedentary time compared to flexibility training, though more research is needed. Future research with larger sample sizes, longer interventions, and possibly more RT sessions to determine a dose-response are important to confirm the extent that RT influences PA outcomes. Because weight retained postpartum appears to contribute to the risk of overweight and obesity in women (7, 9, 35), developing an effective intervention for this population will help to reduce the amount of weight retained postpartum, which will reduce disease risks associated with obesity and improve quality of life for many childbearing women. From the results of the present study, RT may result in improvements in some PA outcomes and should be strongly recommended as part of a balanced weight management program in postpartum women.

Table 1. Participant Characteristics at Baseline

Variable	RT Group n = 30	Flexibility Group n = 30	F	P
Age	26.9 ± 5.1	25.9 ± 4.4	0.82	0.427
Height (cm)	167.7 ± 5.0	163.1 ± 7.3	2.83	0.006
Weight (kg)	73.3 ± 11.4	72.0 ± 13.0	0.40	0.687
BMI (kg/m^2)	26.1 ± 3.7	27.0 ± 4.1	0.97	0.335
Pregnancy Weight Gain (kg)	35.6 ± 11.7	16.6 ± 4.6	0.04	0.967
Months postpartum	3.6 ± 1.6	3.9 ± 1.8	0.36	0.721
Weight Retained Postpartum (kg)	6.5 ± 3.7	6.5 ± 4.1	0.04	0.687

[a] Values represented are mean ± SD.

[b] F and P values represent differences between the RT and Flexibility groups at baseline.

[c] RT = Resistance Training

[d] BMI = Body Mass Index

Table 2. Attrition

Reasons for Attrition	Baseline	2 Months	4 Months	Total
Injury		3		3
Loss of Interest	1			1
Pregnancy		2	1	3
Quit after Baseline Testing	2			2
Lack of Time	1	1		2
Moved	1		1	2
Unknown	1	1	2	4
Total				17

[a] Data represents the number of participants that dropped out during each period.

Table 3. Baseline Characteristics for Completers Only

Variable	RT Group n = 20	Flexibility Group n = 23	F	P
Age	26.4 ± 4.0	26.0 ± 4.0	0.36	0.722
Height (cm)	167.6 ± 5.1	162.8 ± 7.6	2.40	0.021
Weight (kg)	69.1 ± 8.2	72.1 ± 13.2	0.86	0.395
BMI (kg/m^2)	24.6 ± 2.9	27.1 ± 3.9	2.36	0.023
Pregnancy Weight Gain (kg)	16.3 ± 5.0	15.6 ± 2.9	0.59	0.560
Months postpartum	3.4 ± 1.4	3.6 ± 1.6	0.60	0.557
Weight Retained Postpartum (kg)	5.4 ± 2.4	5.8 ± 3.2	0.40	0.694

[a] Values represented are mean ± SD

[b] F and P values represent differences between the RT and Flexibility groups at baseline.

[c] RT = Resistance Training

[d] BMI = Body Mass Index

Table 4. Flexibility Changes

Variable		RT Group n = 20			Flexibility Group n = 23		F†	P†
	Baseline	2 Month	4 Month	Baseline	2 Month	4 Month		
Sit-and-reach (cm)	29.8 ± 9.3	32.1 ± 7.2	33.8 ± 7.5*	31.7 ± 7.8	35.9 ± 7.0	35.6 ± 7.3*	2.90	0.096

[a] Values represented are mean ± SD

[b] P† = Group by period interaction

[c] *Within group changes

[d] RT = Resistance Training

Table 5. Strength Changes

Variable	RT Group n = 20			Flexibility Group n = 23			F	P†
	Baseline	2 Month	4 Month	Baseline	2 Month	4 Month		
Curl Ups	37.2 ± 21.1	68.3 ± 50.3	120.0 ± 87.9*	54.7 ± 44.6	65.5 ± 52.0	78.2 ± 60.2*	8.10	0.007
Bench (kg)	27.0 ± 6.2	31.7 ± 6.9	36.9 ± 9.0*	28.6 ± 5.4	30.7 ± 6.2	30.8 ± 6.0*	31.39	< 0.001
Leg (kg)	80.4 ± 15.2	95.4 ± 17.3	105.4 ± 18.3*	91.9 ± 23.0	94.1 ± 22.2	98.0 ± 27.6*	8.74	0.005

[a] Values represented are mean ± SD

[b] P† = Group * period interaction

[c] *Within group changes

[d] RT = Resistance Training

Table 6. Changes in BMI and Body Weight

Variable	RT Group n = 20			Flexibility Group n = 23			F†	P†
	Baseline	2 Months	4 Months	Baseline	2 Months	4 Months		
BMI (kg/m^2)	24.6 ± 2.9	24.1 ± 3.0	23.6 ± 3.0*	27.1 ± 3.9	26.6 ± 4.2	26.3 ± 4.2*	2.41	0.128
Weight (kg)	69.1 ± 8.2	67.8 ± 8.2	66.2 ± 8.0*	72.1 ± 13.2	70.6 ± 13.6	69.9 ± 13.5*	2.78	0.103

[a] Values represented are mean ± SD

[b] P† = Group by period interaction

[c] *Within group changes P < 0.05

[d] RT = Resistance Training

[e] BMI = Body Mass Index

Table 7. Physical Activity Time

Variable	RT Group n = 20			Flexibility Group n = 23				
	Baseline	2 Month	4 Month	Baseline	2 Month	4 Month	F	P†
Counts/Day	213082 ± 48095	241867 ± 63422	240382 ± 75614	265422 ± 150124	278766 ± 136985	248541 ± 109605	2.35	0.134
Sedentary	1212 ± 44	1199 ± 36	1196 ± 46	1182 ± 68	1168 ± 61	1186 ± 61	3.98	0.054
Light Activity	213 ± 46	222 ± 36	228 ± 44*	238 ± 57	250 ± 49	234 ± 50	5.09	0.030
Moderate Activity	14 ± 11	15 ± 11	13 ± 7	16 ± 16	19 ± 15	18 ± 18	0.15	0.701
Vigorous Activity	1 ± 1	2 ± 5	3 ± 7	4 ± 9	3 ± 8	1 ± 3	2.14	0.152
MVPA	15 ± 11	18 ± 12	15 ± 10	20 ± 24	22 ± 22	19 ± 20	0.17	0.686

[a] Counts/Day represents the average total counts over 24 hours.

[b] Data for sedentary, light-, moderate-, vigorous-intensity time, and MVPA represent minutes per day in means and SD.

[c] P† = Group by period interaction with control of baseline

**[d] ***Within group changes $P < 0.05$.

[e] MVPA = Moderate to Vigorous Physical Activity

[f] RT = Resistance Training

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Appendix A

Prospectus

Chapter 1

Introduction

Obesity rates in the United States are at alarming levels and seem to be continually rising (1). Obesity has been linked to many diseases including heart disease, type 2 diabetes, high blood pressure, hypercholesterolemia, and some cancers (2). While obesity is a concern for both men and women, women have higher obesity rates than men (3). This may be partially attributed to lifestyle changes that occur during pregnancy and postpartum. Specifically, the postpartum period has been associated with decreased levels of physical activity (PA) (4-9). Some research has shown that the percentage of women who can be categorized as insufficiently active increases significantly from pre-pregnancy to postpartum and that total leisure time PA levels decline from prepregnancy to 6 months postpartum by about 1.4 hours per week (5).

Decreased levels of PA have been shown to effect weight retained postpartum. Weight retention beyond 6 months postpartum increases the likelihood of long term weight retention and obesity (10-12). Weight retained postpartum has been shown to be a good indicator of weight development in the second pregnancy (13) and one study showed that obesity rates among elderly women increased as the number of childbirths increased (11).

One important factor in weight maintenance is PA, particularly spontaneous physical activity (SPA) (14). Studies have shown that resistance training (RT) increases SPA levels in older adults and in cardiac rehabilitation patients (15,16). As physical strength increases, activities of daily life may be done with less effort potentially resulting in increased PA levels (16).

Resistance training and subsequent increased levels of SPA postpartum could be effective in decreasing postpartum weight retention; however, no studies have been conducted to discover the effects RT and SPA during the postpartum period to confirm these assumptions.

Problem Statement

The purpose of this study is to compare strength and SPA changes in postpartum women randomly assigned to either a four-month progressive RT program or a flexibility training program.

Hypothesis

Resistance training will increase strength and SPA levels in postpartum women while flexibility training will have no effect.

Null Hypothesis

Neither RT nor flexibility training will have an effect on strength or SPA in postpartum women.

Assumptions

1. Participants will follow the prescribed RT and flexibility protocols.
2. Participants will accurately report any RT or stretching done outside of the supervised sessions.
3. Participants will record PA information accurately.
4. Participants will wear accelerometers as instructed during the testing periods.
5. Participants will not alter their normal PA levels significantly when wearing an accelerometer for testing.

Limitations

1. Because this study is limited to postpartum women who have a social support network that will allow them to participate in the resistance and flexibility training programs, results may be confounded by selection bias and can only be generalized to that population.

Delimitations

1. Subjects will be postpartum women from Utah County.

2. Subjects must not have engaged in a RT program two or more days a week for the previous six months.

3. Subjects must be nonsmokers.

4. Subjects must be healthy and able to provide a physician’s release form.

5. Subjects must be willing to be randomized into either a flexibility group or RT group and be able to perform the prescribed protocol.

6. Subjects must be at least 5 lbs over their prepregnancy weight.

7. Subjects must be at least six weeks but not more than eight months postpartum.

8. Subjects must not be planning on becoming pregnant within the next year.

9. Subjects must not be participating or planning to participate in a commercial weight loss program.

10. Subjects must have a social support network that will allow them to break away from their motherly responsibilities for three hours each week in order to perform the prescribed protocol.

Definition of Terms

Postpartum – The period from delivery to 1 year postdelivery.

Spontaneous physical activity (SPA) – All nonexercising activities associated with daily life including walking around the house, gardening, fidgeting, etc as measured by a Actigraph GT1M accelerometer after subtracting self-reported exercising activities from total activity.

Strength – The ability to exert force against resistance.

Repetition maximum – The total amount of weight a person can lift for a specified number of times.

Repetition – The number of times a weight is lifted.

Set – A previously determined number of repetitions performed a specified number of times.

Moderate intensity exercise –The intensity required to walk at a brisk pace.

Significance of the Study

Obesity is a public health concern across the globe costing billions of dollars each year in the United States (17). Because women have higher obesity rates than men (1,3), and because weight retained postpartum may increase the risk of overweight and obesity in women (10,13,18-20), developing effective interventions in this population that focus on reducing the excess weight retained postpartum could help to reduce later overweight and obesity in women.

Chapter 2

Review of the Literature

Obesity rates have increased dramatically in the United States over the past 20 years (1). Obesity has been linked to many diseases including heart disease, type 2 diabetes, high blood pressure, dyslipidemia, stroke, and some cancers (2). While the rising rates of obesity are a concern for both men and women, women tend to have higher obesity rates than men (21). One potential contributor to obesity in women may be changes that occur during pregnancy and postpartum.

The purpose of this review will be to discuss the role of postpartum weight retention in the development of obesity in women and the possibility of RT as an intervention to increase strength and SPA and decrease the amount of weight retained postpartum.

Pregnancy, Postpartum Weight Retention, and Obesity in Women

Postpartum weight retention may increase the likelihood of overweight and obesity and their related health problems. Women who are obese are at greater risk for complications during pregnancy and delivery, including gestational diabetes, preeclampsia, eclampsia, cesarean delivery, and premature birth (22). Infants born of obese women are also more likely to die within the first year of life compared to infants born to nonobese women (22). The exact cause of obesity in women is difficult to pinpoint but research suggests that the effects of childbirth may play a role (12,23-26).

Olson et al. (2003) studied the prenatal and one year postpartum body weights of 597 women over the age of 18 years who had given birth at least once. Body weight and height were obtained at the women's prenatal visits during the first or second trimester, and six months postpartum (9). Weight and height were self-reported via a questionnaire at one year postpartum (9). These researchers reported that 1 year after giving birth, the average amount of weight retained by the subjects was 1.51± 5.95 kg more than their first recorded weight measurement (9). However, the variation in the amount of weight retained by the subjects was large ranging from -19.09 kg to 27.5 kg (9). They found that women who gained more weight than recommended by the Institute of Medicine during pregnancy, retained more weight at one year postpartum (9). About 25% of the women in the study gained a significant amount of weight (4.55 kg or more) from their first measurement to one-year postpartum (9).

Ohlin and Rössner (1990) studied a sample of 1,423 Swedish women to discover the amount of weight retained at one year postpartum. They found that on average, the women in their study retained about 1.5 kg at one year postpartum (27). Similar results were found by Schauberger et al. (1992) when they studied 795 White women and found that the average weight retained at six months postpartum was about 1.4 kg.

Greene et al. (1988) showed a relationship between postpartum weight retention and later weight gain. Their study involved a sample of 7,116 women who became pregnant twice during the six years of the study (10). The women were monitored for weight changes between pregnancies as well as for postpartum weight loss (10). Greene et al. concluded that after adjusting for normal weight gain with age, even women who do not gain excessive amounts of weight during pregnancy were likely to retain about 1 kg of body weight above the normal age associated weight gain with each pregnancy with some women gaining substantially more.

Linné, Barkeling, and Rössner (2004) followed 563 women from the SPAWN study for 15 years to determine the amount of long-term weight gain and weight retention that could be attributed to pregnancy in women. The women were asked to fill out questionnaires about their exercise and eating habits before, during, and up to one year after delivery (13)et al.). Anthropometric data was also obtained (13). After 15 years the women were asked to fill out the same questionnaires and anthropometric data were again obtained (13). The results showed that those who retained the most weight postpartum were more likely to have gained high amounts of weight during pregnancy, and that weight gained between the first and second pregnancies was the most significant. Weight gained during the first pregnancy and retained at one year postpartum was found to be a good predictor of weight development in the second pregnancy (13). This research suggests that those who gain large amounts of weight during pregnancy and do not lose the excess weight postpartum are at greater risk for gaining more weight with a second pregnancy.

Bastian et al. (2005) studied the effects of childbirth in elderly women. They found that obesity rates in elderly women increased as the number of live births increased. Heliovaara and Aromaa (1981) also found that obesity was strongly related to parity in women aged 25-34 years. The results of these studies suggest that multiple pregnancies could have an impact on later overweight and obesity in women.

Hunt et al. (1995) conducted a study to determine if morbidly obese women could attribute their obesity to pregnancy related weight gains and retention. Their study involved 96 morbidly obese women and 115 random control women from Utah (19).). Women were excluded from the study if they had been more than 30 lbs over their ideal weight between the ages of 20 to 24, or before their first pregnancy (Hunt et al.). Self-reported weight measurements were obtained for prepregnancy, highest weight during pregnancy, and six months postpartum

(19). The results showed that morbidly obese women gained significantly more weight than the controls, but only for the first pregnancy, and that obese women retained 4 kg more than controls at six months postpartum for the first pregnancy, and 1.6 kg more for subsequent pregnancies (19). Weight gains during pregnancy were similar between the morbidly obese and the controls for more than one pregnancy (19). They concluded that pregnancy may have influenced the development of morbid obesity in these women (19).

Not all studies have agreed that postpartum weight retention could be a risk factor for obesity in women, however, Harris et al. (1997) conducted a retrospective study of 243 mothers from England where they found that after adjusting for age related weight gains, some women in their study actually weighed less after pregnancy than they had before. In addition, a prospective study of White childbearing women in the United States between the ages of 25 to 45 showed that after 10 years of follow-up, the women in the study showed only a modest increase in weight associated with childbirth and that the absolute risk of childbearing women gaining more than 13 kg of weight after 10 years was only 2% greater than the risk of the women who had no children (23).

While not all evidence has agreed that women retain more weight postpartum than the normal age-associated weight gains, many studies have shown that weight retained postpartum is significant (9,20,27-29). More research is needed in this area to make solid conclusions.

Physical Activity Patterns Postpartum

Physical activity is an important part of a healthy lifestyle. Regular PA can help reduce the risk of heart disease, cancer, and type 2 diabetes as well as improve mood, strengthen bones and muscles and assist in weight loss and maintenance (30). According to Thorburn and Proietto

(2000), PA is made up of three different components: spontaneous physical activity (SPA) (activities of daily living); obligatory physical activity (activity one must do to live); and voluntary physical activity (planned exercise).

It has been shown that PA levels tend to decrease during pregnancy (4). Pereira et al. (2007) studied 1442 pregnant women and calculated the change in their prepregnancy, 2nd trimester and 6 months postpartum self-reported PA levels. They found that total leisure time PA levels declined during pregnancy and remained 1.4 hours per week lower than prepregnancy levels at 6 months postpartum (5). Weekly hours of leisure time PA failed to return to prepregnancy levels due to a decline in light/moderate and vigorous intensity exercise (5). The percentage of women in the study who could be categorized as insufficiently active increased from 12.6% before pregnancy to 21.6% during pregnancy and 21.7 % at 6 months postpartum (5).

Sampselle, Seng, Ueo, Killion, & Oakley (1999) studied the PA postpartum of 1,003 women. They found that 54.8% of women reported to be less active than normal at 6 weeks postpartum. They also found that those who reported being more physically active postpartum retained significantly less weight than those who reported being less active (6).

Harris et al. (1997) found that about 50% of the women in their sample had decreased PA levels postpartum which were associated with greater long-term weight gain. The women in the study attributed their decrease in PA levels to a decreased amount of time, energy, opportunity, and motivation to engage in PA (7). Symons, Downs, and Hausenblas (2004) found in their retrospective study of 75 postpartum women that activity levels decreased from prepregnancy to postpartum in light, moderate, and vigorous intensity levels.

Olson et al. (2003) conducted a prospective cohort study on 540 women over the age of 18 who had given birth at least once. They measured PA levels during the first or second trimester and then six months and one year postpartum. The results showed that those with low PA postpartum had greater postpartum weight retention (9)).

Treuth, Butte, and Puyau (2005) did not find a decrease in total postpartum PA levels however, when comparing them with prepregnancy levels in their sample of 63 women. The only difference in activity they found was in the mode of activity (31). Conditioning and occupation related activities decreased, while walking and home activities increased (31). Despite the lack of change in PA found in this study, the majority of evidence has shown that PA levels tend to decrease postpartum.

The reduction of PA levels during pregnancy and postpartum is a concern because of the important role it plays in weight reduction and maintenance. According to Sampselle et al. (1999), little is known about postpartum exercise patterns and most recommendations for PA during the postpartum period are given in the context of returning to PA with caution and often only small amounts of PA are encouraged. The American College of Gynecologists recommends that women from four to six weeks postpartum should resume prepregnancy exercise routines as their physical capabilities permit (32).

Spontaneous Physical Activity

Recent studies have indicated that SPA could play a significant role in weight maintenance (4). SPA is defined as the activities associated with daily life (33). In 2000 the World Health Organization in conjunction with the Obesity Task Force turned their attention to decreasing weight gain by encouraging more SPA (34). While research in this area is still in its infancy, it appears that increasing SPA could have a positive impact on weight management.

According to Ravussin, Lillioja, Anderson, Christin, and Bogardus (1987), SPA accounts for 100-800 kcal of total energy expenditure per day. Low levels of SPA can lead to body weight gain (35). Levin et al. (1999) studied 16 nonobese volunteers and measured body composition using duel energy x-ray absorptometry (DXA) and energy expenditure using doubly labeled water before and after eight weeks of consuming an excess of 1000 kcal/day above what was needed to maintain body weight. The results showed that nonexercise activity thermogensis (NEAT) which is made up of activities associated with daily living, including fidgeting, spontaneous muscle contraction, and maintaining posture, contributed the most to increased caloric expenditure in the volunteers ranging from an increase of 98 kcal/day to more than 692 kcal/day (14). They concluded that those who have good activation of NEAT are more likely to burn excess energy consumed than those who have poor NEAT activation.

Currently, there is little data available for SPA in postpartum women. However, because women in the pregnancy and postpartum stages tend to become less active, it may be beneficial to find ways to increase movement and SPA levels in this population. A search of the terms “spontaneous physical activity postpartum” in Medline returned no results indicating that research has yet to be done to discover the specific levels of SPA postpartum and how it contributes to a decrease in overall PA.

Benefits of Resistance Training

Resistance training has been shown to produce many benefits, including development and maintenance of muscular strength, endurance, fat-free mass, and bone-mass density (36). Despite the benefits associated with RT, only 17.5% of American women meet the current recommendations for RT (37).

Because there are no known studies of RT in postpartum women, the following studies will show results of RT in nonpostpartum women. Schmitz, Jensen, Kugler, Jeffery, and Leon (2007) conducted a RT study in women between the ages of 25 to 44 years. The randomized control trial was conducted on 164 overweight and obese women of many different ethnicities (38). In the study the subjects were divided into an intervention group and a standard care group (38). The intervention participants were assigned to complete a supervised RT program twice weekly for 16 weeks (38). At the end of the 16 weeks they were instructed to continue RT unsupervised for the remainder of the two years (38). The standard care group was sent American Heart Association brochures that encouraged PA (particularly walking) but did not encourage RT (38). Study results showed that women in the intervention group had larger decreases in body fat percentage and intraabdominal fat compared to the standard care group at year one, and even larger differences were measured at year two (38)). They also found that bench press and leg press strength increased in the treatment group (6.66%±1.69% and 13.2%±2.95%) from baseline to year two while the control group decreased in bench press strength (2.7±1.80%) and increased only slightly in leg press strength (3.48%±3.12%) by year two (38). Schmitz et al. explained that the findings of the study highlight the potential for RT to provide benefits for obesity prevention over time.

Peterson, Peterson, Raymond, Gilligan, Checovich, and Smith (1991) conducted a study to see if adding a RT program to an endurance dance program would increase muscular strength and bone mass when compared to endurance dance training alone or sedentary controls. Their study consisted of 59 women between the ages of 36 to 67 who were recruited from a larger study and were separated into one of three groups: dance endurance group, RT and dance endurance group, and sedentary control group (39). At the end of the one-year intervention, they found no significant increase in bone mineral density but a significant increase in strength was found in the RT and endurance dance group when compared to the endurance dance only or the control group (39).

Schmidz Jensen, Kugler, Jeffery, and Leon (2003) found statistically significant improvements in fat-free mass, fat mass, and body fat percentage after 15 weeks of RT in 30 midlife women (age 30-50) when compared with a control group. Upper and lower body strength also increased in the treatment group compared with the controls (40).

Similar results were found by Prabhakaran, Dowling, Branch, Swain, and Leutholtz (1999) when they randomly assigned 24 women with a mean age of 27 years to either a nonexercising control group or a RT group. After the 14-week intervention they found that strength increased significantly in the RT group. They also found decreases in total cholesterol, LDL cholesterol, and body fat percentage in the RT group while no changes were found in the control group (41).

Pregnant women are encouraged to continue RT during pregnancy if they were already participating in a RT program prior to pregnancy with slight variations and under the supervision of a doctor (30). Women may also engage in RT after pregnancy but should be advised by a doctor as to how and when to begin RT postpartum (30). While we know that RT is important and can be done during pregnancy and postpartum, to this point no studies have addressed the benefits of RT specifically during the postpartum period.

Resistance Training and Spontaneous Physical Activity

While research determining the influence of RT on SPA is scarce, two studies have shown that RT increased total daily energy expenditure (including SPA) in older adults (15,16). Hunter et al. studied 15 older adults 61 to 77 years of age who performed a RT program for 26 weeks. The program consisted of 45 minutes of supervised RT three times per week (16). They found that RT in these adults increased the total daily energy expenditure by increasing resting energy expenditure and PA (including free-living PA or SPA) and the resting metabolic rate when compared to pretraining levels (16).

Ades et al. (2005) studied 51 women with known Coronary Heart Disease (CHD) and assigned them to either a RT or yoga group for six months. They measured PA levels with doubly labeled water (15). Both groups were similar in important characteristics (15). At the end of the six-month intervention they found that women in the RT group had significant increases in SPA energy expenditure, the control group did not (15). On the other hand, a study conducted by Poehlman et al. found no significant change in total energy expenditure with RT long term in the young women in their study. Poehlman et al. (2002) suggested that any change in energy expenditure while engaging in a RT program would likely be short-term changes (42).

If RT increases PA levels, particularly SPA levels, a RT program could be particularly helpful for women during the postpartum period. This area would benefit from further research.

Flexibility Training

Stretching has been recommended as part of an overall fitness program for healthy adults (43). Stretching increases tendon flexibility and range of motion (43). There are three main types of stretching: static, proprioceptive neuromuscular facilitation (PNF), and ballistic (43). While

PNF stretching has been shown to be the most effective type of stretching, static stretching has proved very effective as well (43) According to the American College of Sports Medicine, the main effect of stretching is an increase in the visoelestic properties of the tendons (36). Stretching increases the length of the muscle due to the relaxation of the actin-myosin complex and alterations in the extracellular matrix (36). These improvements in the length and flexibility of the muscle have been shown to increase joint range of motion (44).

Stretching may decrease the risk of injury when done properly and in conjunction with a warm-up (45). However, not all studies have shown a decrease in injury with stretching (46). Mechelen et al. randomly assigned 421 male recreational joggers to a control group and an intervention group. The intervention group was educated and asked to perform a proper warm-up, cool-down and stretching routine before running (46). The control group did not receive the intervention, but both groups were asked to keep a daily log of their running time and distance and were asked to report any injuries (46). No reduction in injuries to the soft tissue were reported for the intervention group compared to the control group (46).

Witvrouw, Mahieu, Danneels, and McNair (2004), in a review of the evidence, found that while conflicting evidence exists about the benefits of stretching in injury prevention in sports, when the type of sport is taken into account, the research appears to agree. They explained that stretching has been shown to decrease the risk of injury in sports like football and soccer where explosive muscle contractions are typical (47). In these types of sports, the muscle tendons need to be in a position to store and release high amounts of elastic energy (47). In other sports where the same type of explosive energy is not needed such as jogging, or swimming, the amount of absorbed energy remains low so the muscle tendon being able to absorb energy is not needed to prevent injury in these sports (47).

Stretching may have an acute effect on lower body strength. In a study done by Bacurau et al. (2009), they found that after 20 minutes of static stretching maximal leg press strength decreased, however, no evidence has shown that stretching influences SPA levels.

Flexibility groups have been used as control groups for exercise related studies. Irwin (2003) used a flexibility control group when studying the effects of exercise on intra-abdominal body fat in postmenopausal women. The flexibility group showed only slight changes in body fat and weight when compared with the exercise group, and only 7% of the flexibility group reported increases in PA (48). Lox, McAuley, and Tucker (1996) used a flexibility control group when studying the effects of a RT and aerobic training program on strength, body composition, and cardiovascular fitness in HIV-1 subjects (49) The result showed improvement in all areas for the treatment groups—no improvements were seen in the control group (49).

Summary

This review of the literature has shown that postpartum weight retention could influence obesity later in a women's life and could benefit from further research. Some interventions have been conducted in the postpartum stage to help encourage weight loss, but nothing has been conducted to see what impact RT could have on this population to increase SPA postpartum. Because SPA has been correlated strongly with a decrease in weight gain, this may be an effective intervention for women in the postpartum stage, and warrants investigation.

Chapter 3

Methods

Design

Sixty postpartum women will be recruited to participate in a randomized trial that compares resistance and flexibility training in postpartum women over a four month period. The RT group will engage in an RT exercise protocol that includes 1-3 sets per training session, 8-10 repetitions per set, 10 different exercises that work all major muscle groups, and performed on two nonconsecutive days per week. The flexibility training group will engage in a flexibility program that includes two training sessions each week, four different stretches (sets) per muscle group, holding each stretch for 10-30 seconds. To avoid confounding the study, the flexibility training group will be advised not to perform RT exercises over the course of the study.

Subjects

Sixty postpartum women will be recruited for this study from the BYU community and Utah County via BYU campus mail, fliers, posters, word of mouth, the BYU and local Utah County newspapers, and doctors' offices and hospitals. Institutional Review Board approval at Brigham Young University will be obtained prior to beginning the study. All subjects will provide informed consent before participating. All subjects included in the study must be healthy according to the Physical Activity Readiness Questionnaire (PAR-Q) (Thomas, Reading, Shephard, 1992) and Health History Questionnaire. All subjects must also provide a signed physician’s release form stating that the subject is healthy and can safely participate in the study. In addition, all subjects must be at least six weeks, but not more than eight months, postpartum and at least 5 lbs over their pre-pregnancy weight when they begin participation in the study.

Subjects must not be planning to become pregnant within the next year, be nonsmokers, and have a social support network that will allow them to break away from their motherly responsibilities to perform the prescribed twice weekly RT sessions or the weekly flexibility training sessions. Subjects must be willing and able to participate in the group they are assigned to and follow the prescribed protocol. Subjects must also not be planning to leave the area for a year following the initiation of the study.

Subjects will be excluded from the study if they are unable to perform RT or moderate-intensity exercise, have engaged in RT or flexibility training twice or more per week within the last six months, or are participating or planning to participate in a commercial diet or weight-loss program. All subjects in the RT group will be given a four month membership to a local physical therapy clinic (Central Utah Clinic, Sports Fitness and Physical Therapy, Sports Acceleration, 1055 North 500 West, Provo, UT 84604) to ensure access to RT equipment but will be instructed not to use the aerobic exercise equipment to prevent unequal access between the groups.

Procedures

Baseline, Two, and Four Month Testing

At baseline, two, and four months, all subjects will be tested for strength, flexibility, and PA level. Each testing period will include two visits separated by at least eight days to allow for PA to be assessed for one week. During the first visit at baseline, all subjects will complete an informed consent, PAR-Q, and health history questionnaire. After a five-minute warm-up of walking on a treadmill at moderate intensity and a brief lower body sit-and-reach stretch (found on page 30), subjects will perform a standard sit-and-reach (50), v sit-and-reach (50), and a skin distraction test (50) (found on page 35) to assess flexibility. These flexibility tests were chosen because they are nationally standardized tests and have been found to be valid and reliable (Heyward, 2006). The v sit-and-reach and standard sit-and-reach tests will each be performed three times and the best score will be used for data purposes.

In order to prepare for strength assessments on the second visit, all subjects will be instructed on the proper lifting techniques for the leg press, bench press, and for the partial abdominal curl-up test (found on page 32). Each participant will be allowed to practice these exercises to minimize any possible learning effects that could weaken the results of the study. Also on the first visit, each subject will be given an Actigraph GT1M accelerometer (Actigraph LLC, Walkton Beach, FL) and activity log. The accelerometer is a small computerized device, about the size of a pedometer that counts PA movements and stores them for later downloading and data analysis. Subjects will be instructed to wear the accelerometer on their right hip for seven consecutive days. In addition, subjects will record any planned exercise on an activity log. The activity log will include a column to record the intensity, time of day (to the minute), duration, and mode of the planned exercise completed. The keeping of the activity log will coincide with the same seven days the accelerometer will be worn. Subtracting the planned exercise from the PA assessed via accelerometer will allow SPA to be assessed.

On the second visit, accelerometers will be collected and the information downloaded to an Excel spreadsheet. Subjects will be asked to change into a standard swimming suit and asked to use the bathroom before height and weight data are collected. After each subject is assessed for height using a wall-mounted stadiometer and weight using a digital scale, subjects will change back into athletic clothes and perform the same five minute warm up and the sit-and-reach stretch performed at the previous testing session. Subsequently, a supervised 3-8 repetition maximum (RM) for the bench press and leg press will be performed. Information from weight, height, and RM tests will be used to estimate each subject's 1RM (equation found on page 31). Finally, subjects will complete the ACSM partial curl-up test (51) to assess abdominal strength with one modification. After baseline testing the subjects will be randomized into either the flexibility or the RT group using a random numbers generator from the SAS verson 9.1 statistical software package. The same measurements and protocol will be used for follow-up testing at two and four months.

Resistance Training Protocol

After baseline testing, subjects randomized to the RT group will be prescribed an RT program adapted from the recommendations of the American Heart Association and the American College of Sports Medicine (52). During the first month each RT session will be supervised to ensure proper lifting techniques are performed and will consist of 1 set of 8-10 repetitions for 9 different exercises that work all major muscle groups. Intensity for each exercise will be approximately 80% of the subjects 1RM or the highest weight that can be lifted for 8-10 repetitions. The subjects will be instructed to rest at least 90 seconds between sets.

The RT program will be progressive. When subjects can perform 12 or more repetitions for any given exercise, the weight will be increased by 1 machine increment or 2-10% (53). The RT exercises will include leg extensions, seated leg curl, leg press, biceps curl, shoulder press, chest press, lat pull-down, seated row, and abdominal curl-ups. All RT exercises will be performed via machines except the shoulder press which will be performed using free weights and the abdominal curl-ups which will use the subjects own body weight. The RT exercises will be performed as outlined below:

Leg Extensions (quadriceps): The subject will sit on the edge of the seat and place her feet behind the machine pads. While keeping her back straight and holding on to the sides of the chair, the subject will extend her legs completely then return to starting position (54).

Seated Leg Curl (hamstrings and gluteus maximus): The subject will lie face down on the bench with the back of her feet up against the pads of the machine. While holding on to the sides of the machine for balance, the subject will lift her feet up toward their buttocks as far as possible then return to starting position (54).

Vertical Leg Press (quadriceps, gluteus maximus, hamstrings, calves): The subject will sit with her back straight, legs bent, and feet shoulder width apart on the leg press platform. The subject will push the platform upward until her legs straighten completely then return to starting position (54).

Biceps Curl (biceps): The subject will stand erect with feet shoulder width apart, arms straight, with the curl up bar held in the palm-up position. The subject will bend at the elbows and raise the bar until it touches the shoulders then return the bar to starting position (54).

Shoulder Press (triceps, deltoids): The subject will sit on the bench with her feet flat on the floor and grasp the dumbbells with her palms facing outward. With back straight, the subject will raise the dumbbells to shoulder height (the starting position) and then raise the dumbbells over her head until arms are full extended. The dumbbells will then be lowered to starting position (54).

Chest Press (pectorals, anterior deltoids, triceps): The subject will sit on the bench with her feet flat on the floor and her back flat against the chair. The bar will rest at chest level and the subject will press the bar forward while keeping the back straight until the arms are fully extended then return to starting position (54).

Lat Pull-Down (latissimus dorsi, trapezius, rhomboids, biceps): The subject will sit on the machine bench and grasp the bar in a wide grip with arms straight and palms facing down. The subject will then pull the bar down until it touches her upper chest while keeping the upper body straight and then return to starting position (54).

Seated Row (trapezius, deltoids, forearms): The subject will sit on the bench with arms fully extended and feet flat on the floor. The subject will then grasp the bar with the palms facing downward and while keeping the back straight pull the bar until it touches their lower chest then return to starting position (54).

Abdominal Curl-Up (midsection): The subject will lie on the floor with her legs bent feet flat on the floor, and hands folded over her chest. The subject will then curl up to about a 30 degree angle, and then return to starting position by touching first the lower back, then the upper back, then the head to the floor (54).

Like the first month, during the second month the subject will complete the same 9 exercises, the same number of repetitions (8-10 per set), and the same number of training sessions (two per week). However, unlike the first month, two sets of each exercise will be performed. The first set of each exercise will consist of 10 repetitions and will be performed using the highest weight obtained from the previous resistance training session for that exercise. The same weight will be used for the second set but the subject will be asked to perform as many repetitions as possible. Furthermore, when subjects can complete the second set of each exercise for 12 or more repetitions the weight for each set will be increased by ~2-10% or one machine increment at the following training session.

At least one session will be supervised each week. For the nonsupervised RT session, subjects will receive an exercise log and record the exercise, sets, repetitions, and weight lifted, and report that information following each completed session via e-mail, fax, or telephone.

During months three and four, the same protocol will be followed as months one and two with the main difference being that three sets per exercise will be completed during each session. For each participant, the first and second set will consist of 10 repetitions and will be performed using the highest weight obtained from the previous RT session for that exercise. Like previous months, when the number of repetitions completed meets or exceeds 12 on the third set, each set will be increased by 2-10% or one machine increment on the following training session.

Subjects will be instructed not to engage in any additional RT outside of the prescribed protocol and location. Subjects will spend approximately 60-80 minutes each week completing the prescribed RT.

Flexibility Protocol

After baseline testing, subjects randomized to the flexibility group will be prescribed a flexibility program adapted from guidelines by the American College of Sports Medicine (two nonconsecutive days each week, four different stretches per muscle group, holding each stretch for 10-30 seconds) (36) and provided with a flexibility log to record their stretching sessions. Compliance with the prescribed protocol will be verified each month by phone and at each data collection period (2 and 4 months). Subjects will also be invited to attend a weekly group flexibility session held on the BYU campus where they will have the opportunity to receive additional instruction on stretching exercises and ask any questions they have regarding flexibility training. The prescribed stretches will include four stretches (sets) for each of the following muscle groups: hamstrings and low back, calves, quadriceps, neck, shoulders and arms, and torso.

Hamstrings and Low Back

Sit-and-reach (both legs): The subject will sit flat on the floor with both legs stretched out straight in front of her. The subject will then slowly reach toward her toes until they feel slight discomfort and hold (50).

Sit and Reach (one leg): The subject will sit flat on the floor with one leg pulled in close to the body and the other leg stretched strait out in front. The subject will slowly reach toward the toe of the straight leg until she feels mild discomfort and then hold (50).

Straddle: The subject will sit flat on the floor with both legs stretched out as far as possible forming a “v.” The subject will slowly reach with both arms, first to one leg, then to the middle and then to the opposite leg (50).

Lower Back: The subject will lie on her back; pull both knees into their chest and hold (50).

Calves

Gastrocnemius and Achillies: The subject will place both hands on a wall with the front leg bent and the back leg strait. While keeping the heel of the back leg pressed to the floor the subject will lean toward the wall until mild tension is felt. After holding the stretch for 10-30 seconds the subject will slightly bend the back leg and again lean forward until mild tension and hold. The stretch will be performed on both legs for 2 sets each (50).

Quadriceps

Standing Quadriceps Stretch: The subject will stand with one hand resting on a stationary surface for support and the other hand holding the same side leg by the ankle and pulling the heel into the buttocks. The stretch will be performed on both legs for two sets (50).

Laying Down Quadriceps Stretch: The subject will lie down on her back on the edge of a table with one side of her body near the edge. With the outside leg lowered over the edge of the table, the subject will bend her leg and pull the heel of the bent leg to the buttocks. This stretch will be performed on both legs for two sets (50).

Neck

Head Rotation: The subject will sit upright and slowly turn her head once from left to right as far as possible trying to look over their shoulder while stretching (50).

Shoulder to Ear: The subject will sit upright and place their left hand on the top portion of the right side of her head and gently bring their head down as if she is trying to touch her ear to her shoulder. The stretch will be performed on both sides (50).

Chin to Chest: The subject will sit upright and slowly lean her head forward as if they were trying to touch her chin to her chest (50).

Shoulders and Arms

Shoulder Abductors: The subject will flex one arm behind her back with the opposite arm grasping the elbow from behind and pulling it toward the midline of her back (50).

Triceps Brachii: The subject will pull one arm up overhead bent at the elbow with the hand resting on the opposite shoulder blade. The opposite arm will be placed on the elbow behind the head with a downward pull (50).

Lateral Shoulder: The subject will hold one arm straight while taking the opposite arm and placing it on the elbow of the straight arm and pulling the arm across the body. This stretch will be performed on both arms (50).

Brachioradialis: The subject will kneel down placing both hands on the floor with the tops of the hands against the floor and fingers pointing toward knees. The subject will then exhale while leaning against the floor (50).

Torso

Upward Reach*:* The subject will stand in an upright position and reach both hands up toward the sky as far as possible and hold (50).

Upper Back: The subject will place both hands on the wall and bend at the waist while keeping the arms straight and pressing down on the wall to produce an arch in the back for two sets (50).

Cobra: The subject will lie on her stomach on the floor with her torso raised up off the floor by her arms bent at a 90 degree angle and elbows resting on the floor. The subject will then stretch her chest toward the ceiling while the stomach remains on the floor and hold (50).

Measurements

Strength Assessment

Strength will be assessed for both the RT and flexibility groups at baseline, two and four months. Strength tests will be performed for the legs and buttocks (leg press) (51), chest and triceps (chest press) (51), and abdomen (modified ACSM partial curl-up test) (51). A 3-5 RM will be used for both the leg press and bench press assessments to reduce the risk of injury.

The strength assessment protocol, at each data collection period, will consist of a 5 minute aerobic warm up walking on a treadmill at moderate intensity to increase muscle temperature and reduce the risk of injury, followed by a sit-and-reach stretch (stretch explained on page 27). To ensure accurate measurements a goniometer will be used to position the knee at a 90 degree angle from the foot plate for the leg press, and handles will be positioned at chest and nipple level for the chest press. The position of the equipment will be recorded, via hole numbers on the machines, to ensure consistent positioning for follow-up tests.

Each subject will perform 10-20 sub-maximal warm-up repetitions for both the leg press and bench press. A starting weight will be selected that is within 50%-70% of the subjects estimated capacity to be lifted three to five times. Weight will then be progressively increased by no less than 5 lbs until the subjects can no longer lift the weight more than five times. Each successful attempt at lifting the weight will be followed by a three minute rest period (36) The greatest amount of weight lifted successfully three to five times will be used in the Brzycki equation (Weight lifted (lb) ÷ (1.0278 - (reps to fatigue X 0.0278)) to determine 1RM (51).

To perform the modified partial curl-up test the subject will lie supine on the mat with the legs shoulder-width apart, arms straight down by the sides, feet flat on the mat, and knees at a 90 degree angle. A piece of tape will mark the zero point at which the subject’s middle finger on each hand must touch before beginning the test. Another piece of tape will be placed 10 cm beyond the zero mark and the metronome will be set to 40 bpm. The subject will be asked to lift her shoulders off the mat and touch the 10 cm tape with her fingers on every beat of the metronome. The subject's palms and feet must stay in contact with the mat and the shoulders and head must touch the floor with every curl-up. The fingers must also touch the zero mark between each curl-up. The modification will be that the test will be performed without a time limit. The subjects will perform as many curl-ups as possible until they either stop, or cannot stay in rhythm with the cadence. The only crunches that will not be counted are if the subject's feet or hands come off the floor, they are not in rhythm with the metronome, or they lose proper form. The number of curl-ups performed successfully will be recorded to assess abdominal strength.

Physical Activity Assessment

Physical activity will be assessed using an Actigraph GT1M accelerometer worn over the right hip for seven consecutive days set at 60 second epochs at baseline, two and four months. Accelerometers are about the size of a pedometer and measure the activities of daily living as well as sedentary or low activity periods. The measurements can then be stored for later downloading and data analysis. Accelerometers have been used in previous research and have been shown to be valid and reliable (55-57). Subjects will be instructed to wear the accelerometer at all times except when in water (ie. swimming or bathing) and will be provided with a log to report times when the accelerometer was removed for such activities, when the subject forgot to wear it, or when they participated in planned self-reported PA. Accelerometer data will be summarized so that there is a mean total count per day (Catellier, Hannan, Murray, Addy, Conway, Yang, et al., 2005) for each participant. In the case of missing data, imputation (the process of predicting missing values from observed values) will be utilized by replacing the missing values for each day with the average of the observed values for that day (Catellier et al.). In this way, complete 24-hour days of physical activity can be analyzed. SPA will be assessed for each subject by subtracting the self-reported physical activity from the total activity measured by the accelerometer.

Flexibility Assessment

Flexibility will be assessed at baseline, two and four months using the v-sit-and-reach test (YMCA sit-and-reach test) (51), the standard sit-and-reach test (51), and the skin distraction test (51). A light five-minute aerobic warm-up and light stretching of the upper and lower body will be performed prior to flexibility testing.

V-sit-and-reach test: The subject will sit on the floor with feet approximately 12 inches apart and legs straight but not locked at the knees. A yard stick will be placed between the subjects legs with heels of the feet even with the 15- in. mark. The subject will then be asked to place one hand on top of the other and slowly reach forward along the measuring tape as far as possible while keeping the knees strait and feet flexed. The subject will be allowed to practice the stretch three times before a measurement is taken. On the fourth try the subject will hold the stretch for approximately three seconds to allow for an accurate measurement. This test measures lower back and hamstring flexibility (51).

Standard sit-and-reach test: The subject will sit with head, shoulders and buttocks up against a wall and their feet flat up against the sit-and-reach measurement box. The subject will place one hand on top of the other and slowly reach along the box until she reaches her maximum distance. The subject will hold the stretch for three seconds while the measurement is recorded. This test measures lower back and hamstring flexibility, but it also takes into account arm and leg length (51).

Skin distraction test: The subject will stand erect while a 0 cm point is marked in the middle of the lumbar spine. A second mark will be placed 15 cm above the 0 cm mark. The subject will be asked to bend forward at the waist as far as possible and the space between the 0 cm mark and the 15 cm mark will be measured again. The difference between the first and second measurements will be the score on the test. This test measures lumbosacral flexion (51).

Data Analysis

The data will be analyzed using the statistical software package PC-SAS (Inst Inc Cary, NC) version 9.1 with statistical significance set at $P < 0.05$. Standard deviations and means will be used to summarize the descriptive and outcome data (demographics, strength, physical activity, body weight). Independent T tests will be utilized to determine differences between groups at baseline for descriptive data, strength, physical activity, and body weight. Mixed effects models will be utilized to determine differences in physical activity across time within and between groups and test for the presence of a group*time interaction. Initial strength will be statistically controlled in all participants. Additional data will be collected such as number of children each subject has and the number of weeks postpartum when beginning the study, and weight gained during pregnancy and will be used as control variables in the statistical models.

Based on the results of this study a list of findings, conclusions, and appropriate recommendations will be included.

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