

THE EFFECTS OF TWO RESISTANCE TRAINING INTENSITIES ON  
GLUCOSE TOLERANCE

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A Thesis  
Presented  
to the Faculty of  
California State University, Chico

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In Partial Fulfillment  
of the Requirements for the Degree  
Master of Arts  
in  
Kinesiology

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by  
Cameron David Kisst  
Summer 2012

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## DEDICATION

I would like to dedicate this thesis to my parents for their unwavering support of me in everything I do. They have given me every opportunity to be successful and without them I would not be where I am today.

I would also like to dedicate this thesis to my loving girlfriend Alyse Kendig, who has encouraged me from the start of this project and kept me focused throughout this past year.

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## ABSTRACT

### THE EFFECTS OF TWO RESISTANCE TRAINING INTENSITIES ON GLUCOSE TOLERANCE

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To determine the effects of intensity of an acute bout of resistance exercise on glycemic response, nine healthy college-aged ( $23.9 \pm 2.3$  years) males participated in two separate bouts (65%, 85% of 1 repetition maximum) of resistance exercise in random order. Each subject took part in three laboratory visits that were separated by a minimum of 72 hours. Subjects were given a baseline oral glucose tolerance test (OGTT) followed by a 1 repetition maximum strength test to assess baseline glucose tolerance and strength in the squat, deadlift, bench press, overhead press, and lat pull down. Following the baseline testing, subjects were randomly assigned to either a 65% or 85% one repetition maximum workout that was immediately followed by an OGTT and then were tested again at the opposite intensity. Each exercise was performed for three sets to failure with 2 minutes of rest between each set. Overall there were no significant differences between the baseline OGTT, post-65% exercise OGTT, and the post-85% exercise OGTT at any

of the 5 blood sampling periods. In all five lifts more work was performed in the 65% exercise session with 26% less total work being done in the 85% exercise session. It can be suggested that the less dramatic glycemic response of the post-65% exercise group compared to that of the post-85% exercise is a product of the greater amount of work done in the 65% one repetition maximum strength exercise session. The greater work would have also led to a greater glycogen depletion which would have stimulated muscles to take up blood-borne glucose to a greater degree to replenish the depleted glycogen stores. The only way this can truly be evaluated however is to calculate the area under the curve to look at the entire 120 minute period rather than each time point individually.

## CHAPTER I

### INTRODUCTION

Muscular contraction increases GLUT-4 transporter protein translocation, increases in total GLUT-4, and blood glucose uptake. This is an underlying principle for exercise prescription among individuals with type 2 diabetes. It has been demonstrated that acute bouts of aerobic exercise can lead to metabolic benefits like, decreases in blood glucose and increased glucose tolerance. Acute bouts of resistance exercise have also been shown to improve glucose tolerance. What remains unclear is the effect of resistance training intensity and its influence on improved glucose tolerance.

#### Purpose of Study

This study examined whether a single full body resistance exercise session, performed at two different intensities, can positively affect glucose tolerance as assessed by an oral glucose tolerance test (OGTT).

#### Hypotheses

The hypotheses are as follows:

1.  $H_0$ : There will be no significant differences between the baseline OGTT and the post-exercise OGTT's.

$H_1$ : There will be significant differences between the baseline OGTT and the post-exercise OGTT's.

2  $H_0$ : There will be no significant differences in OGTT between low and high exercise intensities.

$H_1$ : There will be significant differences in OGTT between low and high exercise intensities.

### Importance of the Study

The present study has implications in the prescription of resistance training for individuals with type 2 diabetes that may not be able to exercise aerobically, often enough, or at all. Positive outcomes of the study will imply that strength training independently, at a specific intensity, could be sufficient for ameliorating impaired glucose tolerance in individuals with chronic diseases such as type 2 diabetes. This would also lead to future research on strength training for chronic disease management and improved glucose tolerance.

### Limitations

A limitation of the study is the small volume of blood drawn from the finger sticks and the multiple sticks needed throughout the two hour OGTT. The subject pool is also a limitation because they represent healthy college aged males and not individuals with type 2 diabetes.

### Delimitations

The study utilized college aged males with two years weight lifting experience. The exercise protocol followed a strictly strength exercise format that utilizes the squat, deadlift, bench press, overhead press and lat pull down. Two different intensities were utilized for the purposes of evaluating exercise intensity and glucose

response. To that end, exercise intensities of 65% and 85% of the one repetition maximum for each subject were employed.

## CHAPTER II

### REVIEW OF LITERATURE

#### Introduction

The importance of exercise to ameliorate the symptoms of chronic diseases like diabetes has been well documented over the years (Eriksson, Taimela, Koivisto, 1997; Young, Enslin & Kuca, 1989). The majority of exercise based research and type 2 diabetes has focused on aerobic exercise. However, recently there have also been a number of studies using both aerobic and resistance exercise modalities.

The prevalence of diagnosed, undiagnosed, and pre-diabetes was determined to be approximately 12.9% of people in the U.S. ages 20 and older were diabetic of whom 40% were undiagnosed. It was also determined that 25.7% of that same age group had impaired fasting glucose and 13.8% had impaired glucose tolerance with 30% sharing both impairments. To simplify, over 40% of the U.S. population ages 20 and older have some form of hyperglycemic condition or glucose intolerance (Centers for Disease Control and Prevention, 2012; Cowie et al., 2009).

Skeletal muscle is a unique tissue. It is heterogeneous, that is it exists in several different fiber types. There are fast twitch white also known as type IIb, fast twitch oxidative also known as type IIa and slow twitch oxidative also known as type I fibers. Fiber type distribution is important with regard to athletic performance (Brooks, Fahey, & Baldwin, 2005), but more importantly with regard to the present study, insulin sensitivity (Cortright et

al., 2006, Hickey et al., 1995, Tanner et al., 2002). It has been shown that morbidly obese individuals have a lower amount of type I fibers and a greater amount of type IIb fibers. This is of great concern as type IIb fibers are insulin resistant (Hickey et al., 1995, Tanner et al., 2002). The insulin resistance associated with type IIb fibers is thought to be due to the lack of oxidative capacity of these fibers (Berggren, Chapman, & Houmard, 2008). This raises an interesting question as it cannot necessarily be determined if the fiber type distribution causes obesity or if obesity (or a combination of inactivity, poor diet and genetics) causes the fiber type distribution.

Muscle is also very metabolically active. It can increase its metabolic rate several fold from rest to exercise (Brooks et al., 2005). This makes muscle very important with regard to energy balance. No other tissue in the body can expand its metabolic rate to the same degree as muscle.

Finally, skeletal muscle represents approximately 40% of body weight. Quantitatively, it represents the single largest tissue type in the body. It has been shown that skeletal muscle is responsible for over 80% of post-prandial glucose disposal (Ferranniniet al., 1985). A number of studies have shown that exercise improves glucose tolerance in individuals with type 2 diabetes and/or insulin resistant individuals (Derave et al., 2003; Eriksson et al., 1997). Classically, aerobic exercise has been employed because it utilizes large muscle groups for extended periods of time. Presumably, this maximizes the effects of exercise to enhance the ability of muscles to take up and dispose of post-prandial glucose due, at least partially, to glycogen depletion during exercise.

## GLUT-4 Transporter Protein and Glucose Disposal

The glucose transport protein, abbreviated “GLUT” for GLUcose Transporter was first elucidated in 1985 by Mueckler and colleagues (Mueckler et al., 1985). The GLUT elucidated by Mueckler has since been termed the GLUT-1 as it was the first GLUT to be discovered. It exists in cells that have an absolute requirement to use glucose as fuel, such as red blood cells and neurons. The GLUT’s are characterized by having 12 membrane-spanning domains, forming a channel in which glucose, or in the case of GLUT-5, fructose, moves through. Since the study by Mueckler et al., it has been determined that there is an entire family of GLUT’s. Further, the GLUT that has gained most attention is GLUT-4. The reason for this is because GLUT-4 was found to move or translocate from the interior of cells in response to insulin. This occurs in insulin-sensitive cells or tissues such as adipose tissue and skeletal muscle in order to increase glucose transport, take up glucose for storage and oxidation purposes (Brooks et al., 2005). The ability of insulin to signal translocation is important for whole body glycemic control, and is a very complicated process that is beyond the scope of the present review.

In addition to insulin, muscle is able to independently stimulate glucose transport. This is significant because it allows the tissues of the body to direct glucose to the where the fuel is needed most. The sequence of events leading to the increase in glucose transport via GLUT-4 translocation is completely separate from insulin signaling. Although separate, the same concepts are shared in that there is sequential activation of signaling peptides that stimulate the GLUT-4 containing vesicles to the cell surface. When contraction occurs ATP is split to ADP + inorganic phosphate ( $P_i$ ). Most of the

ADP and  $P_i$  are recycled to reform ATP. However some ADP enters the adenylate cyclase reaction which takes two ADP's and sacrifices one to make an ATP (i.e.  $ADP + ADP \rightarrow ATP + AMP$ ). The ATP of course is utilized in energetic metabolism during muscular contraction; however the fate of AMP is quite unique. It activates a signaling peptide called AMP-activated kinase (AMPK). AMP-activated kinase in turn, initiates the process to stimulate GLUT-4 translocation. It should be apparent therefore that as exercise intensity increases, muscle contraction becomes more forceful; there is a greater rise in intracellular AMP and therefore a greater activation in AMPK stimulating a greater translocation of GLUT-4 to the muscle cell surface. It is in this manner that allows muscles to self-regulate how much glucose they need. AMPK has been termed the "energy sensing" peptide of the cell (Brooks et al., 2005).

The exact location of translocation has been demonstrated to be the t-tubules rather than directly to the outer cell surface (Friedman et al., 1991). This is a significant finding because the t-tubules simply act as a channel to allow glucose to flow into the interior portion of the muscle cells. This in turn, allows glucose to enter cells more closely to the point of use rather than diffusing across a great distance from the cell surface to the point where it is utilized.

Lastly, the amount of glucose transport and GLUT-4 translocation stays elevated after exercise. This is presumably to restore muscle glycogen and it has been demonstrated that post exercise glucose transport is higher when muscle glycogen concentration is low. Furthermore, as muscle glycogen increases, glucose transport will decrease (Young, Garthwaite, Bryan, Cartier, & Holloszy, 1983). This phenomenon can be observed in an oral glucose tolerance test (OGTT) in which the amount of glucose in

the blood will increase drastically upon receiving the glucose load, and then drop to a normal level over a short period of time. Similarly, increases in GLUT-4 content will increase the ability of the muscle to super compensate its glycogen stores. GLUT-4 mRNA has been shown to increase up to 3-fold coupled with GLUT-4 protein content increases of 2-fold 18 hours post exercise in rats (Garcia-Roves et al., 2003). These increases had completely reversed 42 hours post exercise. However in the rats fed a carbohydrate free diet GLUT-4 protein was elevated for 66 hours and GLUT-4 mRNA was elevated for 42 hours. The findings of this study provide evidence that prevention of glycogen super compensation after exercise will result in exercise-induced increases in GLUT-4 protein for a prolonged period of time (Garcia-Roves et al., 2003).

It has been shown that exercise intensity is an important factor in determining the exercise response in cycling, running and a combination of running and resistance exercise (Hayashi et al., 2005; Holloszy, 2005; Houmard et al., 2004). High-volume/high intensity exercise increased insulin sensitivity by approximately 85% whereas low-volume/high-intensity exercise increased insulin sensitivity by only 40%. This suggests that at any exercise intensity, more volume will lead to increased insulin sensitivity (Houmard et al., 2004).

It has also been demonstrated that intense run training may have a greater effect on improving glucose tolerance compared to moderate-intensity running as well as resistance exercise (Houmard et al., 2004). However, the assessment of glycemic response for the resistance trained subjects took place 48 hours after the last exercise bout. This long duration of rest may have negated the effects of the last acute bout of resistance exercise due to the disappearance of the GLUT-4 transporter protein.

Further it has been shown that high-intensity exercise has greater effects on glucose effectiveness and glucose-specific insulin sensitivity. This is significant in the prescription of exercise for sedentary people based on intensity and not just duration. This also leaves some unanswered questions as to which exercise modalities other than aerobic exercise can elicit a similar response (Hayashi et al., 2005).

Although it is clear that exercise training increases muscle GLUT-4 content over an extended period of time, short-term training has also been demonstrated to increase muscle GLUT-4 content. Muscle GLUT-4 content increased almost three-fold in previously sedentary middle-aged men after only seven days of training. This was one of the first studies to demonstrate substantial increases of GLUT-4 protein content as a product of short-term exercise training (Houmard, Hickey, Tyndall, Gavigan, & Dohm, 1995).

The mechanism to explain effects of exercise on glucose tolerance appears to be linked to the amount of GLUT-4 that is translocated to the muscle cell surface. Further, the amount of glucose being transported is proportional to the amount of GLUT-4 translocated to the cells surface (Gordon et al., 2008). The exercise response reverses quickly (40 hours post exercise) which may explain the lack of results in some studies such as Fluckey et al. (1994). Although the exercise response of GLUT-4 has been demonstrated to reverse quickly, the total amount of GLUT-4 present in the muscle may not be responsible for glucose uptake by itself.

As noted above, much research supports the hypothesis that there is an exercise induced increase in GLUT-4. To extend the findings of exercise-induced increases, some researchers have explored the effects of cessation of exercise or

detraining. Results of this work is not completely clear as cessation of training may or may not result in a decrease in total GLUT-4 (Host, Hansen, Nolte, Chen, Holloszy, 1998; Houmard et al. 1993). Contrary to the results of Host et al., Houmard et al. found that muscle GLUT-4 content is unaffected while insulin sensitivity was significantly reduced but the total GLUT-4 content was not. This demonstrates that the decrease in insulin sensitivity is not associated with muscle GLUT-4 content (Houmard et al., 1993).

However other research has shown decreased muscle GLUT-4 content with cessation of training. In rats that were previously trained, insulin-stimulated glucose transport as well as muscle GLUT-4 content decreased within 40 hours of training cessation. These data support the hypothesis that glucose disposal is dependent on the GLUT-4 transporter protein (Host et al., 1998). The discrepancy in these results between the two studies is unclear. However, Houmard et al. (1993) used human subjects with a 14 day training withdrawal and Host et al. used highly trained rats that swam for six hours per day, five days per week followed by 40 hours of training cessation. It can be suggested that the large training volume of the rats elicited unusually large amounts of GLUT-4 immediately post-training and also activated the quick reversal.

#### Post-Exercise Glucose Uptake

Glucose transport is not only stimulated during muscular contraction, but also remains elevated for several hours after exercise cessation (Young et al., 1983). Rats fed a high carbohydrate meal after exercise showed a much more rapid reversal of increased glucose transport which coincided with restitution of muscle glycogen. However rats fed a low carbohydrate meal post exercise still had only returned to 50% of the baseline

glycogen stores. These data provide more evidence that exercise-induced increases in glucose uptake can be reversed with a carbohydrate intake post exercise by providing an excess amount of glucose to the blood that will allow the muscle to re-saturate with glycogen stores (Young et al., 1983).

### Strength Exercise and Glucose Tolerance

Classically, endurance training has been employed as a way to ameliorate hyperglycemia (Eriksson et al., 1997). This is because aerobic type exercise generally utilizes large muscle groups for an extended period of time. Presumably this results in a greater depletion of glycogen stores which allows the muscles to have a greater capacity to take up and store glucose (Holloszy, 2005). However, recently researchers have been assessing the use of resistance exercise as an alternative to aerobic exercise. The reason for this stems from the basic fact that individuals with chronic diseases like type 2 diabetes generally have difficulties moving enough because they are substantially overweight. Resistance training therefore provides a modality in which overweight individuals with difficulties in moving can achieve more success and continue to exercise. It has been demonstrated that resistance exercise actually had greater effects with regard to post-exercise glycemia than aerobically-trained individuals (Yaspelkis, 2006). By comparison it has been shown that some aerobic exercise has no effect in post-exercise glycemia in aerobically-trained individuals (Venables, Shaw, Jeukendrup, & Wagenmakers, 2007).

Not only is resistance exercise a viable alternative to aerobic exercise with regard to glycemic control, it has also been demonstrated that resistance intensity effects

glycemia as well (Black, Swan, & Alvar, 2010). It was demonstrated that individuals who exercise at a very high intensity had the greatest effect on glycemic response. Of the four training sessions, the high intensity multiple set protocols demonstrated the greatest effect on both fasting blood glucose and insulin sensitivity.

Alternatively, single bouts of resistance exercise in individuals with type 2 diabetes have demonstrated no difference in the pre- and post-exercise OGTT's. However the lifting protocol that was followed was based on the Delorme-Wakins lifting protocol which calls for the first 2 sets of each lift to be performed at 50% of the subjects 10-repetition maximum weight and the third set to be performed at the 10-repetition maximum weight. Although there was no difference between the pre- and post- exercise OGTT, the exercise protocol followed was relatively low intensity and could account for the lack of change in glucose uptake/tolerance (Fluckey et al., 1994).

Resistance exercise has also been examined and compared to short intense run training and prolonged running. There were no differences in the end glucose value 2 hours after ingestion of the 75 gram glucose sample in individuals engaged in resistance exercise but small differences were observed in both the prolonged running group and the short intense interval running group. The lack of significant difference in the OGTT of the strength training group may be attributed to the 48 hour period prior, where subjects were not allowed to participate in any physical activity (Nybo et al., 2010).

Resistance training has also been demonstrated in animal models, to improve glucose tolerance in both normal and insulin resistant muscle. This is due to the increase in GLUT-4 protein concentration that is activated by an increase in the insulin signaling cascade. (Yaspelkis, Singh, Trevino, Krisan & Collins, 2002; Krisan, et al., 2004).

## CHAPTER III

### METHODS

#### Subjects

The present study recruited subjects from the California State University, Chico Department of Kinesiology and Exercise Physiology. The subjects represent a healthy and active population and fall into the age range of 20-30 years of age. Upon completion of the Medical and Exercise History form any subject who met the following criteria was excluded from participating in the study: Lack of the minimum two years of required strength training experience, orthopedic injuries or severe pain within the last year, cigarette smoking, having diabetes or pre-diabetes, having a positive risk factor for cardiovascular disease as outlined by the ACSM, having any neurological disorders, consistently taking any prescription medications, and positively identifying with any other condition that could put the subject at risk of injury. Of the eleven volunteers that signed up to be test subjects, there was only one subject excluded because of previous injury and one subject to drop out of the study prematurely. Therefore the total number of test subjects was nine.

#### Experimental Apparatus

All OGTT's were determined by glucose assays performed on blood drawn by finger sticks into heparinized tubes. Blood samples were then deproteinized in 8%

perchloric acid and stored at  $-80^{\circ}$  Celsius until assayed. For the oral glucose tolerance tests (OGTT) subjects consumed a standard 75 gram glucose drink (10 fluid ounces, Trutol, NERL Diagnostics) after an overnight fast.

### Experimental Procedure

All procedures complied with federal, state and local guidelines as well as the Helsinki Accord for the use of human subjects. All procedures were approved by the Institutional Review Board (IRB, HRSC) at California State University, Chico. Prior to the first day of data collection subjects completed the informed consent and full health and exercise history. The first day of testing a 2-hour 75 gram OGTT was performed on each subject to establish baseline values of glucose tolerance. Once the OGTT was completed the subject were taken into the Chico State Strength and Conditioning lab to test their one repetition maximum strength in the following lifts: squat, deadlift, bench press, overhead press, and lat pull-down. Subjects were allowed to warm-up and then were asked to perform each lift at a weight appropriate for a maximum of 5-repetitions. The 1-repetition maximum of each subject was calculated based on the weight and number of repetitions performed.

The second meeting was a minimum of 72 hours following the baseline strength test and OGTT and was one of the two strength training sessions the subject completed. Each subject performed, under the supervision of the primary investigator, all 5 lifts from the strength session at either 65% or 85% of the 1-rep max values from the baseline strength test for each subject. The workout intensity was performed in random order and each lift was performed for 3 sets to failure with 2 minute rest periods between

each set. Repetitions were recorded for each set by the supervising primary investigator. Immediately following the training session the subjects took part in the second of three OGTT's that were performed.

The final meeting took place a minimum of 72 hours after the subjects last OGTT and was performed at the opposite intensity of what they had performed in the first session. Under the supervision of the primary investigator, the subjects performed all 5 lifts for 3 sets to failure with a 2 minute rest periods between each set. Repetitions were recorded for each set by the supervising primary investigator. Immediately following the training session the subject took part in the third and final OGTT.

Upon completion of the subject data collection, all samples of blood taken from the OGTT's were thawed and assayed for glucose concentration.

#### Statistical Analysis

A repeated measures ANOVA was used to determine differences in glucose tolerance following two different intensities of strength exercise. Statistical analysis was not performed on any strength exercise or calculated work data as the focus of the study was to evaluate the effects the strength exercise had on an oral glucose tolerance test. Significance was set at  $p < 0.05$ .

## CHAPTER IV

### RESULTS

Subjects taking part in the study met all of the requirements listed previously and were recruited from the Chico State University department of Kinesiology. The mean values of the subjects are  $23.9 \pm 2.3$  years,  $70.4 \pm 2.3$  inches,  $81.6 \pm 12.1$  kilograms, and  $14.0 \pm 5.2\%$  for age, height, weight and body fat percentage, respectively (Table 1). The height, weight, and body fat percentage values were measured using the Bod Pod® located in the California State University, Chico, Department of Kinesiology.

Table 1

*Subject Characteristics*

Subject	Age	Height (In.)	Weight (Kg.)	Body Fat %
A	25	72	70.2	10.8
B	24	70	74.7	17.5
C	24	71	83	13.4
D	24	69	70.7	5.8
E	21	68	71.6	9.7
F	22	68	80.3	15.6
G	29	72	83	11.1
H	23	75	105.2	21
J	23	69	96	20.8
Mean $\pm$ SD	$23.9 \pm 2.3$	$70.4 \pm 2.3$	$81.6 \pm 12.1$	$14.0 \pm 5.2$

The one repetition maximum mean values were  $275.7 \pm 59.5$  lbs.,  $284.2 \pm 60.6$  lbs.,  $233.1 \pm 41.0$  lbs.,  $133.6 \pm 19.2$  lbs.,  $214.3 \pm 36.9$  lbs. for the squat, deadlift, bench press, standing press, and lat pulldown, respectively (Table 2).

Table 2

*One Repetition Maximum Weight (lbs)*

Subject	Squat	Deadlift	Bench Press	Stand. Press	Lat Pulldown
A	261	247	169	100	165
B	245	267	270	120	200
C	310	354	260	150	260
D	205	190	220	125	230
E	240	285	245	135	195
F	222	215	180	120	175
G	281	309	211	154	238
H	319	323	290	159	270
J	398	368	253	139	196
Mean $\pm$ SD	$275.7 \pm 59.5$	$284.2 \pm 60.6$	$233.1 \pm 41.0$	$133.6 \pm 19.2$	$214.3 \pm 36.9$

The 65% exercise session mean weights were  $180 \pm 38.9$  lbs.,  $185 \pm 39.1$  lbs.,  $152.2 \pm 26.6$  lbs.,  $86.1 \pm 13.2$  lbs., and  $140.6 \pm 23.1$  lbs. for the squat, deadlift, bench press, standing press, and lat pulldown, respectively (Table 3). For the same workload the repetition means, combined repetitions over three sets, were  $41.4 \pm 11.0$ ,  $29.6 \pm 7.4$ ,  $30.7 \pm 8.9$ ,  $24.6 \pm 3.1$ , and  $28.8 \pm 9.0$  for the squat, deadlift, bench press, standing press, and lat pulldown, respectively (Table 4).

The 85% exercise session mean weights were  $235.6 \pm 50.5$  lbs.,  $235.2 \pm 46.3$  lbs.,  $197.8 \pm 33.2$  lbs.,  $112.8 \pm 16.4$  lbs., and  $183.3 \pm 30.9$  lbs., for squat, deadlift, bench press, standing press, and lat pulldown, respectively (Table 5). For the same workload the repetition means, combined repetitions over three sets, were  $21.7 \pm 7.7$ ,  $20.8 \pm 7.8$ ,  $13.4 \pm$

Table 3

*65% of One Repetition Maximum Weight (lbs)*

Subject	Squat	Deadlift	Bench Press	Stand. Press	Lat Pulldown
A	170	160	110	65	110
B	160	175	175	75	130
C	200	230	170	95	170
D	135	125	145	80	150
E	155	185	160	90	130
F	145	140	120	75	115
G	185	200	135	100	155
H	210	210	190	105	175
J	260	240	165	90	130
Mean $\pm$ SD	180 $\pm$ 38.9	185 $\pm$ 39.1	152.2 $\pm$ 26.6	86.1 $\pm$ 13.2	140.6 $\pm$ 23.1

Table 4

*65% of One Repetition Maximum (Total Repetitions over Three Sets)*

Subject	Squat	Deadlift	Bench Press	Stand. Press	Lat Pulldown
A	43	28	31	25	32
B	23	25	19	23	24
C	48	25	31	30	31
D	57	39	47	22	40
E	52	38	23	26	14
F	48	39	25	28	24
G	37	30	30	21	23
H	31	21	42	25	43
J	34	21	28	21	28
Mean $\pm$ SD	41.4 $\pm$ 11.0	29.6 $\pm$ 7.4	30.7 $\pm$ 8.9	24.6 $\pm$ 3.1	28.8 $\pm$ 9.0

Table 5

*85% of One Repetition Maximum Weight (lbs)*

Subject	Squat	Deadlift	Bench Press	Stand. Press	Lat Pulldown
A	225	210	145	85	140
B	210	225	225	100	170
C	265	232	220	125	220
D	175	165	190	105	195
E	205	245	205	115	170
F	190	185	155	100	150
G	240	265	180	130	205
H	270	275	245	135	230
J	340	315	215	120	170
Mean $\pm$ SD	235.6 $\pm$ 50.5	235.2 $\pm$ 46.3	197.8 $\pm$ 33.2	112.8 $\pm$ 16.4	183.3 $\pm$ 30.9

4.4, 15.0  $\pm$  3.2, and 17.6  $\pm$  2.7 for the squat, deadlift, bench press, standing press, and lat pulldown, respectively (Table 6).

Total work for each lift in the 65% exercise was 16533.8  $\pm$  3805Joules (J), 13378.2  $\pm$  2248J, 7719  $\pm$  2822J, 5364.5  $\pm$  1069J, and 12895.4  $\pm$  5565J for the squat, deadlift, bench press, overhead press, and lat pull-down respectively. Total work for each lift in the 85% exercise was 11256.9  $\pm$  3424J, 11939.9  $\pm$  4140.6J, 4315.5  $\pm$  1413J, 4234.6  $\pm$  821J, 9983.4  $\pm$  2151J for the squat, deadlift, bench press, overhead press, and lat pull-down respectively. Total combined work at each intensity was 55890.9J for the 65% exercise and 41730.3J for the 85% exercise. In all five lifts more work was done in the 65% exercise session with 26% less total work being done in the 85% exercise session. The largest difference observed was the 44% less work done on the bench press, followed by 32% less work done on the squat, 23% less work done in the Lat pull-down, 21% less work done in the overhead press, and 11% less work done in the deadlift (Figure 1).

Table 6

*85% of One Repetition Maximum (Total Repetitions over Three Sets)*

Subject	Squat	Deadlift	Bench Press	Stand. Press	Lat Pulldown
A	18	17	11	16	17
B	14	24	7	20	18
C	16	26	9	15	13
D	37	30	18	12	18
E	23	12	13	16	19
F	29	26	20	18	21
G	16	12	15	9	15
H	24	29	17	15	21
J	21	11	11	14	16
Mean $\pm$ SD	21.7 $\pm$ 7.7	20.8 $\pm$ 7.8	13.4 $\pm$ 4.4	15.0 $\pm$ 3.2	17.6 $\pm$ 2.7

In all three OGTT's there was a noticeable rise and fall of blood glucose concentration. The baseline OGTT started at 92.5 mg/dl and spiked to 115.5 mg/dl at the 30 minute time point before steadily declining to 109.6 mg/dl, 101.0 mg/dl, and 89.7 mg/dl for the 60, 90, and 120 minute time points, respectively. The post-65% exercise OGTT had a much less dramatic rise and fall in glucose concentration starting at 92.5 mg/dl and rising to only 104.9 mg/dl at the 30 minute time point and 104.2 mg/dl, 99.2 mg/dl, and 91.8 mg/dl for the 60, 90, and 120 minute time points, respectively. The post-85% exercise OGTT started at 95.5 mg/dl and spiked to 114.7 mg/dl at the 30 minute time point before declining to 99.8 mg/dl, 97.2 mg/dl, and 94.3 mg/dl for the 60, 90, and 120 minute time points, respectively.

Overall there were no significant differences between the baseline OGTT, post-65% exercise OGTT, and the post-85% exercise OGTT at any of the 5 blood sampling periods. The largest differences observed were at the thirty minute and sixty

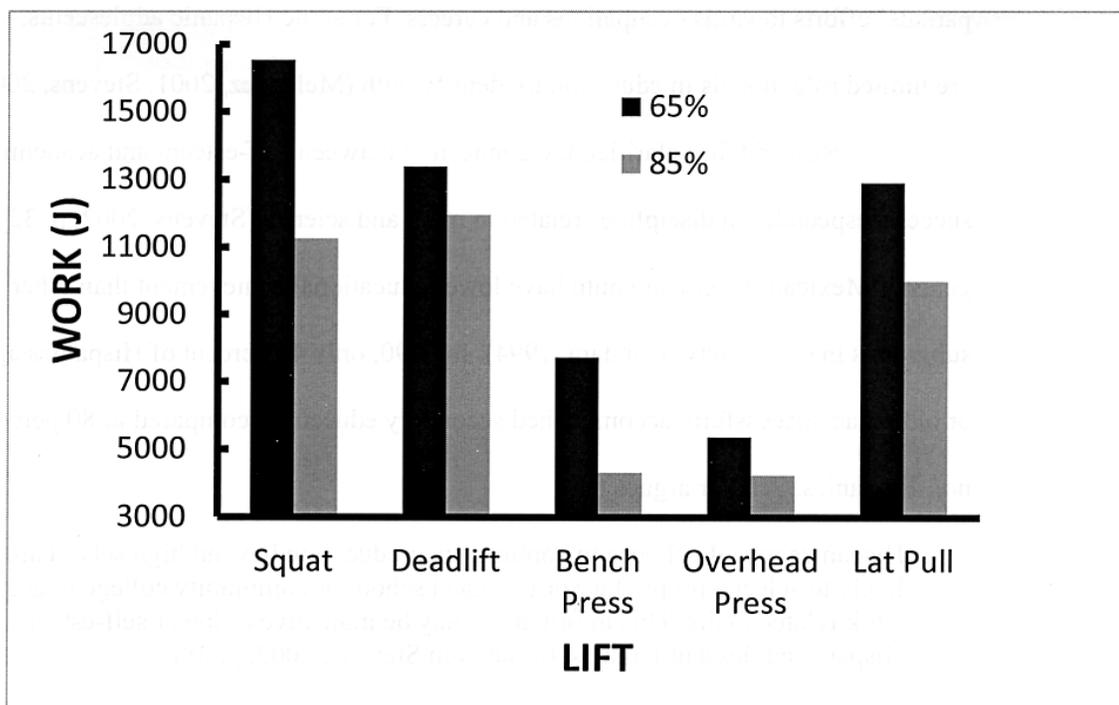


Figure 1. Mean work (Joules) performed in each lift.

minute sampling periods. At the thirty minute sampling period the mean differences between the baseline OGTT and the post-65% exercise OGTT was 10.7 mg/dl ( $p = 0.153$ ), and the mean difference between the post-65% exercise OGTT and the post-85% exercise OGTT was 9.8 mg/dl ( $p = 0.192$ ).

At the sixty minute sampling period the largest mean difference was between the baseline OGTT and the post-85% exercise OGTT with a mean difference of 9.8 mg/dl ( $p = 0.167$ ). This difference demonstrates a large drop in blood glucose between the thirty and sixty-minute sampling periods in the post-85% exercise intervention (Figure 2).

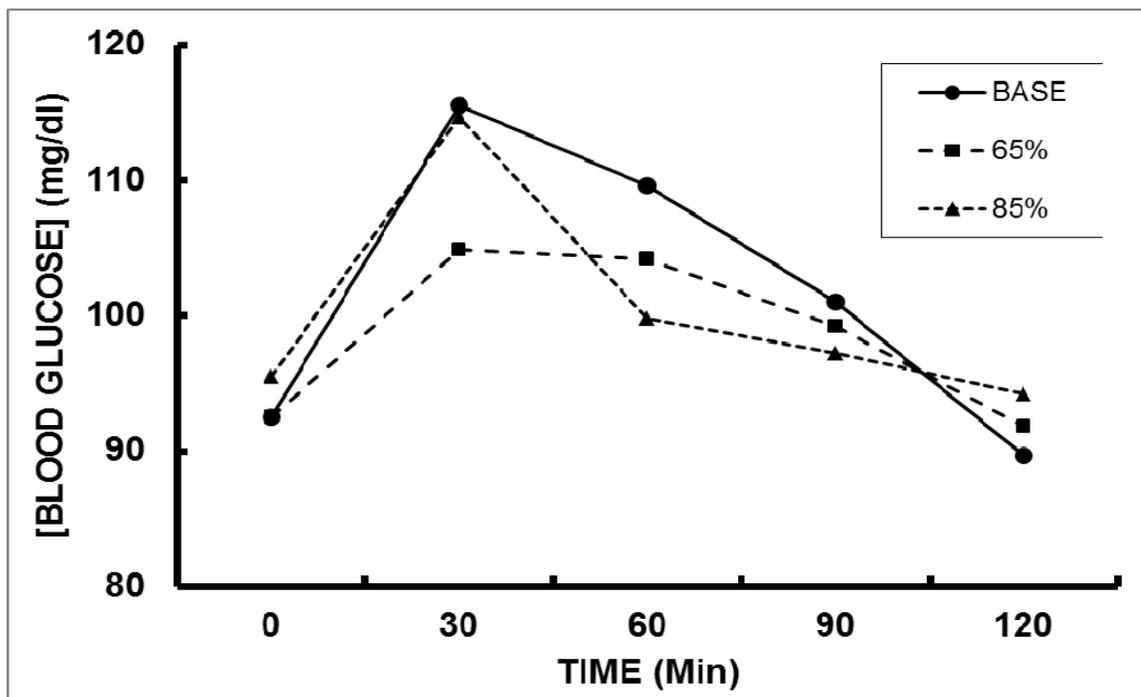


Figure 2. Blood glucose concentration at each time point throughout the two hour OGTT.

## CHAPTER V

### DISCUSSION

This study examined whether a single full body resistance exercise session, performed at two different intensities, can positively affect glucose tolerance as assessed by an oral glucose tolerance test (OGTT). Several studies have examined acute and chronic exercise and their effects on glucose uptake and glucose tolerance but this is the first study that evaluated the effects on glucose tolerance from a strictly strength exercise session.

The present study demonstrated at the thirty-minute time point there was a 10.7 mg/dl difference between the baseline OGTT and the post-65% exercise OGTT, however this was not statistically significant. Following the thirty minute mark there is little difference between the post-65% exercise OGTT and the post-85% exercise OGTT. However the large difference between the post-85% exercise OGTT and the baseline OGTT at the sixty minute mark suggests that the major difference between the 65% and 85% exercise may only be the blood glucose response to the glucose load within the first thirty minutes. It can be suggested that the less dramatic curve of the post-65% exercise group compared to that of the post-85% exercise is a product of the greater amount of work done in the 65% one repetition maximum strength exercise session. Presumably the greater work done would have led to greater AMPK activation which would have stimulated GLUT-4 translocation to a greater degree leading to greater glucose uptake

and a decreased glycemic response. Further the greater work would have also led to a greater glycogen and a decreased glycemic response. Further the greater work would have also led to a glycogen depletion which would have stimulated muscles to take up blood-borne glucose to a greater degree to replenish the depleted glycogen stores. The only way this can truly be evaluated however is to calculate the area under the curve. That is to calculate the total glycemic response for the entire 120 minute period. This however was not performed in the present study. Although there were no statistical differences at any time point in the OGTT's there was a noticeable change in curves when comparing each OGTT. Following the investigation a sample size calculation demonstrated that with the means and standard deviations produced in the experiment, a sample size of 36 would have elicited significant differences between the three different OGTT's.

Although there was a greater amount of work done in the 65% exercise, the distance the bar traveled in the work calculation was estimated and may not account for some of the test subjects not squatting deep enough or having restricted range of motion in any of the other lifts. It also may be suggested that the lack of significant results could be due to the population used in the study. Healthy college-aged males with a minimum of two years of resistance training experience do not represent a population that has issues with glucose tolerance. Further the subjects recruited in the present study had average fasting glucose concentrations of 92 mg/dl thus this sample has normal or even superior glycemic control as, stated above, they all had at least two years of resistance training experience.

Even though there was no statistical difference found between OGTT's, the glycemic response after the 65% trial was lower than both the baseline and 85% trial. Given that more intense exercise leads to higher intracellular concentrations of AMP which leads to subsequent greater AMPK activation and greater GLUT-4 translocation, the lower overall glycemic response curve might be explained by a greater overall activation of AMPK. This would result in more GLUT-4 translocation, more glucose transported into the muscle, and lower levels of glucose in the blood. Although muscle glycogen concentrations were not measured it is highly likely that muscle glycogen concentrations were lower following the 65% trial as opposed to the 85% trial and baseline OGTT. We can make this assumption based on the finding that compared to the 65% trial, 26% less work was done in the 85% trial and no work was done prior to the baseline OGTT.

### Summary

Noticeable changes were found at the thirty and sixty minute time points between the baseline OGTT, post-65% exercise OGTT, and the post-85% exercise OGTT (Figure 2). However there was no statistical significance showed at any of the five time points. Although statistical analysis was not performed on the work data, there was 26% less work done in the 85% exercise session as compared to the 65% exercise session (Figure 1).

### Conclusion

Acute strength exercise at 65% of one repetition maximum and 85% of one repetition maximum have no significant effects on glucose tolerance in healthy college aged males.

### Future Research

Future investigations might use a similar study design with test subjects that better represent a population with type 2 diabetes. As stated above, a sample size calculation showed to achieve statistical significance in the present study 36 subjects were needed. Future research may utilize a sample size that is larger than what was used in this study. Another measure that may be used in future research is area under the curve. What this measurement enables researchers to evaluate is the OGTT as a whole two hour measurement, rather than looking at differences between each time point.

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## APPENDIX A

California State University, Chico  
Department of Kinesiology  
Informed Consent

My name is Cameron D. Kisst. I am a graduate student in the Kinesiology and Exercise Science department at California State University, Chico and the primary investigator for this study. I am conducting this study for my thesis for the Master's degree requirement at CSU, Chico.

**PURPOSE**

The purpose of this study is to determine if a single one hour full body resistance exercise session, performed at two different intensities, can positively affect glucose tolerance as assessed by an oral glucose tolerance test (OGTT).

**PROCEDURES**

The following procedures have been demonstrated and explained to me and I agree to voluntarily participate in the following with the supervision of the primary or co-investigator:

1. I understand that I will be the subject of three separate oral glucose tolerance tests. Each test will require me to drink a 75 gram pure glucose beverage and give 5 small blood samples drawn from a finger stick over a two hour period. I understand I will also be required to fast for a minimum of 9 hours prior to each OGTT.
2. I understand that I will be required to fill out a 24 hour dietary recall.
3. I understand that my participation is strictly voluntary and I may choose to withdraw or not participate at any time and that there is no penalty for non-participation or withdrawing from the study.
4. I understand that the data will be published but all names, consent forms, and other identifiable information will be kept confidential under lock and key. After the publication of the study, all information will be destroyed.
5. I understand that, if I choose, I will receive a copy of the results.
6. I understand that the study will be performed at the California State University, Chico Exercise lab on five separate days. I understand the risks and discomforts involved with the study.
7. I will participate in three different resistance training sessions. The first session will test my 1 repetition maximum in the following lifts: Squat, Deadlift, Bench Press, Overhead Press, and Lat. Pull down. The following two exercise sessions will utilize the same 5 lifts as the first session. The intensities of these sessions will vary and all lifts will be performed for 3 sets to volitional fatigue.

8. I understand that taking part in this study may restrict my physical activity levels for a short period of time prior to data collection.

### **RISKS**

I understand that the exercise may be uncomfortable and there are risks related with any exercise. Although rare, the risk of muscle or ligament strain, sprain or heart attack can occur due to maximal exercise. There will be slight discomfort due to finger stick for the blood draw during the three oral glucose tolerance tests.

### **BENEFITS**

There will be no direct benefit to you as a participant in this study. However, the results and conclusions from this study will be available to you upon request.

### **CONFIDENTIALITY**

As a subject, you will be assigned a code number and the key to that code will be kept by the principal investigator. Records of this study will be stored in a locked file cabinet in room 134 Yolo Hall and destroyed two years after publication or five years after the study (i.e. after the investigators have exhausted all publication options). You will not be personally identified in any reports or publications that may result from this study.

### **RIGHT TO REFUSE OR WITHDRAW**

Participation is voluntary. There is no penalty for non-participation. You may choose to participate or withdraw from the study at any time without penalty or reprisal.

### **EXCLUSIONARY CRITERIA**

Upon completion of the Medical and Exercise History form any subject who meets the following criteria will be excluded from participating in the study: Lack of the minimum 2 years of required strength training experience, orthopedic injuries or severe pain within the last year, cigarette smoking, having diabetes or pre-diabetes, having a positive risk factor for Cardiovascular disease as outlined by the ACSM, having any neurological disorders, consistently taking any prescription medications, and positively identifying with any one of the conditions listed in question 16.

### **QUESTIONS**

If you have any questions, please feel free to contact me (209-985-7112). You may also report any comments regarding the manner in which this study is being conducted to the Human Subjects Research Committee at CSUC (898-4766).

**MY SIGNATURE BELOW INDICATES THAT I HAVE CHOSEN TO VOLUNTEER AS A RESEARCH PARTICIPANT AND THAT I HAVE READ, UNDERSTOOD, AND HAVE RECEIVED A COPY OF THIS CONSENT FORM.**

Participant name (print name) \_\_\_\_\_ Date \_\_\_\_\_

Participant name (signature) \_\_\_\_\_

Investigator (print name)\_\_\_\_\_Date\_\_\_\_\_

Investigator (signature)\_\_\_\_\_

**Primary Investigator:** Cameron D. Kisst

**Co-Investigator:** John L. Azevedo, Jr. PhD

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February 21, 2012

Cameron Kiist  
185 East 2nd Ave #1  
Chico, CA 95926



Dear Cameron Kiist:

As the Chair of the Campus Institutional Review Board, I have determined that your research proposal entitled "The effects of two resistance training intensities on glucose tolerance" has been granted clearance through an expedited review. This clearance allows you to proceed with your research.

I do ask that you notify our office should there be any further modifications to, or complications arising from or within, the study. In addition, should this project continue longer than the authorized date, you will need to apply for an extension from our office. When your data collection is complete, you will need to turn in the attached Post Data Collection Report for final approval. Students should be aware that failure to comply with any HSRC requirements will delay graduation. If you should have any questions regarding this clearance, please do not hesitate to contact me.

Sincerely,

John Mahoney, Ph.D., Chair  
Human Subjects in Research Committee

Attachment: Post Data Collection Report

2012114

HUMAN SUBJECTS IN REVIEW COMMITTEE

Amendment

Under Federal law relating to the protection of Human Subjects, this amendment is to be completed by the Principal Investigator if there are any changes to the original, approved application. Please return to HSRC Chair, c/o Lisa Bernal-Wood, HSRC Assistant (898-5413), Office of Graduate Studies, Student Services Center, Room 460, Zip 875.

Name: Cameron Kisst Empl ID #: 004123705

Phone(s) and Email: (209)985-7112 c.kisst@yahoo.com

Faculty Advisor (If student): John L Azevedo PhD

Phone and Email Address: jlazevedo@csuchico.edu

College/Department: Kinesiology

Title of Project: The effects of two resistance training intensities on glucose tolerance.

Changes to Original Approved Application: Originally it was planned that the post-exercise oral glucose tolerance test (OGTT) would be performed 24 hours after the exercise session. Now each post-exercise OGTT will immediately follow both training sessions rather than waiting 24 hours. The reason for this change is to eliminate the need to control for post-exercise diet. Each OGTT will take place within minutes of finishing the workout and will be completed 2 hours post-exercise. Each workout and OGTT will take place in the morning after a minimum 8 hour overnight fast.

Multiple horizontal lines for additional text or signature.

Your Signature:  Current Date: 3-5-2012

Approved By:  Date: 3-7-12  
John Mahoney, Chair

## APPENDIX B

**CALIFORNIA STATE UNIVERSITY, CHICO**

**MEDICAL AND EXERCISE HISTORY**

NAME \_\_\_\_\_ DATE \_\_\_\_\_

BIRTHDATE \_\_\_\_\_ AGE \_\_\_\_\_ HEIGHT \_\_\_\_\_ WEIGHT \_\_\_\_\_

1. How many days do you exercise in a week? (circle one) 1-2    3-4    5+
2. On average, what is the duration of a typical exercise session for you? (circle one) 10-20    30-60    60+ min/session
3. Describe the intensity of your exercise (circle one)  
1 = none  
2 = light (e.g. casual walking, golf)  
3 = moderate (e.g. brisk walking, jogging, cycling, swimming)  
4 = heavy (e.g. running, high intensity sport activity)
4. What types of exercise do you engage in and how much do you do each session? (circle all that apply)  
1 = none  
2 = walking  
3 = jogging/running  
4 = swimming  
5 = cycling  
6 = team sports (basketball, softball, soccer, etc.)  
7 = racquet sports  
8 = weight training  
9 = other \_\_\_\_\_
5. Do you measure your heart rate during exercise? 1 = yes    2 = no
6. How long have you had a regular exercise program? \_\_\_\_\_ Months - Years
7. What condition or shape do you consider yourself to be in now (in terms of physical fitness)?  
1 = poor  
2 = fair  
3 = good  
4 = excellent
8. Do you smoke? 1 = yes    2 = no

\_\_\_\_\_

9. Has a close blood relative had or died from heart disease or related disorders (Heart Attack, Stroke, High Blood Pressure, Diabetes etc.)?  
 1=Mother  
 2=Father  
 3=Brother - Sister  
 4=Aunt - Uncle  
 5=Grandmother - Grandfather  
 6=None  
 If yes- Give ages at which they died or had the problems.
- 
10. Indicate which of the following apply to you (circle all that apply).  
 1 = high blood pressure  
 2 = high blood fats or cholesterol  
 3 = cigarette smoking  
 4 = known heart disease or abnormalities  
 5 = family history of heart disease (parents or siblings before age 50)  
 6 = sedentary lifestyle  
 7 = stressful lifestyle at home or at work  
 8 = diabetes mellitus  
 9 = gout (high uric acid)  
 10 = obesity
11. Any medical complaints now (illness, injury, limitations, neurological symptoms)?  
 1 = yes      If yes, describe completely \_\_\_\_\_  
 2 = no      \_\_\_\_\_  
 \_\_\_\_\_
12. Any major illness in the past?  
 1 = yes      If yes, describe completely \_\_\_\_\_  
 2 = no      \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
13. Any surgery or hospitalization in the past?  
 1 = yes      If yes, describe completely \_\_\_\_\_  
 2 = no      \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
14. Are you currently taking any medications (prescription or over-the-counter: including birth control)?  
 1 = yes      If yes, list drugs and dosages \_\_\_\_\_  
 2 = no      \_\_\_\_\_  
 \_\_\_\_\_
15. Have you ever had any neurological problems?  
 1 = yes      If yes, describe completely \_\_\_\_\_  
 2 = no      \_\_\_\_\_  
 \_\_\_\_\_
16. Do you now have, or have you ever had, any of the following? (circle all that apply)  
 1 = heart murmurs  
 2 = any chest pain at rest  
 3 = any chest pain upon exertion

- 4 = pain in left arm, jaw, neck
- 5 = any palpitations
- 6 = fainting or dizziness
- 7 = daily coughing
- 8 = difficulty breathing at rest or during exercise
- 9 = any known respiratory diseases
- 10 = any bleeding disorders or problems with bleeding

Please describe fully any items you circled: \_\_\_\_\_

---

17. Do you now have, or have you ever had, any of the following? (circle all that apply)

- 1 = any bone or joint injuries
- 2 = any muscular injuries
- 3 = muscle or joint pain following exercise
- 4 = limited flexibility
- 5 = any musculoskeletal problems which might limit your ability to exercise

Please describe fully any items you circled: