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The Effect of Resistance Training to Failure on Insulin Sensitivity and Muscle Adaptations in Overweight Men

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ABSTRACT

Background: Insulin resistance, systemic inflammation, body fat development, and energy imbalances are all associated with inactivity. In Asian populations, resistance training (RT) has been proven to be similarly helpful for diabetic controls. RT voluntary to failure is the inability to perform a repetition over a full range of motion with a given overload due to fatigue and more advantageous since it ensures the recruitment of most motor units and muscle fibres. Objective: To investigate the effects of 6 weeks of resistance exercise training, compromised of 1 session/week (RT1) and 3 sessions/week (RT3) voluntary to failure on overweight men. Besides that, this study also determine the early time – course of RT voluntary to failure on muscle strength, and muscle mass on overweight men. Methods: 20 overweight men have engaged in a program of 6 weeks RT voluntary to failure. The exercises consist of upper and lower exercises; inclined leg press, bench press, leg extension, shoulder press, hip abduction, seated row, calf raise, latissimus pulldown, and biceps curl. For group RT1, participants performed the exercise in one session per week, while participants of group RT3 did the exercise in 3 sessions per week. Each participant performed approximately 60 minutes of RT voluntary to failure every week at 80% of their one-repetition maximum (1RM) effort. The 1RM test was performed at baseline, week 3 of RT and post–intervention while insulin sensitivity (HOMA – IR) was performed at baseline and post-intervention. Result: Insulin sensitivity – HOMA-IR difference of 1.07% (RT1) and 2.78% (RT3), Muscle mass (kg) increment of 1.44% (RT1) and 1.13% (RT3), and body fat (%) decrement of 1.41% (RT1) and 2.95% (RT3). The differences in the total sum of strength for both groups were not more than 10% of the nine exercises RT voluntary of failure for 6 weeks, 3891kg (RT1) and 3745kg (RT3). Conclusion: An improvement in insulin sensitivity (HOMA – IR), muscle mass (kg) and body fat (%) were seen after 6 weeks of single–set RT voluntary to failure in both groups. However, RT1 had an improvement in muscle mass only while RT3 had good results in insulin sensitivity and body fat (%). Both groups experienced an increase in muscle strength. By our findings, RT voluntary to failure can assist those in overweight population to improve their insulin

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sensitivity and muscle adaptations and it can also be utilised as a substitute for those who had a time constraint to exercise.

Keywords: *body fat, insulin sensitivity, muscle mass, muscle strength, resistance training voluntary to failure*

INTRODUCTION

Skeletal muscle has an often-underappreciated role in health (Wolfe, 2006) with low muscle strength being linked with an increased risk of a range of poor health outcomes, including all-cause, cardiovascular disease (CVD), cancer, and respiratory disease mortality (Celis-Morales et al., 2018). Low muscle mass may influence the development of insulin resistance and Diabetes Miletus Type-2 (T2DM) because skeletal muscle is a significant location for glucose absorption and deposition, and so plays an essential role in the regulation of blood glucose levels (Han et al., 2018). Therefore, not surprising that the current physical activity recommendations include advice for adults to perform muscle-strengthening activities two days per week (Samuelson, 2004).

The resistance training (RT) had been shown to be equally effective for glycaemic control in Asian population. Progressive RT has added advantages in terms of increasing the muscle strength. A previous studied had also summarised that progressive RT leads to review clinically significant reductions in glucose level (Hameed et al., 2012). The recommending resistance exercise training takes into consideration many variables, including the number of sets, repetitions, and load. For novice lifters, the American College of Sports Medicine (ACSM) recommended RT 2-3 days per week with 1-3 sets of 8-12 repetitions with a training load of 60-85% one-repetition maximum (1RM) which promotes muscular hypertrophy and can maximize strength (Brad et al., 2014). Intensity is the most important variables for effective RT, where multiset protocols with moderate repetitions schemes and short inter-set rest intervals is introduce to optimise the hypertrophic response (Stefanaki et al., 2019).
RT voluntary to failure is the inability to perform a repetition over a full range of motion with a given overload due to fatigue. Theoretically, training for temporary muscular failure is more effective since it ensures that as many motor units and muscle fibers as feasible are recruited (Ismail et al., 2019). There are a few studies that evaluated resistance to failure in terms of muscle adaptation and insulin sensitivity. Ismail et al's (2019) study has been shown with ten overweight men on the Caucasian population did the RT voluntary to failure with three times per week. The result's study showed improvement of muscle increase and 16 % insulin in the 6 weeks by RT voluntary to failure exercise program. It also shown that a time – efficient with the session lasting 15 min until 20 min only. This may have important public health implications as the time commitment of exercise can be reduced, and it is well established that time is a major barrier to exercise participation (Trost et al., 2002). However, it remains to be established if this shorter duration form of exercise is able to improve insulin sensitivity and muscle adaptations in Malaysia overweight population.

Therefore, this study investigated the effects of the 6 weeks of resistance exercise training, compromised of 1 session/week and 3 sessions/week to voluntary failure, on i) insulin sensitivity and ii) the time-course of adaptations in muscle strength and muscle mass in overweight men.

LITERATURE REVIEW

Resistance training voluntary to failure

RT is main method of exercise that can improving muscle mass and strength but RT voluntary to failure was recommended to maximize the progression. It has been suggested that RT be performed

until muscle failure, which is defined as the point at which the engaged muscles are unable to complete another repeat in the appropriate range of motion (Bell, 2009). The American College of Sports Medicine (ACSM) recommends that the frequency of training be determined by volume, intensity, level of conditioning, recovery ability, number of muscle groups exercise each workout, and activity selection, primarily for beginners. They suggested that novices should train the full body 2-3 times per week, whereas intermediates should train 3 times per week if total body training is desired (Fisher et al., 2011). In a previous studies, training to muscle failure resulted in much higher gains (41.2 % to 19.7%) in dynamic strength compared to submaximal sets of exercise, as well as significantly higher improvements in isometric strength compared to ending the exercise short of failure (Fisher et al., 2011).

Effect to muscle adaptations

RT has regularly been demonstrated to result in rapid and significant gains in muscular strength and hypertrophy in a number of populations. The prescription of RT factors such as load, volume, and inter-set rest time influences the optimization of muscle adaptations (Brad et al., 2014). The effect of muscle adaptations more effective in long term duration including muscle mass, muscle strength (muscle and body fat percentage. Increases in muscle mass, which provide a bigger reservoir for glucose disposal, and direct effects on skeletal muscle that increase glucose transport activity are both possible outcomes of RT exercises (Jessee, 2018). Because the muscle linked to full muscle fibre recruitment and type II fibre activation, which are known to be more hypertrophy-responsive, the motor unit engaged in muscle strength requires large relative training loads to generate hypertrophy.

Effect to insulin sensitivity

Insulin resistance is a typical symptom of ageing, and it can promote the loss of skeletal muscle mass by lowering the physiological effects of insulin. Plasma glucose levels will rise and T2DM will start to develop if insulin resistance keeps increasing and the compensatory increase in insulin production is insufficient. RT is a useful tool for improving insulin sensitivity and controlling body composition in obese people who have sedentary lifestyles (Mogharnasi et al., 2019). The previous study found that 6 weeks of RT voluntary to failure, consisting of one set to volitional failure of nine exercises lasting 15–20 minutes per session and performed three times per week, improved insulin sensitivity by 16 % in healthy and overweight men (Ismail et al., 2019).

METHODS

Participants

This study was participated by a total 20 randomly sampled overweight men, aged between 18 – 45 years old who resided in Perlis, Malaysia. These participants have a Body Mass Index (BMI) >25kg/m² - 29.9kg/m^2 category. Besides that, they were identified as free from injury, metabolic or cardiovascular disease, normotensive (blood pressure <140/90mmHg), and did not participate in any moderate to high intensity aerobic exercise or resistance exercise in the past 2 years. The participants were divided into 2 groups; first group (RT1) did 1 session/week of resistance exercise to failure while second group (RT3) did 3 sessions/week of resistance exercise to failure for 6 weeks.

RT voluntary to failure protocol

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 are with the equipment and measurement protocol used in this study. Next, participants were engaged in a preliminary measurement that includes insulin level; Homeostatic Model Assessment for Insulin

Resistance (HOMA – IR), muscle mass (kg), body fat (%) and pre -1RM (muscle strength). The other variables such as blood glucose, a food diary's form for 7 days (MyFitnessPal software), and physical activity (PA) measurement by using the Garmin Forerunner 745 for 7 days also took in baseline measurement for anthropometric profile only. 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. For group RT1, participant did one session exercise per week, while the RT3 did the exercise for 3 sessions per week. The RT exercise was performed using exercise machine for the beginner and the 9 exercises focused on major muscles for the upper and lower body. The exercises were incline leg press, bench press, leg extension, shoulder press, hip abduction, seated row, calf raise, latissimus pulldown and biceps curl. After 6 weeks of RT voluntary to failure exercise, the participants performed a post measurement of insulin level; Homeostatic Model Assessment for Insulin Resistance (HOMA – IR), muscle mass (kg), body fat (%) and post-1RM (muscle strength). This study was approved by the Research Ethic Committee of Universiti Teknologi MARA, REC/12/2021 (UG/MR/1027) and adhered to the ICH Good Clinical Practice Guidelines, Malaysia Good Clinical Practice Guidelines and the Declaration of Helsinki.

Data analysis

All data were presented as mean ± standard deviation (SD) and analysed using SPSS (version 27). Paired t-tests were performed to compare the pre and post values within each exercise group RT1 and RT3 to examine the main effect of different RT exercise session (RT1 and RT3) on insulin sensitivity and muscle adaptation. The data was analysed using two – way analysis of variance (ANOVA) for repeated measures to compare the difference changes related variables over times between RT1 and RT3. These variables included muscle mass, body fat percentage, and insulin sensitivity (HOMA-IR). Mauchly's test of sphericity applied, and sphericity violate estimate the Greenhouse - Geisser was used to correct the data. When significant differences between groups were identified, post hoc Student's t tests using the Holm-Bonferroni adjustment were performed. The significance was set at $p \leq 0.05$.

RESULTS

Anthropometric profile

The number of participants in RT3 and RT1 was ten (n=10) respectively. The anthropometric and physical characteristics of the participants were shown in Table 1.

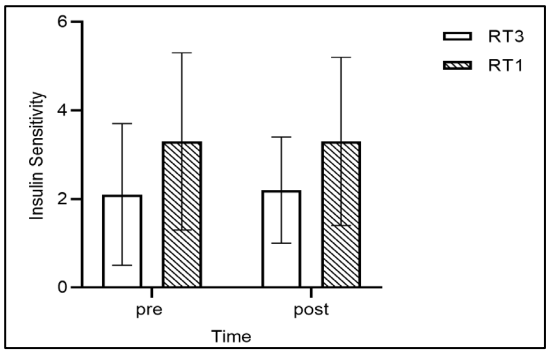
Table 1 Anthropometric and physical characteristics of the subject.

		RT3	RT1
		n = 10	n = 10
Age		21 ± 2	34 ± 9
Height (cm)		171.6 ± 3.9	169.9 ± 6.7
Weight (kg)			
	Pre	85.5±8.1	87.2 ± 11.5
	Post	83.3 ± 8	85 ± 11.6
BMI (kg/m^2)		28.3 ± 2.8	29.4 ± 3.1
Blood pressure (mmHg)			
Pre	systolic	139.7 ± 19.7	124.4 ± 10.7
	diastolic	84.2 ± 14.8	83 ± 8.9
Post	systolic	126.1 ± 9.3	124.5 ± 10.4
	diastolic	76.5 ± 13.3	77.8 ± 8.5
Nutrition (g)			
Protein		316.4 ± 193.7	321.5 ± 63.8
Carbs		645.1 ± 98.7	909.6 ± 174.2
Fats		167.4 ± 36.3	232.1 ± 37.5

Garmin Forerunner 745		
Steps (per/day)	6802 ± 2502	5115 ± 2361
Calories burn (kcal/day)	2145 ± 452.63	2191 ± 104.81

Note: RT3: resistance training 3 times per week; RT1: resistance training 1 time per week; BMI: body mass index. Data was presented as mean ± SD

Insulin sensitivity (HOMA – IR)



The changes in insulin sensitivity (HOMA – IR) were identified between RT3 and RT1, with the value of 2.78% and 1.07% respectively. However, no significant effect of time and effect of exercise towards changes of insulin sensitivity were observed in this study (Figure 1).

Figure 1: Changes in HOMA - IR between RT3 and RT1 for 8 weeks of exercise training.
Data was presented as mean ± SD. RT3: resistance training 3 times per week.
RT1: resistance training 3 times per week.

Muscle adaptations

The percentage difference in muscle mass for RT3 was 1.13% increment, whereas for RT1 was 1.44% increment. For the differences in body fat, the pre and post – test recorded for RT3 were 2.95% decrement, whereas for RT1 was 1.41% decrement in body fat. Paired t – test result for muscle mass and body fat percentage shown a significant statistic effect ($p < .005$), specifically on the effect of time and effect of exercise for muscle mass (Figure 2) and body fat percentage (Figure 3).

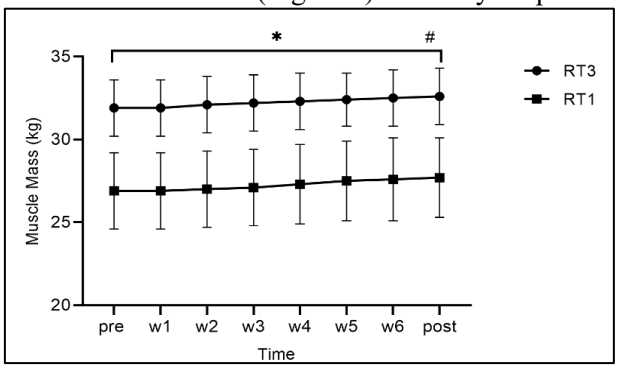


Figure 2: Changes in muscle mass (kg) between RT3 and RT1 for 8 weeks of exercise training.
#Significant effect of time. *Significant changes in muscle mass between RT3 and RT1 at each time point. Data was presented as mean ± SD. RT3: resistance training 3 times per week; RT1: resistance training 3 times per week.

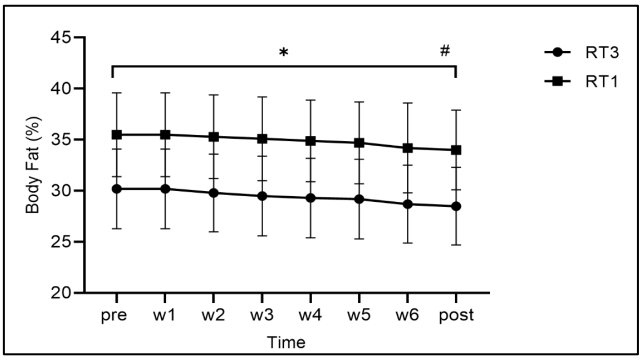


Figure 3: Changes in the body fat (%) between RT3 and RT1 for 8 weeks of exercise training.

#Significant effect of time. *Significant changes in muscle mass between RT3 and RT1 at each time point. Data was presented as mean ± SD. RT3: resistance training 3 times per week; RT1: resistance training 3 times per week.

Total sum of strength

The total sum of strength (kg) in both groups; RT3 (967.72 ± 1005.67) and RT1 (924.11 ± 1075.56) shown an improvement from baseline pre-measurement until 6 weeks of exercise program training and post–measurement. Specifically, the Shoulder Press differences between RT3 and RT1 were 20%, the Bench Press differences between RT3 and RT1 were 26%, the Leg Press differences between RT3 and RT1 were 1%, the Leg Extension differences between RT3 and RT1 were 1.1%, the Calf Rotary Raises differences between RT3 and RT1 were 1%, the Seated Rowing differences between RT3 and RT1 were 10%, the Lat Pulldown differences between RT3 and RT1 were 8%, the Biceps Curl differences between RT3 and RT1 were 8%, and the Hip Abduction differences between RT3 and RT1 were 1.6%.

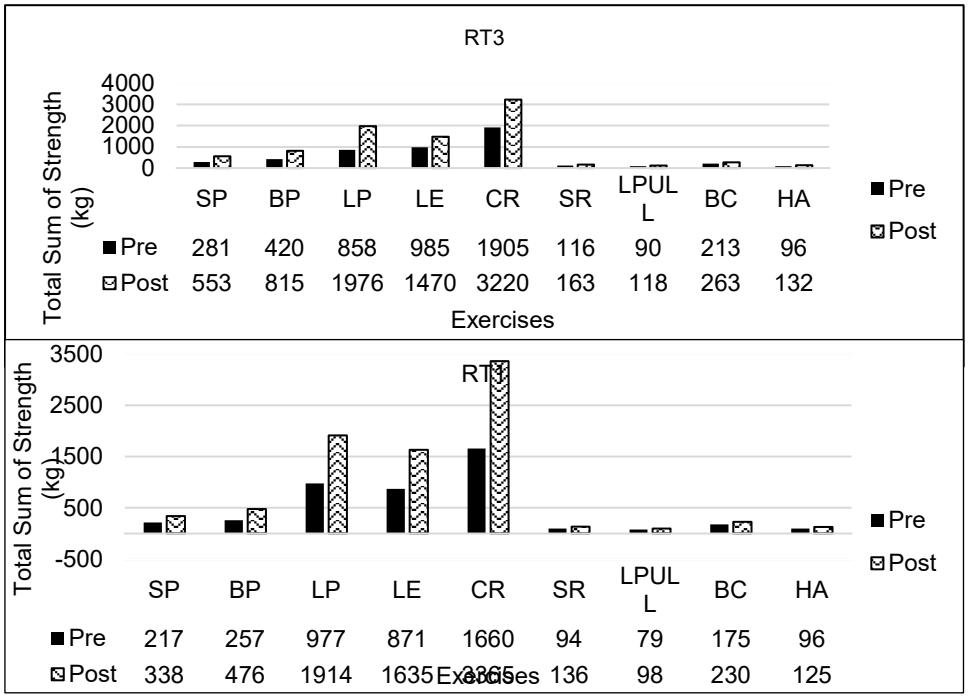


Figure 4: (i) (ii) Number of total sums of strength (kg) between RT3 and RT1 for 9 exercises training voluntary to failure.

Data was presented as a total sum. RT3: resistance training 3 times per week; RT1: resistance training 3 times per week. SP: shoulder press; BP: bench press; LP: leg press; LE: leg extension; CR: calf rotary raise; SR: seated rowing; LPULL: lat pulldown; BC: biceps curl; HA: hip abduction.

DISCUSSION

This study proven that 6 weeks of RT voluntary to failure included nine exercises on major muscle, resulted an improvement in muscle mass higher in RT1 than RT3 while insulin sensitivity and body fat percentage more advancement in RT3 than RT1. As the mentioned, RT1 had done the training 3 sets of 80% 1RM voluntary to failure per day than RT3 only done 1 set of 80% of 1RM voluntary to failure per day. In previous study, the researcher shown that performing multiple sets of resistance exercise does not result in greater gains than performing single sets to temporary muscular failure and is therefore less time and energy efficient (Fisher et al., 2011). RT1 observed had a significant result in muscle mass increase between effect of time and effect of exercise.

Interestingly, the value of blood pressure of pre baseline measurement and post measurement for both groups also recorded increased values. This was proven by Ashton et al., (2020) had a significant improvement in systolic and diastolic blood pressure either in long term or shirt term resistance exercise training. This signifies that the participants had a neural adaptation of their body. In a prior study, the researcher suggested that training at 80% of 1RM for 6 weeks resulted in greater neural adaptations than training at 30% of 1RM, which may ultimately account for the greater gains in muscle strength seen after high-load training (Jenkins et al., 2017). The differences in total sum of strength identified for RT1 and RT3 were not more than 10% in nine exercises of RT voluntary of failure. In the recent study, similar to performing three or five repetitions of each exercise, the 1SET training condition may be useful in increasing muscle strength. According to these results, resistance-trained individuals can significantly increase their levels of strength with just as 39 minutes of weekly RT and yet see gains that are on level with those made with a five-fold longer time commitment (Schoenfeld et al., 2019). RT voluntary to failure training program beneficially among overweight population especially towards T2DM patients in insulin sensitivity. In previous study, an improvement in insulin sensitivity of 16% was seen in healthy men who performed one set of nine exercises to voluntary failure, lasting 15-20 minutes per session (Ismail et al., 2019). In addition, there was a study indicated that a single resistance training session of 60 – 80% of 1RM for 24 weeks on obese women had a favourable effect on blood sugar and insulin levels for 18 to 24 hours after exercise (Campa et al., 2020). However, in this study both groups recorded no significant increase in insulin sensitivity between the effect of time and effect of exercise. In the previous three studies, no significant effect of resistance training on insulin sensitivity was identified. These researchers assumed that a rigorous diet and strength training programme may have attempted to alter too many health habits, resulting in a diminished potential effect (Ismail et al., 2022).

As a recommendation, it is advised that the sample should be larger and include women for the next study. Based on prior research, the researchers' focus in their study of the women's population of RT voluntary to failure was primarily on the Caucasian demographic (Stefanaki et al., 2019) has shown that had increases in muscle size and strength are same, at 30 or 80% of 1RM, after 6 weeks of resistance training, 1 set to volitional failure, in young women. Additionally, it was advised to adhere more strictly to a food intake during the training programme to get better results for pre- and post-measurements of blood glucose and insulin levels.This study had a limited sample size have restricted the ability to identify differences between the groups. Also, this study focused mainly on sedentary, overweight man.

CONCLUSION

In summary, it has been verified that RT voluntary to failure helps the population of overweight men by improving muscle adaptation and insulin sensitivity. An improvement in insulin sensitivity (HOMA – IR), muscle mass (kg) and body fat (%) were seen after 6 weeks of single–set RT voluntary to failure in both groups. Both groups experienced an increase in muscle strength. However, RT1 had the best result in muscle mass (kg) by doing only once per week and 45 minutes of exercise RT

voluntary to failure while RT3 had the best result in body fat (%) and insulin sensitivity (HOMA – IR) with 3 times per week and 15 - 20 minutes per session of exercise RT voluntary to failure. As a result, RT voluntary to failure is significantly recommended to be introduced as an alternative to treatment for especially overweight populations and it can also be utilised as a substitute for those who had a time constraint to exercise.

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AUTHORS' CONTRIBUTION

Dzulkarnain, A., Syahirah, A., and Gray, S. conceived and planned the experiments. Dzulkarnain, A. and Syahirah, A. carried out the experiments and data preparation. Kamal, H. and Al Hafiz, A. planned and carried out the simulations. Kamal, H. and Gray, S. contributed to the interpretation of the results. Dzulkarnain, A. and Syahirah, A. took the lead in writing the manuscript. Gray, S., Ain, E., and Masshera, J. 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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