EXERCISE-INDUCED CHANGES IN BODY FAT, UPPER LEG SKELETAL MUSCLE AREA, BMI AND BODY WEIGHT IN OVERWEIGHT PEOPLE WITH RISK OF DEVELOPING TYPE 2 DIABETES

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ABSTRACT

The study compared effects of maximal resistance training (MRT) versus endurance resistance training (ERT) in overweight people at risk of developing Type 2 Diabetes. Dependent variables included changes in body fat %, upper leg skeletal muscle area (left + right), BMI and body weight pre-to post intervention. Eighteen individuals, 33- 69 years of age, were randomly assigned to one of two groups. Group 1 engaged in MRT three days/week over a four month period while members of Group 2 acted as controls. Later, Group 2 engaged in ERT three days/week over a four month period and the members acted as their own controls. Both interventions consisted of eight exercises. Pre- to post changes were significant for MRT with a reduction in BMI (p=0.013) and body weight (p=0.010), while percentage of body fat was significantly reduced (p=0.009) and skeletal muscle area increased (p=0.021) with ERT. The results support both approaches as interventions in primary prevention of obesity and consequently in reducing risk of Type 2 Diabetes.

Key words: BMI, resistance training, impaired glucose tolerance, percentage of body fat, skeletal muscle.

INTRODUCTION

Impaired glucose tolerance (IGT) and Type 2 Diabetes, as well as hypertension and overweight, are major challenges for current public health management [6, 23, 33]. Many adults with diabetes are overweight and more than half of adults with diabetes are obese [9]. Obesity is associated with cardiovascular risk factors such as increased blood glucose [1]. A lifestyle involving limited physical activity seems to be one of the most important reasons for the development of obesity [8, 23, 27]. Physical inactivity and increased body weight are expected to increase the prevalence of Type 2 Diabetes in Europe from 3.5% to 4.75% over the next 25 years [34]. At the same time, obesity is a serious health concern among more than 300 million people worldwide, and its prevalence increased by 50 % in only seven years [32].

Resistance training can lead to changes in body fat, skeletal muscle, body mass index (BMI) and body weight as it is known to increase the volume of muscle and hence overall muscle mass. Maximal resistance training (MRT) [5] aims to build increased muscle mass under anaerobic exercise conditions. Optimal intensities during resistance training are 60–80% of 1RM. Conventional aerobic endurance resistance programs include multiple bouts of low work-load exercises at 45–65% of 1RM training, with intervals of pauses to slow down the heart-rate and allow muscle cells to be refilled with oxygen.

Lifestyle interventions appear to be effective in the prevention of Type 2 Diabetes among people with IGT. Results from a recent study suggested that screening for Type 2 Diabetes and IGT, with appropriate intervention for those with IGT, in an above average risk population aged 45, is cost effective [13]. Several studies have reported improvements in glucose tolerance with resistance training [16, 28, 29], whereas others have not [18, 36]. It is still unclear to what extent this type of intervention has beneficial effects on metabolism in individuals with normal glucose tolerance (NGT) [25]. Resistance training reduces total body fat mass in men and women, independent of dietary caloric restriction [7, 24]. Resistance training may reduce visceral adipose tissue in older men and women. In a review study, Gordon et al. [14] claimed that supervised resistance training improves glycaemic control and insulin sensitivity in adults with Type 2 Diabetes. However, further research is needed to explore the mechanism(s) behind glucose tolerance improvements following resistance training, and to determine the optimal frequency, intensity and duration of such training. A recent study by Hansen et al. [15] concluded that maximal, as well as endurance resistance training (ERT), caused a reduction in insulin resistance in individuals at risk of developing Type 2 Diabetes. Lifestyle interventions seem to be at least as effective as drug treatment [12].

The development of obesity is associated with a worsening of blood glucose and increased risk of other cardiovascular factors [1]. Results from the "Look AHEAD trial" showed that weight loss in patients with diabetes improved glycolic control, reduced blood pressure and improved blood lipids [20]. Observational studies also support a likely link between weight loss and reduced mortality in people with Diabetes [1].

Active men with normal and overweight BMIs appear to face fewer health risks than their inactive counterparts. Elevated BMI is a key driver of diabetes risk, with relatively modest attenuation with activity. However, BMI and physical inactivity are independent risk factors in the development of Type 2 Diabetes, although the effects of the combination of these two factors are unclear [17]. One study reported a greater risk of Diabetes both for physically active and inactive overweight and obese participants than in active individuals with normal weight. Analyses of the combination of level of physical activity and BMI score state that adiposity, as associated with an above normal BMI, is a critical determinant of Diabetes [30]. A prospective study by Siegel et al. [26] reported that normal and overweight BMIs in men, who were active, were associated with a reduced risk of Diabetes in comparison with their inactive controls. There was no significant difference in Diabetes risk (incidence of Diabetes, hazard ratios (HRs)) between highly active versus highly inactive men with obesity. This lack of difference suggests that the increase in BMI may be one important factor in the risk of Diabetes, even though inactivity alone may not be an important predisposing factor. Hansen et al. [15] suggest that resistance training improves both glycemic control and insulin sensitivity. Potential mechanisms behind this are the physiological changes induced by resistance training. Other determinants are discrete pathways to provide additive insulin signaling benefits [3]. Most people with Diabetes and IGT are overweight or obese. Such conditions may provoke increased motivation for compliance to prevent the development of Diabetes.

Interventions conducted by general practitioners seem to be limited, indicating that intervention strategies should specifically be tailored to the individual, assisted by training practitioners [22].The aim of the present study is to compare the effects of maximal resistance training and endurance resistance training in overweight people at risk of developing Type 2 Diabetes. Dependent variables included changes in body fat, upper leg skeletal muscle area (left + right), BMI and body weight pre-to post intervention.

MATERIAL AND METHODS

Participants

Eighteen perticipants, who were classified as IGT in a large-scale public health screening study in Norway in 2004 [21], according to standards set by theWHO [31], volunteered for this study. The sample consisted of 4 men and 14 women. The participants were randomized into two groups with 9 individuals in each. To accommodate gender differences, two men were randomized into each group. (Group 1: Males=2; mean age=47.5 years, Females=7; mean age=46.5 years. Group 2: Males=2, mean age=60.5 years, Females=7, mean age= 44.4 years. Overall age range 33–69 years). Both groups fulfilled the criterion for BMI, and were overweight (Group 1, mean-value 28.55 kg/m^2, SD=4.3, Group 2, mean value 27.17 kg/m^2, SD=4.1). During the second intervention, consisting of conventional endurance ERT (Group 2), there were two drop-outs. Written informed consent was obtained from each of the study participants in accordance with the Helsinki Declaration [2]. The study was approved by the Regional Committee for Ethics in Medical Research (Ref. No. 4.2006.2549).

Procedures

Participants in Group 1 were involved in a lifestyle intervention program for four months. This program focused on MRT (Bernstein inverted pyramid system [4]), 3 days/week (5 x 3–4, 60–85% 1 RM) [5]. Members of Group 2 acted as controls and Group 2 was put on hold until Group 1 had completed the prescribed training program. Group 2 started the life style intervention program, which was composed of conventional ERT 3 days/week (3 x 12–15, 45–65% 1 RM), following the initial four month wait [5]. Both groups performed the intervention at a fitness center. The first three weeks focused on providing instructions on how to properly perform assigned exercises. The guided interventions consisted of eight exercises for the whole body: (1) total abdominal, (2) lower back, (3) press for thighs, (4) leg press, (5) chest press, (6) arm press, extension for triceps, (7) pull down for upper back and (8) arm curl for biceps. The principles behind the heavy muscle strength-promotion training were maximal intensity with a load that was lifted 4 repetitions to exhaustion. Then, a reduced load was permitted for every new set of 4 repetitions without breaks in between, continuing until the muscles were exhausted [4]. Before and after the resistance exercises, the individual walked for 10 minutes on a treadmill to warm up, and walked 10 minutes after the resistance training to cool down. ERT included intensity training, with a load that permitted twelve – fifteen repetitions, in sets of three, with a break of 1.5–2 minutes between sets. Similar to the procedure for Group 1, participants in Group 2 walked for10 minutes to warm up on a treadmill before resistance exercising, and walked an additional 10 minutes to cool down after resistance exercises.

Measures

Clinical measures were taken with the participants wearing under-garments without shoes; height was rounded off to the nearest 1 cm and weight to the nearest 0.5 kg, and these measures were used for the BMI algorithm (kg/m^2). The WHO categories for BMI were used [32]: Normal weight (18.5 – 24), overweight (25 – 29), and obese (≥30). Furthermore, waist circumference was measured horizontally at the height of the umbilicus to the nearest 1 cm when the participant was standing with arms hanging relaxed. Four skinfold measures on biceps, triceps, subscapularis and suprailiac together with measured waist circumference, combined with age and gender were used in the algorithm to calculate the total body fat index [10]. Upper leg skeletal muscle mass was estimated by magnetic resonance imaging (MRI) technology.

Method of choice for scanning

Measurements were performed on a 1.5 T GE Signa HDX MRI scan with software version 14.0.M5. The measurement protocol was based on T1 weighted FSE (Fast Spin Ecco) MRI in order to be able to make an image suitable for measuring the parameters of interest. This was found sufficient to clearly differentiate between muscle mass, sub-cutaneous adipose and bone tissue.

For the upper leg the following technical parameters were used: Freguency 512; Phase 256; NEX (Number of Excitations) 20; ETL (Ecco Train Length) 3; FOV (Field of view) 46; slice thickness 8,0 mm, spacing between slices 2,0 mm; TR (Repetition Time) 340 msec; TE (Ecco Time) min-full; BW (Band With) 15.63.

The protocol was designed to produce imaging uptake at the same location for all participants and at the same location when carrying out pre- and post- measurements. Estimates were made 24 cm proximal to the knee joint. This seemed to be the most suitable area as it included all muscle groups of interest.

The MRI provided a transverse picture through the upper leg. Based on these images, we used a software toll (from SECTRA RIS) with a marker of region of interest to delineate the muscle tissue, subcutaneous adipose tissue and bone. This approach excluded the greater neurovascular bundles of the lower extremities. The results were given as square mm (mm^2), and subtraction was used to determine the area of each tissue compartment [19].

Statistical analysis

The SPSS 17.0 statistical package was applied in all statistical analyses (SPSS Inc, Chicago, Ill, USA). T-tests were carried out to assess homogeneity between the groups. Potential differences were investigated between pre- and post- assessments, and between groups by repeated measures analysis of variance (ANOVA) with one within (pre–post) and one between (Group 1 vs. Group 2) factors. T-tests for dependent samples were used to assess changes from pre- to post intervention in Groups 1 and 2. T-test statistics were assessed to arrive at a main effect for each exercise intervention. Furthermore, measures of net mean changes were compared to determine any superiority.

RESULTS

Means and standard deviations are given for each group at baseline (Table 1). Scores are given for percentage of body fat, upper leg skeletal muscle area (left + right), BMI and body weight. The study groups fulfilled the criterion for an overweight BMI (Group 1, mean-value 28.55 kg/m^2, SD=4.3, Group 2, mean-value 27.17 kg/m^2, SD=4.1). T-tests showed homogenity between the groups with no signifcant differences in mean value of the dependent variables.

Table 1. Means and standard deviations (±SD), t-scores and p-values for groups of homogeneous dependent variables (percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight at baseline (n= 18).

	Group 1 (n=9)		**Group 2 (n=9)**			
Variables	**Mean**	**SD**	**Mean**	**SD**	**T-score**	**p-value (2-tailed)**
Percentage body fat (%)	39.7	4.9	36.7	5.5	1.16	0.260
Skeletal muscle area (mm)	25730	3811	24473	5238	0.582	0.569
BMI (kg/m^2)	28.55	4.3	27.20	4.2	0.69	0.498
Body weight (kg)	76.8	11.6	78.2	16.9	-0.21	0.835

Means and standard deviations in percentage body fat, upper leg skeletal muscle area, BMI and body weight before and after four months of MRT for Group 1 are presented in Table 2. T-scores and p-values are given for pre to post-differences. A significant decrease in weight was seen from pre to post-intervention (p=0.010). The decrease was accompanied by a significant increase in BMI from pre to post-intervention (p=0.013).

Table 2. Means and standard deviations (±SD) of percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight before and after four months of MRT in a group of overweight individuals (n=9) at risk of Type 2 Diabetes. T-scores and p-values are given for pre- and post-measures.

Variables	**Pre mean**	**SD**	**Post mean**	**SD**	**T-Score**	**p-value**
Percentage body fat (%)	39.7	4.9	38.6	5.0	2.17	n.s.
Skeletal muscle area (mm)	25730	3812	25800	3408	-0.42	n.s.
BMI (kg/m^2)	28.55	4.3	27.40	3.9	3.20	0.013
Body weight (kg)	76.8	11.6	74.0	11.9	3.37	0.010

n.s.=not significant

Means and standard deviations in percentage of body fat, upper leg skeletal muscle area, BMI and body weight before and after four months of ERT are presented for Group 2 in Table 3. T-scores and p-values are given for pre- to post-differences. A significant decrease in percentage of body fat was seen from pre to post intervention (p=0.009). The decrease was contrasted with a significant increase in sceletal muscle area from pre to post intervention (p=0.021). No significant change was found for BMI and body weight, which might indicate that body mass shifted from fat to skeletal muscle mass due to the four months of ERT.

Table 3. Means and standard deviations (SD) of percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight before and after four months of endurance resistance training in a group of overweight individuals (n=7) at risk of Type 2 Diabetes. T-scores and p-values are given for pre- and post-measures.

	Pre		**Post**			
Variables	**Mean**	**SD**	**Mean**	**SD**	**T-score**	**p-value**
Presentage body fat (%)	38.01	6.09	36.30	6.14	3.82	0.009
Skeletal muscle area (mm)	25420	5697	26290	5805	3.12	0.021
BMI (kg/m^2)	28.0	4.1	27.6	4.8	0.95	n.s.
Body weight (kg)	82.7	15.1	83.6	16.1	1.53	n.s.

n.s.=not significant

Results from the two-way repeated ANOVAs stated that F-scores for overall effects of the time factor were significant for BMI and body weight due to reductions from pre to post intervention (Table 4). F-scores for overall differences between groups were not significant. However, the group-by-time interaction was significant for percentage of body fat, BMI as well as body weight ($p<0.003$, 0.011 and 0.01, respectively) due to relatively marked reductions in all three measures only in the maximal resistance intervention group (Group 1).

Table 4. F-scores and p-values for effects of maximal resistance training upon change in percentage body fat, upper leg skeletal muscle area (left + right), body mass index (BMI) and body weight from pre- to post-intervention (Time T, Group, G), compared with pre- and post-values in a waitinglist control group (n=18).

	Time (T)		**Group (G)**		**T x G**	
Variables	**F-score**	**p-value**	**F-score**	**p-values**	**F-score**	**p-values**
Presentage body fat (%)	0.61	n.s.	0.39	n.s.	12.64	0.003
Skeletal muscle area (mm)	0.07	n.s.	0.36	n.s.	0.05	n.s.
BMI (kg/m^2)	7.70	0.014	0.17	n.s.	8.24	0.011
Body weight (kg)	8.07	0.012	0.18	n.s.	8.47	0.01

n.s.=not significant

T-test statistics were assessed to arrive at a main effect for each exercise intervention (Table 5). Measures of net mean changes were compared to determine any superiority and to compare the mean change for each dependent variable. The comparison showed that there were no significant mean changes for the variables, except for weight (p=0.004), thus indicating that there was only a partial superiority of one intervention to the other.

Table 5. Compared net Mean differences, t-scores and p-values of maximal and endurance resistance training for percentage of body fat, upper leg skeletal muscle area (left + right), body mass index (BMI), and body weight (n=16, Group 1: 9, Group 2: 7).

Variables	**Mean difference**	**t-score**	**p-value**
Presentage body fat (%)	0.641	0.955	0.356
Skeletal muscle area (mm)	-408.05	-1.756	0.101
BMI (kg/m^2)	-0.757	-1.510	0.153
Body weight (kg)	-3.684	-3.431	0.004

DISCUSSION

The findings indicate that MRT is somewhat superior to ERT in reducing body weight and BMI. Moreover, ERT appeared to be more efficient than MRT for reducing body fat and increasing skeletal muscle. This pattern of changes indicates that overall body mass shifted from fat to skeletal muscle mass due to the four months of ERT. One could therefore argue that the results encourage the use of both types of resistance training despite the significant effect upon increase in skeletal muscle area only from ERT.

Reduction of BMI and related weight loss are associated with improved glycolic control, reduced blood pressure, and improved blood lipids. All these changes reduce the risk of developing Type 2 Diabetes [11]. The present findings add further support to the review study by Anderson et al. [1] who concluded that weight management appears to be the most important therapeutic task for people with Type 2 Diabetes. Resistance training appears to significantly induce these changes. However, in the present study, weight and BMI reductions following ERT were not significant. The reason for this is probably that the increase in skeletal muscle area compensated for the loss of body fat. These findings, together with those reported by Braith and Stewart [7], show that training reduced total body fat in men and women, independent of dietary caloric restrictions.

A recent systematic review [35] identified seven studies on the effects of multi-component lifestyle interventions in people with IGT. The interventions included exercise, diet and weight loss goals. Only one study included a structured exercise training intervention. Four studies used the incidence of Diabetes over the course of the study as an outcome measure. A reduction in Diabetes risk by approximately 50 % (range 42–63 %) was reported in these four studies despite the fact that only small changes in physical activity were achieved. Therefore, the reduced risk of Diabetes was most likely attributable to factors other than physical activity. In this way, the contribution of physical activity, independent of dietary changes and weight loss, in the prevention of Type 2 Diabetes in people with symptoms associated with pre-diabetes, is still equivocal. In relation to obesity treatment, the present study furthers our understanding of resistance training as a tool for health care providers in this field, particularly given that most people with Diabetes and IGT are overweight or obese. The present findings encourage recommending MRT as well as ERT for overweight individuals as well as individuals perhaps at risk of developing Type 2 Diabetes.

In conclusion, MRT and ERT are promising approaches in the use of exercise to prevent obesity and consequently Type 2 Diabetes. BMI and body weight appeared to respond significantly to MRT, whereas ERT led to a significant decrease in body fat and increase in skeletal muscle area. The investigation provides important novel insight for prevention and treatment. The effects discovered here may depend on the approach to resistance training in this study and the choice of a comparative design. Superior prevention may result from a combination of the two approaches.

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