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The Effect of Exercise and Diet on Insulin Resistance

Kinsey M. Nelson
Ouachita Baptist University

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Kinsey M. Nelson

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Amanda Perry, thesis director

Detri Brech, second reader

Johnny Wink, third reader

Dr. Barbara Pemberton, Honors Program director

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Kinsey M. Nelson

University Professor: Amanda Perry

Ouachita Baptist University

Abstract

This paper explores the effects of diet and exercise on an insulin-resistant individual, integrating the recommendations for exercise and diet as put forth by a variety of peer-reviewed articles. The purpose of this experiment was to determine if insulin resistance is a reversible condition, and if so, whether exercise alone, nutrition alone, or some combination of the two would be the most effective treatment. The results of this twenty-week trial suggest that insulin resistance may be reversible. Exercise alone was not found to be effective in decreasing insulin levels. Changing to a low-carbohydrate diet with no exercise saw a vast transformation in the individual's insulin levels. A combination of diet and exercise led to a slight decrease in insulin levels, but because the individual was already back in the normal range, future tests are necessary to establish the exact extent of diet and exercise together on insulin levels.

Keywords: exercise, diet, insulin, insulin resistance, nutrition, reversible condition

The Effect of Exercise and Diet

On Insulin Resistance

Type II diabetes is now more prevalent than ever, and is beginning at younger ages. The general population is greatly aware of how important the prevention of diabetes is through proper diet and exercise, but what about those individuals who have already been diagnosed with one of the early stages of diabetes, insulin resistance or prediabetes? At this point, is it too late to go back?

Insulin resistance is characterized by a need for increased insulin levels in order to keep blood sugar under control. At this point on the diabetes spectrum, blood sugar is still within normal levels; only insulin is increased. This in and of itself is not necessarily dangerous. The real danger lies in the time ahead, when cells eventually become insensitive to any amount of insulin, and blood glucose begins to rise. Hyperglycemia leads to a multitude of life-threatening complications, including but not limited to cardiovascular disease, retinopathy, renal failure, and severe nerve damage, especially in the feet[1]. A prolonged state of insulin resistance with no change in lifestyle habits leads to a higher risk of developing hyperglycemia and the complications associated with it. However, a diagnosis of insulin resistance may not make a future diagnosis of diabetes set in stone. Is it possible to decrease insulin levels to a normal range once and for all? The purpose of this study was to find if insulin resistance was reversible.

Review of Related Literature

Previous research on this subject has yielded mixed results. G. M. Reaven (2005)[2] found evidence that weight loss does increase insulin sensitivity, but that the type of diet chosen may make the situation worse overall. For instance, an individual who successfully loses weight via a low-fat, high-carbohydrate diet runs the risk of increasing insulin beyond a level commensurate with the benefits induced by the weight loss. Reaven warns that though even the tiniest weight loss can increase insulin action, this does not necessarily make Insulin Resistance Syndrome (IRS) symptoms disappear as though they never existed, so it may be that insulin resistance, even as the very first stage of developing diabetes, is not completely reversible[2].

Surprisingly, Reaven claims that, unlike weight loss, changes in nutrition have a minimal impact on the rate of glucose uptake by surrounding tissues. Diet only somewhat dictates the severity of the IRS presented, according to the author. This seems counterintuitive since most people grow up hearing that poor diet (e.g. eating too many sweets or drinking sodas) is what leads to diabetes, so it seems like it would be common sense that an improved diet would drastically affect IRS, but apparently this may not be the case[2].

Interestingly enough, not every tissue in the body is equally resistant/sensitive to insulin even in people with IRS. Reaven describes three different examples of what happens when the different tissues in the body have varying levels of insulin resistance or sensitivity. Most relevant is the example of polycystic ovary syndrome (PCOS), in which the insulin insensitivity is mostly centered on the ovaries. Though the ovary is not sensitive to insulin for glucose uptake, it is still sensitive to insulin's command to secrete testosterone[2]. Testosterone helps tissues take up more glucose, so it does raise the question of why the individual's ovaries are insulin resistant if both insulin and testosterone are telling the ovaries to take up glucose. This, however, is not explained by Reaven.

S. R. Colberg, a leading researcher in diabetes, has stated in multiple articles[3,4,5] that exercise (both cardiovascular and strength training) is imperative in individuals with diabetes. In her 2008 article "*Enhancing insulin action with physical activity to prevent and control* *diabetes*"[3], exercise is seen as the most important lifestyle change or habit in order to prevent or control diabetes. Colberg concurs that insulin's sensitivity can be enhanced, especially if regular exercise habits are established, and maintains that exercise is more effective than any other measures singularly[3]. Exercise forces the body to use carbohydrates for energy and makes insulin more sensitive. Strength training causes an increase in muscle, and muscle requires energy. Therefore, strength training will produce a higher intake of glucose. It may be assumed that this information is most likely applicable to insulin-resistant individuals.

To target glycogen rather than fat, Colberg says to engage in moderate to high intensity aerobic workouts, and resistance training works just as well to increase insulin sensitivity. Furthermore, Colberg advises to go no more than two days in a row without exercise because the effects of an exercise session will last no more than a maximum of forty-eight hours[3].

Most relevant is Colberg's evidence for the reversibility of prediabetes, and thus, insulin resistance is reversible when individuals lose weight. Therefore, exercise is imperative because it is the primary way to remove fat surrounding the organs, and abdominal fat is the most common fat placement found in diabetes. Colberg only lightly touches on the nutrition aspect, suggesting plenty of fiber and foods with a low glycemic index[3], but this author has plainly put diet on the back burner where it applies to insulin sensitivity enhancement.

A 2010 joint position statement from the American College of Sports Medicine (ACSM) and the American Diabetes Association (ADA) with Colberg as a corresponding author[4] echoes the sentiments of the previous articles, namely that exercise, including both cardiovascular and resistance training, can prevent or control certain stages of diabetes by enhancing insulin sensitivity. However, this statement makes no mention of nutrition, though some of the research explained in this article and outlined below alludes to the possibility that the beginning stages of diabetes are reversible.

1) Exercise immediately causes the body to rely on carbohydrates for energy supply to the muscles. Therefore, carbohydrates (which raise blood sugar) are being taken up and preventing chronic hyperglycemia. If an individual in the beginning stages of diabetes exercises regularly, it makes sense to assume that eventually insulin can decrease to normal levels since blood glucose has been maintained at healthy levels.
2) Skeletal muscles increase in mass due to long-term resistance training. More muscle means a greater need for energy coming from the glucose stored in the blood. As aforementioned, this suggests that it is possible to decrease insulin resistance.
3) Insulin sensitivity improves for several hours immediately following an exercise bout, so by regularly partaking in exercise it seems plausible that insulin sensitivity would be in a permanent state of improvement[4].

A third contribution by Colberg, *The Diabetic Athlete*[5], is more useful for people with Type 1 diabetes than those with Type 2 diabetes, and the author clearly sees exercise as more beneficiary and effective than diet. Colberg uses the exercise guidelines suggested by the ACSM, specifically 20-60 minutes of moderate aerobic activity for three to five days per week, including a short warm up and cool down. In addition, Colberg says that devoting two to three days to resistance training will further increase insulin sensitivity as well as the basal metabolic rate. However, diabetic athletes should be wary of intense exercise as it comes with a greater risk of hyperglycemia[5].

Colberg's information is more useful for Type 1 diabetics because the author details when it is best to use insulin injections, when to supplement for a workout, and what time of day is best for exercise. This obviously does not apply to most Type 2 diabetics or insulin-resistant individuals. Colberg does not put forth a suggested diet to follow, but instead talks about what to eat prior to a workout, what supplements may be necessary during an extended workout, and what to consume post-workout. However, this is more useful for Type 1 athletes and advanced Type 2 athletes who struggle with maintaining blood sugar levels and is not necessary for those in the beginning stages of Type 2 diabetes.

In "*Stemming the Tide*[6]", an article by Case, Manore, and Thompson (2006), the authors clearly see exercise as more beneficial for diabetic or insulin-resistant individuals than diet, but their primary focus is on prevention rather than treatment of diabetes. Exercise improves insulin resistance and helps with weight control to a degree, while nutrition has been seen as the main contributor to a healthy weight. No specific diet is proposed, though the writers agree that carbohydrates have a large influence - "fiber-rich, unprocessed" carbohydrates and "whole grain foods" seem to be the best option. The recommended fat intake is less than 18 grams per day but n-3 fatty acids are very beneficial[6].

The authors also looked into risk factors to watch out for in order for individuals to try to evade the onset of diabetes. For the purpose of this particular thesis, the following risk factors listed by Case et al. are considered relevant: 1) Body mass index (BMI) categorized as overweight/obese, 2) polycystic ovary syndrome (PCOS), and 3) a mostly inactive lifestyle which Case et al. defines as being fewer than three exercise sessions per week[6].

In 2012, the diabetes research and support organization Lilly Diabetes published "My Carbohydrate Guide[7]." This brochure emphasizes the importance of a rather strict diet. It suggests that women eat 45-60 grams of carbohydrates per meal, and 15 gram snacks if necessary. It also goes on to break each meal up into 3 or 4 different carbohydrate choices, with each carbohydrate choice equaling 15 grams. Example nutrition labels are given to demonstrate converting the grams of carbohydrates in a particular food into its equivalent carbohydrate choice (e.g. 1 carbohydrate choice, a half of a carbohydrate choice, etc.)[7] However, this is unnecessary since the meals consumed by the individual in this experiment will oftentimes not consist of multiple different carbohydrates. Therefore, for research purposes it makes more sense to simply count total grams of carbohydrates consumed and hit between 45 and 60 grams per meal.

Methods

ACSM's exercise plan is one of the most trusted sources of guidance for physical activity for the majority of individuals looking to become and/or remain healthy. Colberg is a strong proponent for this regimen, which includes 20-60 minutes of cardiovascular exercise 3-5 days a week (depending on the exercise), and a couple days of strength training. Therefore, these guidelines put forth by ACSM were used by the subject of the study.

Because insulin resistance is a precursor to diabetes, the subject of the study followed the recommendations set forth by the *My Carbohydrate Guide* brochure published by Lilly Diabetes. The primary suggestion from this guide is to limit carbohydrate intake to 45-60 grams per meal, and keep any snacks at no more than 15 grams.

For six weeks, the participant followed only ACSM's exercise guidelines with no regards to the amount or type of macronutrients being consumed (**See Table 1A**). This session was followed by another six-week session involving dieting only based on the aforementioned carbohydrate guide (**See Table 1B**). Exercise was kept to walking as was necessary. The third set of six weeks consisted of both exercising and dieting according to the research-based suggestions (**See Table 1C**). Food consumption and exercise regimens were recorded daily on MyFitnessPal™.

Between each session, the participant had a one-week break in which she kept exercise to a minimum and ate as she would normally. During this time, she had her insulin levels and A1C (three-month blood sugar average) tested for insulin resistance reversibility. These results were compared to the control lab tests taken at the very beginning of the experiment.

Table 1A: Exercise Only

Day:	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Breakfast:	29 g*	29 g	14 g	37 g	37 g	37 g	37 g
Lunch:	74 g	15 g	61 g	108 g	37 g	68 g	55 g
Dinner:	35 g	39 g	41 g	64 g	91 g	80 g	70 g
Snacks:	46 g	24 g	125 g	12 g	0 g	0 g	0 g
Carbohydrate Total:	155 g	107 g	256 g	198 g	165 g	185 g	163 g
Exercise:	9 minutes High-Intensity Interval Training (HIIT) workout	Warm-up and cool-down: 10 minutes each on the elliptical. Core and lower body strength training.	Warm-up and cool-down: 10 minutes each on elliptical. Upper body	30 minutes cardio	Rest Day	Rest Day	30 minutes cardio

Table 1A The first six-week trial was focused on consistent physical activity, with no limitations or guidelines for food consumption. The participant kept track of the amount of carbohydrates consumed each meal, *recorded in grams, as well as a total for the entire day. The participant exercised five days a week, with two rest days, based on ACSM's guidelines[4]. A synopsis of each day's workout is included. At least three days a week were predominately cardiovascular exercise, and a minimum of two days a week were predominately strength training, often with a short cardiovascular warm-up and cool-down. High-intensity interval training (HIIT) was a workout used with the participant's discretion, and can be considered both cardiovascular and strength training. Non-HIIT cardiovascular exercise consisted of an elliptical, a stationary bike, and/or powerwalking. Strength training included a variety of body-weight, free-weights, and machine-assisted exercises.

Table 1B: Diet Only

Day:	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Breakfast:	22 g*	19 g	27 g	30 g	20 g	20 g	21 g
Lunch:	28 g	49 g	27 g	28 g	0 g	13 g	29 g
Dinner:	54 g	33 g	30 g	31 g	15 g	27 g	46 g
Snacks:	0 g	25 g	41 g	39 g	2 g	3 g	2 g
Carbohydrate Total:	105 g	126 g	125 g	128 g	37 g	63 g	98 g
Exercise:	None	None	None	None	None	None	None

Table 1B The second six-week trial was focused on diet, with physical activity limited to the absolute minimum amount of walking necessary for daily activities. The participant kept track of the amount of carbohydrates consumed each meal, *recorded in grams, as well as a total for the entire day. The goal per meal was 45-60 grams of carbohydrates, with three meals a day. Snacks were allowed, provided that they, as well as the closest meal, still did not exceed 60 grams combined. In this case, snacks of approximately 15 grams of carbohydrates and a meal of 45 grams of carbohydrates were suggested[7]. Occasionally, the participant skipped a meal due to sleep schedule or lack of hunger. This was not considered to have a significant impact on results because skipped meals infrequently occurred both before and during the experiment. Also, the participant ate less than the suggested 45-60 grams of carbohydrates for breakfast due to a preference for lighter breakfast fare consisting mostly of protein. Because the participant consumed a low-carbohydrate breakfast both before the experiment and consistently throughout the experiment, this was not considered to have a significant effect on the results.

Table 1C: Exercise and Diet

Day:	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Breakfast:	27 g*	27g	4 g	4 g	27 g	0 g	29 g
Lunch:	38 g	49 g	28 g	41 g	28 g	25 g	0 g
Dinner:	39 g	38 g	4 g	61 g	25 g	25 g	44 g
Snacks:	0 g	19 g	8 g	8 g	0 g	26 g	0 g
Carbohydrate Total:	104 g	133 g	44 g	114 g	80 g	76 g	73 g
Exercise:	30 minutes cardio	Rest Day	Lower Body strength training	25 minutes cardio	Rest Day	10 minutes cardio warm-up, upper body strength training	60 minutes cardio

Table 1C The third six-week trial was focused on a combination of exercise and diet, using the guidelines aforementioned for both. The participant kept track of the amount of carbohydrates consumed each meal, *recorded in grams, as well as a total for the entire day. A synopsis for each day's workout is included.

Results

Before beginning the experiment, the subject's insulin levels and three-month blood glucose average (A1C) were tested. The normal range for fasting insulin is 2.6-24.9 µIU/L. The subject's insulin level was 42.3 µIU/L, which is almost double the maximum normal level. After exercising for six weeks, the subject's insulin dropped to 41.7 µIU/L, which is only a 1.4% decrease. However, after six weeks of restricting carbohydrates, insulin was tested at 12.1 µIU/L, which was a 70.9% decrease from the previous test. Finally, insulin after both exercise and diet was at 7.0 µIU/L, which was a 42% decrease from the previous lab result and a total decrease of 83.5% from the pre-trial insulin level (**See Table 2**).

A1C levels before the experiment, after the exercise-only trial, and after the diet-only trial all remained stable at 5.6, which is at the high end of the normal range. However, it jumped to 5.8 after the combination trial even though insulin levels continued to drop (**See Table 2**). This discrepancy of a 3% increase is most likely due to the fact that a different lab (Clinical Pathology Laboratories in Round Rock, Texas) analyzed the last blood test, whereas the first three blood tests were analyzed by American Esoteric Laboratories based in Memphis, Tennessee.

Table 2: Results

	Insulin (Ref. Range: 2.6-24.9 µIU/L)	**A1C (Ref. Range: 4.3-5.6)**
Pre-trial	42.3	5.6
Post-exercise only	41.7	5.6
Post – diet only	12.1	5.6
Post- combination	7.0	5.8

Significance. There are two important inferences that may be made based on these results. First, this experiment shows that insulin resistance is reversible. Second, diet alone decreases insulin more than exercise alone. This implies that insulin resistance is more strongly tied to an individual's eating habits than it is to his/her exercise routine. However, because the subject's insulin levels were already within the normal range before beginning the combination period, an additional study is needed to determine whether diet only or the combination of diet and exercise yield better results in insulin-resistant individuals.

Potential Sources for Error. This experiment was performed by only one individual due to lack of resources to recruit multiple individuals and also track or enforce their exercise and nutrition plans. Also, because one individual completed three different trials, even with attempts to neutralize effects from one trial to another, it is probable that one trial's results were influenced by the preceding trial. Additionally, carbohydrate counting was difficult when the food was prepared from scratch instead of prepackaged meals. Finally, two different labs were used to measure insulin and blood glucose.

Conclusions and Further Study

Based on the results of this research, it is possible to reverse the insulin-resistant condition with consistent exercise and a low-carbohydrate diet. Contrary to what reviews of related literature proposed, this research found nutrition alone to be more influential than exercise alone or a combination of both diet and exercise in reducing the amount of insulin needed to maintain a healthy blood glucose level. However, because the diet-only trial normalized the individual's insulin, the following combination trial was not able to prove its full potential. It is possible that a combination of both diet and exercise could be equally or more beneficial than diet alone, provided that the combination trial begins with similarly high insulin levels.

Due to the potential sources of errors aforementioned, this study should be repeated on a larger scale to accurately draw statistically significant results. In a future, more comprehensive study, there should be multiple participants, with every participant completing only one of the three trials. Each trial should have at least twenty participants. Additionally, more developed technology should be used for tracking macromolecule intake in order to ensure accuracy, particularly when counting carbohydrates. It would also be prudent to provide the food for the participants in order to ensure consistency. Lastly, the same lab should be used to analyze all blood tests.

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