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# Resistance Training Voluntary to Failure Effects to Muscle Thickness and Strength in Overweight Women

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**ABSTRACT**

*Skeletal muscle has an often-underappreciated role in health, with low muscle strength being linked with increased risk of a range of poor health outcomes. It has been demonstrated recently that if exercise is performed voluntarily to failure, then gains in muscle mass and strength are similar regardless of the load at which exercise is performed. The aim of this study was to compare the effect of resistance training voluntary to failure on muscle thickness and strength in overweight women. Twelve overweight women (age 31 ± 8years; height 157.7 ± 4.7cm; weight 71.9 ± 8.9kg; body mass index 28.9 ± 3.2 kg m²) were recruited to the study. Resistance training involved three sessions per week for 6 weeks. Each session involved one set of nine exercises, performed at 80% of one-repetition maximum voluntary to failure. Session lasted 15-20 min. Muscle thickness (ultrasound) and muscle strength were measured at baseline and post – intervention. Resistance training resulted in a 5.2 ± 4.6% ($P < 0.05$) increased in muscle thickness and 31.0 ± 8.2% ($P < 0.05$) increased in muscle strength than baseline, respectively. Six weeks of resistance training three session per week with 20 minutes per session voluntary to failure at 80% of 1RM increases in muscle thickness and strength in overweight women.*

***Keywords***: *muscle strength, muscle thickness, overweight women, resistance training voluntary to failure, ultrasound*

## INTRODUCTION

In the 2019 National Health and Morbidity Survey, 50.1% of our adult population were reported to be overweight (30.4%) or obese (19.7%) (NHMS, 2019). In a survey of Malaysian adult, the prevalence of obesity was found to be 20.1% and greater in woman by 24.9% than men 15.6% (NHMS, 2019). However, the best non-pharmacological method for treating and preventing overweight, cardiovascular and metabolic diseases has been suggested as exercise. More specifically, the two forms of exercise that are most usually advised are resistance training and aerobic training (García-Mateo et al., 2020).

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Resistance training (RT) is frequently advised on such a continuing (i.e., long-term) basis for people of all ages as well as a variety of patient groups because it is well known to enhance strength (Thomas et al., 2020). Moreover, resistance training has shown that there is a more positive effect on muscle strength especially for adults who are overweight or obese (Orange et al., 2020). Skeletal muscle provides an important role in health that is often undervalued. Low muscular strength is associated with higher type 2 diabetes incidence and increased risk of a variety of health problems, including all-cause, cardiovascular disease, cancer, and respiratory disease mortality (Wolfe, 2006; Han et al., 2018). Resistance training has been shown to have a good impact on weight loss, fat loss in conjunction with lean mass retention among overweight (Fragala et al.,2019). Participation in resistance training may boost cardiometabolic fitness, body composition, bone health and psychosocial well-being (Roche et al., 2020). Is there is a significant effect of resistance training voluntary to failure on muscle strength and muscle thickness in overweight women? The objective of this study is to examine the effects of resistance training voluntary to failure on muscle thickness by using Body Metrix BX2000 and strength in overweight women.

## LITERATURE REVIEW

### Resistance Training Voluntary to Failure

The American College of Sports Medicine defined resistance training is a form of exercise involving working a muscle or muscle group against an external resistance to increase muscular fitness (ACSM,2009). According to ACSM (2009) guidelines, a novice should apply a load that is 60 - 70% of their one repetition maximum (1RM), 1 - 3 sets of 8 - 12 repetitions and rest for two minutes in between sets to maximize strength increases. For a beginner, applying a load of 70-85% of their 1RM and performing 1-3 sets of 8-12 repetitions with a rest period of 2 - 3 minutes in between each set will maximize muscle mass increases. It has been mentioned that gains in muscle mass and strength are identical regardless of the load at which exercise is performed to volitional failure (Ismail et al.,2019). It is yet unknown when these adaptations will occur in the early stages of exercise, especially in overweight women. Schoenfeld et al. (2021), have proposed that larger loads are necessary to ensure activation, exhaustion, and subsequent hypertrophy of all muscle fibers to maximize gains in muscle mass and strength.

### Effects on Muscle Thickness

Resistance training has been proven to be useful in a wide range of populations as was already noted as the most efficient way to develop muscle size and strength. For example, many studies in younger individuals have demonstrated that resistance training can enhance muscle size and strength with strength gains outpacing those in muscle mass (Alizadeh et al., 2023). Furthermore, the balance between muscle protein synthesis (MPS) and muscle protein breakdown (MPB) is particularly important in determining muscle size changes and resistance training combined with eating is known to sharply enhance MPS both in absolute terms and relative to MPB. Low loads and blood flow restrictions during resistance training appear to have the main effect on increasing metabolic stress, which appears to stimulate the production of myofibrillar protein by other vessels (Atherton & Smith, 2012). The reduction in oxygen supply to muscle tissue seems to be the main cause of metabolic stress (Evangelista et al., 2019). Few studies compare the acute and subacute effects of traditional training methods and vascular occlusion on muscle thickness (indirect indicative of cell swelling) and cytokines, even though low loads and blood flow restriction models and traditional training showed similar potential for inducing muscle hypertrophy, respectively. Evidence suggested that post exercise session with limited blood flow result in more cellular oedema than regular session (Evangelista et al., 2019).

### Effects on Muscle Strength

As mentioned in most studies the most efficient way to increase muscle strength and hypertrophy is through resistance training, it has been utilized to enhance sports performance, body composition, functionality, and quality of life in a range of populations (Evangelista et al., 2019). However, the proper adjustment of resistance training variables, such as volume, intensity, frequency, rest periods, exercise selection and order, velocity of execution, muscle movements, and range of motion, maximizes neuromuscular adaptations. Brigatto et al., (2019) examined how varied volumes and 32 weekly sets (one set for each muscle group) affected the strength and hypertrophy of muscles after 8 weeks of resistance training. When training with 32 weekly sets per muscle group as opposed to 16 weekly sets per muscle group, there was a greater gain in 1RM and muscle size in the lower body. Improvements in strength are the primary goals of people who participate in resistance training.

## METHODS

### Study Design

The research design used in this phase was experimental. A week prior to the exercise program, all participants were briefed about the objective of the study and were asked to sign the consent form. The procedures of engaging the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) required each participant to sign a consent form to ensure participants are good in health (Warburton et al., 2021). A familiarization session was conducted to ensure all participants were familiar with the equipment and measurement protocol used in this study. All participants were engaged in a preliminary measurement that included pre-1RM (muscle strength) and ultrasound (muscle thickness). All participants were briefed on the exercise regime, protocol, and experimental equipment. The participants will be engaged in 6 weeks of RT voluntary to failure exercise program at 80% of 1RM with 3 sessions per week

### Participants

This study was participated by a total of 12 randomly sampled overweight women, aged between 18-45 years old who resided in Perlis, Malaysia. These participants have a Body Mass Index (BMI) >25kg/m² - 29.9kg/m2 category. Besides that, they were identified as free from injury, metabolic or cardiovascular disease, and did not participate in any moderate to high intensity aerobic exercise or resistance exercise in the past 2 years.

### RT Voluntary to Failure Protocol

The RT exercise was performed using exercise machine and the 9 exercises selected focused on major muscles for the upper and lower body. The exercises were leg press, bench press, leg extension, shoulder press, seated row, calf raise, latissimus pull down, triceps curl and biceps curl. The training intensity is at 80% of 1RM voluntary to failure. Physical trainer is present to observed participants technique during the training and will intervene to stop any incorrectly performed procedures for safety reasons. All repetitions during the exercise are recorded.

### One Repetition Maximum Assessment Protocol (1RM)

The 1RM was carried out to determine the maximum weight that a participant can lift once through a full range of motion. The 1RM is taken from the 9 exercises which are leg press, leg extension, calf press, leg flexion, chest press, seated row, lateral pulldown, biceps curl and triceps curl. Strength machine being used for the test, each participant completed 10 repetitions with a light weight as a preliminary warm-up (muscle-specific warm-up). Following the warm-up, a weight was chosen that the

participants could probably lift with good form and through the full range of motion. Weights were gradually raised for the next tries, as determined by physical trainer, if the participants were able to lift the weight adequately, until the 1RM was established. The 1RM represented the highest load raised with proper technique and full range of motion. The load of 80% 1RM is used during the training program.

### Ultrasound Assessment Protocol

The BodyMetrix Ultrasound (BX2000) device is an A-mode single beam ultrasound to detect the improvement in muscle thickness. This simply means that the device acquires the tissue structure along a single line. The manufacturer of this device is IntelaMetrix, Inc., Livermore, CA. Measurements were performed on the dominant side in a supine position. Trochanterion and tibiale laterale land marking was employed to determine the midpoint of the thigh across the vastus lateralis. After that, the handheld ultrasound device (BodyMetrix BX2000) was used, after application of ultrasound gel, to measure muscle thickness between 35-65% of the thigh length along the belly of the vastus lateralis. Measurements of muscle thickness were then made by clicking on the subcutaneous fat layer and the inferior edge of the vastus lateralis muscle. Muscle thickness results are then displayed.

## DATA ANALYSIS

All data were presented as mean ± standard deviation (SD) and analysed using SPSS (version 27). The baseline (pre) and post-test were analysed by using the paired sample t-tests. This paired sample t-tests, it compared the baseline and post intervention of the research. The data were analysed from muscle strength and muscle thickness.

## RESULTS

### Anthropometric profile

This study was conducted by random sampling in 12 women (n = 12) residing in Perlis, Malaysia area, aged between 18-45 years old and with a Body Mass Index (BMI) 28.9 ± 3.2 kg/m² in the overweight category, height (cm) 157.7 ± 4.7, and weight (kg) 71.9 ± 8.9. The participants were free from injury and medical history of disease that precluded them from physical exercises. Participants did not engage in any moderate to high intensity aerobic exercises or resistance training for the past 2 years.

**Table 1: Anthropometric and Physical Characteristics of the Subject**

| | | **(n = 12)** |
|---|---|---|
| | Baseline | Post |
| Age (y) | 31 ± 8 | 31 ± 8 |
| Height (cm) | 157.7 ± 4.7 | 157.7 ± 4.7 |
| Weight (kg) | 71.9 ± 8.9 | 71.9 ± 8.4 |
| BMI (kg/m²) | 28.9 ± 3.2 | 28.8 ± 3.0 |
| Data are mean ± SD | | |

## Total Sum of Muscle Strength

As shown in Table 2, there were increases ($P < 0.05$) in 1RM for all the exercises with 6 weeks of resistance training voluntary to failure exercise. For the sum of the individual 1RMs, there was 31.0 ± 8.2 % increases after 6 weeks of resistance training voluntary to failure.

**Table 2: One-Repetition Maximum (1RM) For Training Exercises Before and After 6 Weeks of Resistance Training Voluntary to Failure**

| Exercise | | Baseline (kg) | Post-intervention (kg) | Percentage Increase (%) |
|---|---|---|---|---|
| Lat pulldown 1RM | | 38.6 ± 10.3 | 48.0 ± 11.4* | 19.6 ± 5.3 |
| Chest press 1RM | | 41.7 ± 16.8 | 60.4 ± 23.9* | 31.0 ± 14.7 |
| Seated row 1RM | | 34.7 ± 13.3 | 46.3 ± 16.6* | 25.0 ± 9.0 |
| Biceps curl 1RM | | 19.4 ± 7.3 | 26.8 ± 6.9* | 27.4 ± 18.5 |
| Triceps curl 1RM | | 26.2 ± 10.7 | 33.9 ± 11.8* | 22.9 ± 12.0 |
| Leg extension 1RM | | 46.0 ± 11.8 | 57.9 ± 11.5* | 20.6 ± 10.9 |
| Leg flexion 1RM | | 12.0 ± 8.6 | 17.1 ± 11.1* | 30.2 ± 13.9 |
| Leg press 1RM | | 83.3 ± 33.8 | 125.9 ± 34.3* | 33.9 ± 14.2 |
| Calf press 1RM | | 67.8 ± 21.1 | 119.3 ± 33.1* | 43.2 ± 13.8 |
| Sum of individual 1RMs | | 369.5 ± 87.0 | 535.6 ± 88.7* | 31.0 ± 8.2 |

Data are means ± SD. *Significant ($P < 0.05$) difference from baseline values (n=12)

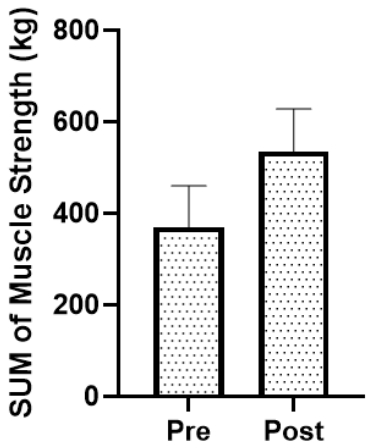


**Figure 1**: **Sum of Muscle Strength (kg) in response to 6 weeks of resistance training voluntary to failure exercise.**
**Data are presented as means ± SD. *Significant ($P < 0.05$) difference from baseline values.**

As seen in figure 1, there is a significance difference (p = < 0.05) between percentage change 31.0 ± 8.2 on sum of muscle strength in response of resistance training voluntary to failure exercise. Overall, the sum of individual 1RMs was higher after the intervention, when compared with baseline.

### Total Sum of Muscle Thickness

**Table 3: Muscle Thickness on Vastus Lateralis (VL) Before and After 6 Weeks Of Resistance Training Voluntary To Failure**

| | Baseline (mm) | Post- Intervention (mm) | Percentage Increase (%) |
|---|---|---|---|
| Muscle Thickness | 33.47 ± 4.0 | 35.30 ± 3.9* | 5.2 ± 4.6 |
| Data are means ± SD. *Significant (P < 0.05) difference from baseline values (n=12) | | | |

As seen in table 3, there is a significance difference (p = < 0.05) between percentage change 5.2 ± 4.6 on vastus lateralis (VL) in muscle thickness acquired after 6 weeks of resistance training voluntary to failure exercise.

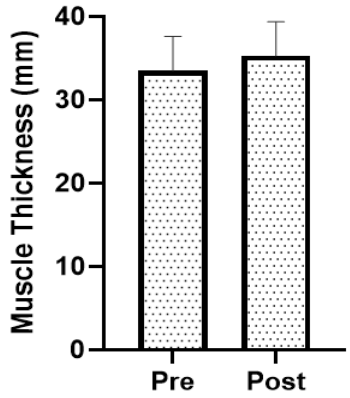


**Figure 2**: **Vastus Lateralis (VL) Changes in Muscle Thickness Acquired Via Body Metrix BX2000 After 6 Weeks of Resistance Training Voluntary To Failure**

## DISCUSSION

This study proven that 6 weeks of resistance training voluntary to failure which included nine exercises on major muscles, taking 20 minutes per session undertaken three times per week, resulted in improvement on muscle strength in healthy overweight women. As mentioned, the training was conducted with 80% of 1RM voluntary to failure. Previous study has demonstrated that 6 weeks of resistance training voluntary to failure improved by 18% in muscle strength, but the subjects were involved overweight men residing in Glasgow (Ismail et al., 2019). Based on this study, we found that only 6 weeks of such simple resistance training voluntary to failure can increase by 31% of muscle strength in Malaysian overweight women. This is the first study to our knowledge that has investigate the 6 weeks of resistance training voluntary to failure in overweight women. Similar finding in the increment of muscle strength at 30% and 80% was mentioned in Stefanaki et al., (2019) but it was conducted towards tyoung women. According to a study, muscle strength developed gradually over the course of 6 weeks, but muscle thickened, and protein synthesis were boosted during the first half of the intervention, not the second. It has been proposed that increase in muscle size helps to increase the

amount of contractile tissue, which in fact increases muscular strength. An important breakthrough in this area was the discovery of two phases in resistance training, the first phase where the increase in strength was neural in origin and the second muscle hypertrophy took over as the primary contributor to strength gain. Conforming from Mitchell et al., (2012) the relative training load had no effect on the size of the hypertrophic response, it did have a noticeable effect on increases in voluntary isotonic strength. In comparison to the 30%-3 group, there was a greater gain in 1RM strength in the 80%-1 and 80%-3 circumstances. These findings imply that significant relative load practice is required to enhance improvements in 1RM strength of the trained exercise. Strength increases were specific to the exercise trained and resulted with combination of muscle hypertrophy and neural changes. In a previous study found there was a significant increase detected by using an A mode Body Metrix ultrasound device at vastus lateralis muscle thickness by 6.2% after completed the 8 weeks of resistance training exercise (Ismail et al.,2019). Appealingly, this study is able to show that the muscle thickness increases up to 5.2% in 6 weeks of resistance training voluntary to failure specifically in overweight women. Another previous study of implementing the 6 weeks of resistance training voluntary to failure in young women by Stefanaki et al., (2019) comparing data for low (30% 1RM) and high (80% 1RM) load at both arms and legs showed an increment in muscle thickness. For vastus lateralis, the muscle thickness increased to 9.4% and 9.3%, similarly to biceps brachii 6.8% and 5.9%. Skeletal muscle mass is a crucial method for maintaining health over the long term and to activate all motor units, muscle fibers and maximize muscular growth the heavy loads are necessary. For this reason, several researchers have proposed that greater loads are necessary to assure activation, exhaustion, and subsequent hypertrophy of all muscle fibers to maximize improvements in muscle mass and strength. Interestingly, this present study found there were a significant correlation between muscle strength and muscle thickness in 6 weeks of resistance training voluntary to failure ($p < 0.05$). This study possessed certain limitation where it mainly focused on overweight women who able to make adjustment on daily schedule, time, and be committed to the training completely. In addition, this study did not concentrate on adhering to a particular dietary plan (routine diet) and not specifically a weight loss training program as people thought. Therefore, resistance training voluntary to failure is one method for increasing muscle strength and muscle size regardless of the load used for the exercise. This may simplify the method of prescribing exercises that take less time.

## CONCLUSION

In conclusion, the present study has shown that 6 weeks of resistance training voluntary to failure performed at 80% of 1RM for three session per weeks resulted in the improvement on muscle strength and increment of muscle thickness in healthy overweight women ($p = < 0.05$). Such exercise, which is of shorter duration than the more traditional and recommend multiple-set resistance exercise training, might be functional to improve muscle, metabolic health as well as well-being.

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## AUTHORS' CONTRIBUTION

Dzulkarnain, A., Puteri, A., and Gray, S. conceived and planned the experiments. Dzulkarnain, A. and Puteri, A. carried out the experiments and data preparation. Zulkifli, I. and Syahirah, A. planned and carried out the simulations. Syahirah, A. and Gray, S. contributed to the interpretation of the results. Dzulkarnain, A. and Puteri, A. took the lead in writing the manuscript. Gray, S., Zulkifli, I., and Irzat, R. provided critical feedback and helped shape the research, analysis, and manuscript.

## CONFLICT OF INTEREST DECLARATION

We certify that the article is the Authors' and Co-Authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication nor has it been published in whole or in part elsewhere. We testify to the fact that all Authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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