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The Effect of Resistance Training on Insulin Sensitivity: A Systematic Review

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ABSTRACT

Background: Despite the increasing number of research claiming that resistance training (RT) has an influence on insulin sensitivity, there is still lack of systematic review conducted to determine the degree of evidence. Objective: Therefore, the primary objective of this review was to study the effect of resistance training on insulin sensitivity by examining the available literatures. Methods: A search of all published studies that examined the effect of resistance training on insulin sensitivity were examined using PubMed and Science Direct databases. Specifically, the keywords used were 'resistance training, strength training, insulin sensitivity, insulin resistance'. During the retrieval process, all articles were rigorously reviewed with exclusion on those that did not fulfill the criteria. Result: Initially, 650 articles were screened and checked for duplication, and 252 articles were retained. The 252 articles were then thoroughly examined through full-text reading. As a result, 23 articles met all the inclusion criteria and were eligible for systematic review. Conclusion: We can conclude that resistance training is an effective way to improve insulin sensitivity.

Keywords: insulin resistance, insulin sensitivity, resistance training, strength training

INTRODUCTION

Physical activity and exercise have traditionally been linked with cardiometabolic disease indicators. Over the last several decades, experimental researchers have revealed that exercise interventions can enhance specific markers of cardio-metabolic health (Burns, Brusseau & Hannon, 2017). Aerobic exercise, which includes walking, cycling, swimming, and jogging, is typically the most researched activity since it has a significant relationship with the health-related fitness components (Armstrong, 2013). Despite the effectiveness of some of these intervention, numerous interventions were lack of strategies to maintain interest, quality, and enjoyment over time, which gave impact on program adherence (Burns, Fu & Podlog, 2017).

Resistance training is another type of exercise that has the potential to improve cardio-metabolic health (Faigenbaum, 2017). Resistance training has generally been accepted as an effective therapeutic strategy for the treatment of a variety of chronic illnesses (Schmitz et al., 2005). People who are overweight or obese may find resistance training to be a pleasurable activity since most of them suffer from mobility issues (Kumar et al., 2019). It may be difficult for this population to achieve the desired intensity and volume of aerobic exercise; thus, resistance training may have been more effective (Kumar et al., 2019). Resistance training may be more successful for those with a heavier body weight since they have more absolute strength than people with a lesser body weight, which may improve their self-efficacy and satisfaction, resulting in long- term adherence to the training program (Colella et al., 2009).

While observational studies linking muscular strength and endurance to particular health markers, it is uncertain if resistance training programs can enhance insulin sensitivity markers in experimental research settings (Burns et al., 2019). Due to the increased rates of type 2 diabetes diagnoses in children and adolescents (Mayer-Davis, 2017), developing strategies to reduce the occurrence of metabolic dysfunction has become a crucial public health concern (Burns et al., 2019). If resistance training can be proven to enhance metabolic health markers, then it can be used as a feasible alternative to aerobic training to enhance metabolic function markers (Burns et al., 2019).

The pooled effects of variety resistance training interventions on metabolic health, particularly measures of insulin and glucose homeostasis, in diverse populations such as obese (Marson et al., 2016), type 2 diabetes mellitus (T2DM) (Nery et al., 2017), youth (Burns et al., 2019), has been demonstrated by several systematic reviews and meta-analyses. The biological mechanism of action is partly caused by the actions of the GLUT4 protein (amongst other), where it improves glycemic control for a few hours after the exercise program has ended (Holten et al., 2004). This mechanism helps to improve insulin sensitivity, which reduces the risk of type 2 diabetes and its related co-morbidities (Lee et al., 2017). Remarkably, most of those metabolic enhancements obtained from resistance training in adults are independent with the changes in body composition (William et al., 2007).

As formerly mentioned, aerobic exercise has been the research hot topic. Researchers discovered that exercise (both aerobic and resistance) enhanced indicators of fasting insulin and insulin sensitivity in adolescents in one meta-analysis (Fedewa et al., 2014). However, it is difficult to examine the effect of resistance training on the metabolic health since it combined both aerobic and resistance training in the intervention. In addition, the review investigated at a variety of measures, including fasting insulin, rather than just insulin sensitivity. Fasting insulin, according to some experts, is a poor indicator of insulin sensitivity/resistance (Levy-Marchal et al., 2010).

While there is a growing number of publications about the effect of resistance training on insulin sensitivity, there is still lack of systematic reviews on this study that has been performed. Many systematic reviews only focus on one population; thus, this review compiled the effect of resistance training on insulin sensitivity on various population, including overweight/obese, T2DM patients, and also youth. This review attempts to fill the gap in understanding the research pattern and trends regarding the effect of resistance training on insulin sensitivity. Therefore, the primary objective of this review was to study the effect of resistance training on insulin sensitivity by examining the available literature.

METHODOLOGY

The systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Shamseer et al., 2015).

PRISMA

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta- Analyses) is a set of guidelines for conducting systematic reviews and meta-analyses to evaluate treatment effectiveness. Since there are currently lack of protocol guidelines for systematic reviews that are not even investigating efficacy of interventions, authors are also recommended to use PRISMA. PRISMA is essential as: 1) it enables authors to organize thoughtfully and thus predict possible issues; 2) it allows authors to consciously document what has been planned before they begin their review; 3) it hinders absurd articles selection in terms of eligibility criteria and data extraction; and 4) it has the potential to decrease duplication of work (Shamseer et al., 2015).

Search Strategy and Data Source

A search of all published studies on the effect of resistance training on insulin sensitivity were examined, with no restrictions on publication date. The following electronic databases were used in the search: PubMed and Science Direct. These two databases were chosen because of their credibility, which is critical in ensuring the quality of the journals examined in this paper. These two terms were listed in the search: resistance training and insulin sensitivity. A manual search of the references from the studies listed in the selected databases was also conducted. Only articles previously published in journals were selected by the author. Dissertations and theses were not accepted.

Identification and Duplication

Identification is the first step in the systematic review process. The procedure involved identifying keywords for the purpose of searching for information. Specifically, the keywords used were 'resistance training, strength training, insulin sensitivity, insulin resistance'. This process yielded a result of 650 documents retrieved from both databases listed above. Duplicate studies were first deleted before the screening procedure could begin. A sum of 398 articles were identified to be duplicates and were removed, leaving 252 papers for the eligibility phase, which were manually reviewed for literature concentrating on resistance training and insulin sensitivity.

Screening Process (Eligibility Criteria)

Screening is a process in which articles are manually included or excluded based on the author's specific criteria. To locate relevant articles to be included in the systematic review process, inclusion, and exclusion criteria were set during the screening step. Studies were considered eligible if they matched the following criteria: 1) document type: article journal. Other sorts of documents were rejected, including review article, case study and books; 2) study design: experimental/intervention (randomized control trial, pre-test/post-test study); 3) intervention: resistance training only, separated from other training; 4) outcome indicator: insulin sensitivity or insulin resistance; 5) language: English. Table 1 shows the earlier mentioned inclusion and exclusion criteria.

Eligibility Process

The author independently evaluated the titles, abstracts, and full texts of the shortlisted studies to ensure that they met the eligibility requirements. During the retrieval process, all articles were rigorously reviewed with any that did not fulfill the criteria being excluded. After excluding irrelevant articles by screening the title and abstract, there were 79 articles to be reviewed thoroughly. A total of 23 articles were shortlisted after reading the full texts of the articles.

Data Extraction

The following data was extracted during the data extraction process:

1) authors and year of publication; 2) sample size; 3) population of the participants (age/diseases/ethnic); 4) exercise prescription during intervention (number of exercises, sets, repetitions, intensity, and rest interval); 5) intervention duration and exercise frequency per week; and 6) findings (result of the intervention). All data were independently extracted by the author.

Data Analysis

To analyze the data, the author utilized descriptive statistics. To account various sample numbers between studies, the author extracted the mean average % per research area of usability.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Document type	Article journal	Review articles, meta-analysis, case study, books
Study design	Intervention (Randomized control trial, Pre-test/Post-test study)	Observational study, interview, survey
Intervention	Resistance training only	Combined training program (aerobic + resistance training) or programs which do not include a significant element of resistance training
Outcome indicator	Insulin sensitivity or insulin resistance as an outcome	Measured other variables such as fasting blood glucose
Language	English	Non-English

RESULT

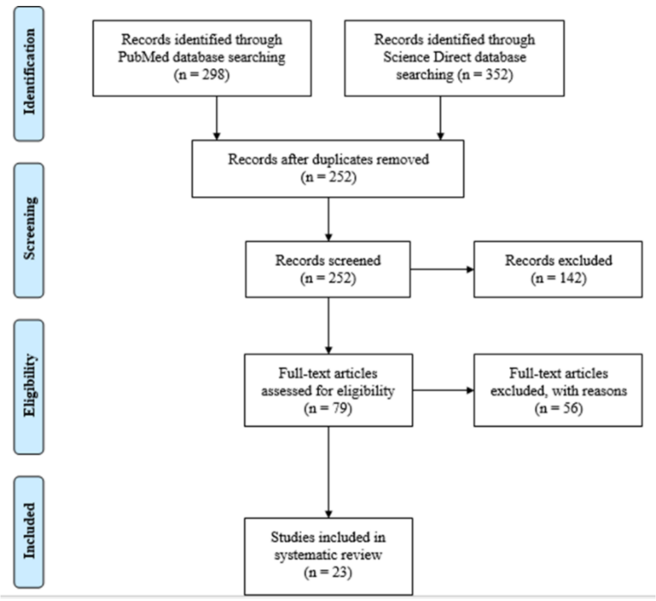

Figure 1. Flow diagram of systematic review process

Initially, 650 articles were screened and checked for duplication, thus 252 articles remained after exclusion of duplicated articles. The remaining articles' titles and abstracts were then assessed for eligibility based on inclusion criteria, and 142 articles were found to be ineligible. The remaining studies (n=79) were thoroughly examined by reading the full text of the study. As a result, 23 studies met all the inclusion criteria and were eligible for systematic review. Table 2 summarized the shortlisted studies.

Table 2. Demographics of Included Studies

No	Authors, pub year	Sample size	Population	Exercise prescription	Intervention duration and exercise frequency	Findings (mean ± se/sd)
1	Ahmadizad et al., 2014 Effects of short-term nonperiodized, linear periodized and daily undulating periodized resistance training on plasma adiponectin, leptin, and insulin resistance	N= 24 NP; No periodiza tion (n=8) DUP; daily undulatin g periodiza tion (n=8) LP; linear periodiza tion (n=8)	Overweight	5 whole body exercises. Week 1-2; 1 set of 10 repetitions at 50–60% of 1RM for all groups. **(NP)** Week 3-8; 2 sets of 12 repetitions at 70% 1RM **(DUP)** Week 3-8; Session 1; 2 sets of 16 repetitions at 55% 1RM; Session 2; 2 sets of 12 repetitions at 70% 1RM; Session 3: 2 sets of 8 repetitions at 85% 1RM **(LP)** Week 3; 2 sets of 18 repetitions at 50% 1RM; Week 4; 2 sets of 16 repetitions at 60% 1RM; Week 5; 2 sets of 14 repetitions at 65% 1RM; Week 6; 2 sets of 12 repetitions at 70% 1RM; Week 7; 2 sets of 10 repetitions at 75% 1RM; Week 8; 2 sets of 8 repetitions at 80% 1RM	8 weeks 3 times per week	The study's primary result was that DUP resistance training reduces insulin resistance index in overweight males more effectively than the NP and LP methods (from 2.7 ± 0.2 to 2.0 ± 0.2)
2	Alvarez et al., 2017 Effects and Prevalence of Non-Responders	N= 17	Overweight/ obese insulin resistant women	3 upper body exercises (free weight); 1 lower body exercise; 12 sets of 3	12 weeks 3 times per week	Reduced in HOMA-IR (-1.6 ± 1.0) from 4.4 ± 1.0 to 2.8 ± 1.0

	after 12 weeks of High-Intensity Interval or 2 Resistant Training in Adult Woman with Insulin Resistance: A Randomized Trial			repetitions at 20-50% of 1RM; 120 seconds rest between set		
3	Benson et al., 2008 The effect of high-intensity progressive resistance training on adiposity in children: a randomized controlled trial	N= 32	Children	5 upper-body exercises; 4 lower-body exercises; 2 abdominal exercises;80% 1RM (RPE 15-18); 2 sets of 8 repetitions	8 weeks Twice per week	Log HOMA2-IR increased (pre-test: 0.3 ± 0.4; post-test: 0.4 ± 0.5)
4	Brooks et al., 2006 Strength training improves muscle quality and insulin sensitivity in Hispanic older adults with type 2 diabetes	N= 31	Elderly with T2DM	5 exercises. week 1-8; 3 sets of 8 repetitions at 60-80% 1RM; week 9-16; 3 sets of 8 repetitions at 70-80% 1RM	16 weeks 3 times per week	Insulin resistance reduced from 7.1 (5.7) to 5.3 (5.5) *data in median (interquartile range)
5	Davis et al, 2009 Randomized Control Trial to Improve Adiposity and Insulin Resistance in	N= 17	Overweight/ obese Latino boys	Upper body and lower body split routine with compound and isolated movements; Nutrition education	16 weeks Twice per week	There were no significant intervention effects on insulin sensitivity (pre-test: 1.5 ± 0.9; post-test: 1.5 ± 0.8)

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	Overweight Latino Adolescents					

6	Davis et al., 2009
	
	Aerobic and Strength Training Reduces Adiposity in Overweight Latina Adolescents
		N= 9	Overweight Latino girls	Periodized; upper body and lower body split routine with compound and isolated movements.
				weeks 1-4 = 1 set of 10-15 repetitions at 62%- 71% of 1-RM;
				weeks 5-10 = 2 sets of 13-15 repetitions at 74%-88% of 1-RM;
				weeks 11-16 = 3 sets of 8-12 repetitions at 92%-97% of 1-RM; Nutrition education
					16 weeks
					2 times per week
						No improvement in insulin sensitivity

7	Hasson et al., 2012 Randomized Controlled Trial to Improve Adiposity, Inflammation, and Insulin Resistance in Obese African-American and Latino Youth	N= 31	Obese African-American and Latino adolescents	Upper body and lower body split routine with compound and isolated movements; Nutrition education	16 weeks Twice per week	Insulin sensitivity decreased by 6.9% for both ethnic
8	Ibanez et al., 2005 Twice-Weekly Progressive Resistance Training Decreases Abdominal Fat and improves Insulin	N= 9	Older men with T2DM	Periodized: 7–8 exercises. weeks 1–8 = 3-4 sets of 10-15 repetitions at 50–70% 1RM; weeks 9–16 = 3–5 sets of 5–6 repetitions at 70– 80% 1 RM; 20% of training: 3–4 sets of 6–8 repetitions at 30–50% 1 RM, as fast as possible	16 weeks Twice per week	Progressive resistance training significantly increased insulin sensitivity by 46.3% (From 2.0 ± 1.2 to 2.8 ± 1.6 • 10^4 • min^{-1} μU^{-1} ml^{-1})

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	Sensitivity in Older Men with Type 2 Diabetes					
9	Ishii et al., 1998 Resistance Training Improves Insulin Sensitivity in NIDDM Subjects Without Altering Maximal Oxygen Uptake	N= 9	Nonobese NIDDM patients	5 upper body exercises; 4 lower body exercises; 2 sets of 40-50% 1RM; 10 repetitions per set for upper-body exercises and 20 repetitions per set for all lower-body exercises; <1 min resting interval between set	4-6 weeks 5 times per week	The glucose disposal rate during the hyper insulinemic-euglycemic clamp increased 48% (6.85 ± 1.86 to 10.12 ± 3.15 mg • kg^{-1} lean body mass • min^{-1})
10	Ismail et al., 2019 The effect of short-duration resistance training on insulin sensitivity and muscle adaptations in overweight men	N= 10	Overweight men	9 exercises; one set each exercise to volitional failure at 80% 1RM	6 weeks 3 times per week	Insulin sensitivity increased 16.3 ± 18.7% (from 61.6 ± 18.0 to 71.3±22.9 mg l^2 $mmol^{-1}$ mU^{-1} min^{-1})
11	Jorge et al., 2011 The effects of aerobic, resistance, and combined exercise on metabolic control, inflammatory markers, adipocytokines, and muscle insulin signaling in patients with type 2 diabetes mellitus.	N= 12	T2DM patients	7 exercises (did not mention prescriptions)	12 weeks 3 times per week	Insulin resistance reduced from 4.54 ± 3.94 to 4.07 ± 2.90

12	Kelly et al., 2015 The effect of a home-based strength training program on type 2 diabetes risk in obese Latino boys	N= 13	Obese Latino adolescents	Home-based strength training (HBST): 3 periodized phases; weeks 1-4 = 1 set of 10-15 reps at light-to- moderate intensity; weeks 5-10 = 2-3 sets at 13-15 repetitions at moderate intensity; weeks 11-16 = 3-4 sets at 8-12 repetitions at moderate-to-high intensity	16 weeks Twice per week	There were no significant overall intervention effects on insulin sensitivity. These finding prove that HBST does not improve insulin sensitivity
13	Kolahdouzi et al., 2019 Progressive circuit resistance training improves inflammatory biomarkers and insulin resistance in obese men	N= 15	Young obese men	8 exercises. Week 1-4; 2 sets of 8-12 repetitions at 65-75% 1RM; Week 5-8; 4 sets of 6-8 repetitions at 75-85% 1RM; rest interval was 3 min between set	8 weeks 3 times per week	Decreased insulin resistance
14	Lee at al., 2019 Effects of Exercise Modality on Insulin Resistance and Ectopic Fat in Adolescents with Overweight and Obesity: A Randomized Clinical Trial	N= 28	Overweight/obese adolescent	8 exercises; 2 sets of 12-15 repetitions to volitional fatigue	6 months 3 times per week	Insulin-stimulated glucose disposal improved (0.7 ± 0.1 mg/kg/min)
15	Lee et al., 2012 Effects of Aerobic Versus Resistance Exercise Without Caloric Restriction on Abdominal Fat, Intrahepatic Lipid, and Insulin Sensitivity in	N= 12	Obese adolescent boys	Periodized; 10 whole body exercises. weeks 1-4 = 2 sets of 8-12 repetitions at 60% of 1-RM; weeks 4-12 = 2 sets of 8-12 repetitions to fatigue; 1-2 min rest in between sets	3 months 3 times per week	Insulin sensitivity improved significantly (0.8 ± 0.2 ml/kg/min per µU/ml); 27% improvements in insulin sensitivity was observed

	Obese Adolescent Boys					
16	Malin et al., 2013 Effect of adiposity on insulin action after acute and chronic resistance exercise in non-diabetic women	N= 20 NBF; Normal body fat (n=8) HBF; High body fat n=12)	Non-diabetic women	**Acute resistance training (ART):** 10 exercises; 3 sets of 10-12 repetitions at 60% 1RM; 30-90 second rest between set **Progressive resistance training (PRT):** 10 exercises; 3 sets of 8-12 repetitions at 60% 1RM; 90- 120 sec rest between set	7 weeks 3 times per week	Insulin sensitivity did not increase statistically after ART, whether in NBF or HBF women. PRT, on the other hand, increased insulin sensitivity by almost 95% in NBF women compared to HBF women.
17	Mavros et al., 2013 Changes in Insulin Resistance and HbA1c Are Related to Exercise-Mediated Changes in Body Composition in Older Adults with Type 2 Diabetes	N= 31	Elderly with T2DM	7 exercises; 3 sets of 8 repetitions at 80% 1RM	12 months 3 times per week	Insulin resistance (HOMA2-IR) increased from 2.73 ± 0.95 to 2.77 ± 1.05
18	Mogharnasi et al., 2019 Effects of upper-body resistance exercise training on serum nesfatin-1 level, insulin resistance, and body composition in obese	N= 20	Obese paraplegic men	5 exercises; 3 sets of 12 repetitions at 60-80% 1RM	8 weeks 3 times per week	Upper-body RT improved insulin sensitivity (8.95%). HOMA-IR reduced from 6.92 ± 1.27 to 6.30 ±1.01

	paraplegic men					
19	Mogharnasi et al., 2018 The Effects of Resistance and Endurance Training on Levels of Nesfatin-1, HSP70, Insulin Resistance and Body Composition in Women with Type 2 Diabetes Mellitus	N= 10	Women with T2DM	9 exercises; 3 sets of 10 repetitions at 30-80% 1 RM; 1- 2 min rest between each 2 sets; 3 min rest between each 2 exercises	10 weeks 3 times per week	Insulin resistance (HOMA1-IR) significantly decreased from 4.92 ± 3.54 to 2.87 ± 1.78
20	Shaibi et al., 2006 Effects of Resistance Training on Insulin Sensitivity in	N= 11	Overweight Latino males	Periodized; upper body and lower body split routine with compound and isolated movements. weeks 1-4 = 1 set of 10-15 repetitions at 62%- 71% of 1- RM;	16 weeks Twice per week	Insulin sensitivity increased 45.1 ± 7.3%
21	Slentz et al., 2011 Effects of aerobic vs. resistance training on visceral and liver fat stores, liver enzymes, and insulin resistance by HOMA in overweight	N= 52	Overweight adults	8 exercises; 3 sets of 8-12 repetitions; 5 pounds load was increased after completing all 3 sets with proper form on 2 consecutive sessions	8 months 3 times per week	Insulin resistance decreased (-0.09 ± 1.3)

	adults from STRRIDE AT/RT					
22	Suh et al., 2019 Effects of Resistance Training and Aerobic Exercise on Insulin Sensitivity in Overweight Korean Adolescents: A Controlled Randomized Trial	N= 10	Overweight Korean adolescents	1 set of 10 upper and lower body exercises; 10-12 repetitions at 60% of 1-RM; 1-1.5 min rest in between sets	12 weeks 3 times per week	Increased in insulin sensitivity index (0.09 ± 0.02)
23	Poehlman et al., 2000 Effects of Resistance Training and Endurance Training on Insulin Sensitivity in Nonobese, Young Women: A Controlled Randomized Trial	N= 17	Nonobese young women	3 sets of 9 upper and lower body exercises; 10 repetitions of 80% 1RM; 1-1.5 min rest between set	6 months 3 times per week	Insulin sensitivity increased (pre, 382 ± 87; post, 417 ± 89 mg/min); Improved insulin sensitivity is probably due to increase in FFM.

DISCUSSION

This main purpose of this review was to examine the effectiveness of resistance training on insulin sensitivity. As aforementioned, resistance training has been recognized as a treatment for various types of diseases. The present review included 23 studies investigating the effects of resistance training on insulin sensitivity. There was various type of resistance training or exercise protocol that has been implemented in these interventions. A total of 16 studies concluded that there was a significant improvement in insulin sensitivity (Ahmadizad et al., 2014; Alvarez et al., 2017; Brooks et al., 2006; Ibanez et al., 2005; Ishii et al., 1998; Ismail et al., 2019; Jorge et al., 2011; ; Lee et al., 2012; Lee at al., 2019; Malin et al., 2013; Mogharnasi et al., 2018; Mogharnasi et al., 2018; Poehlman et al., 2000; Shaibi et al., 2006; Slentz et al., 2011; Suh et al., 2019)

Three studies did not find significant effect of resistance training on insulin sensitivity (Davis et al, 2009; Davis et al., 2009; Kelly et al., 2015) while four studies reported adverse effect (Benson et al., 2008; Hasson et al., 2012; Kolahdouzi et al., 2018; Mavros et al., 2013). Davis and colleagues (2009) performed two studies that implemented same exercise protocol and added nutrition education for two population, which is overweight/obese Latino boys and girls. However, both studies reported no significant intervention effect on insulin sensitivity. They hypothesized that an intense nutrition and strength training program may have sought to improve too many health behaviors, resulting in a diluted potential effect. A study by Kelly et al. (2015) used home-based strength training (HBST) in their intervention. All participants carried out the exercises at their house and being monitored by phone calls once a week to help maintaining the motivation and evaluating their progress. Unfortunately, they also reported no significant effect on insulin sensitivity from their intervention. These finding proved that HBST is not an effective way to improve insulin sensitivity.

A study by Ahmadizad et al. (2014) used non-periodized, linear periodized and daily undulating periodized resistance training to monitor the changes in insulin sensitivity. Each protocol has different exercise prescription (e.g., loads, intensity, and volume). The study's primary result was that daily undulating periodized resistance training reduces insulin resistance index in overweight males more effectively than the non-periodized and linear periodized methods. They concluded undulating periodization is a fun and adaptable method that involves less planning and organization.

The findings of Shaibi et al. (2006) shows that a 16-week resistance training program done twice a week can effectively improve insulin sensitivity. They found that participants (youth) in the intervention significantly increased their insulin sensitivity by 45.1 ± 7.3%. Moreover, the elevation in insulin sensitivity was independent of body composition changes, showing that mechanism other than body composition changes were involved in improving insulin sensitivity. Even though alterations in total fat mass and soft lean tissue mass had no effect on insulin sensitivity, it is possible that decreases in specific fat depots related with insulin resistance, like intrahepatic lipid or intramyocellular lipid (IMCL), made a significant contribution to the enhancements in insulin sensitivity.

CONCLUSION

In conclusion, resistance training has been proven to contribute towards improvement in insulin sensitivity to various population. There were some studies that reported no significant or adverse effects; however, their intervention protocol was a bit different compared to other studies. Thus, we can conclude that resistance training is an effective way to improve insulin sensitivity. Therefore, resistance training can be an alternative treatment for people with metabolic diseases other than aerobic training. Due to the extreme limited number of studies that have been retrieved, much more study on resistance training as a major exercise modality is needed to discover how this exercise modality might be better adjusted to produce advantageous metabolic benefits.

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