

Effect of Supervised Progressive Resistance-Exercise Training Protocol on Insulin Sensitivity, Glycemia, Lipids, and Body Composition in Asian Indians With Type 2 Diabetes

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OBJECTIVE — To evaluate the effect of supervised progressive resistance-exercise training (PRT) protocol on insulin sensitivity, glycemia (blood glucose and A1C levels), lipids, and body composition in Asian Indians with type 2 diabetes.

RESEARCH DESIGN AND METHODS — Thirty patients with type 2 diabetes underwent 12 weeks of PRT of six muscle groups (two sets, 10 repetitions each). The subjects were evaluated with detailed anthropometry and with measurements of the disappearance of glucose per unit time (K) during the short insulin tolerance test (K_{ITT}) for assessment of insulin sensitivity; of fasting blood glucose, A1C, lipids, and high-sensitivity C-reactive protein (hsCRP); of total body fat, regional fat, and lean body mass by dual-energy X-ray absorptiometry; and of cross-sectional skeletal muscle area of upper arm and thigh by computed tomography scan.

RESULTS — Insulin sensitivity improved significantly from mean \pm SD K_{ITT} 1.22 ± 0.73 to 2.13 ± 0.75 ($P < 0.0001$) after the intervention. Significant decline (mean difference \pm SD) from baseline was recorded in levels of the following parameters: A1C ($0.54 \pm 0.4\%$, $P < 0.001$), fasting blood glucose (2.7 ± 2.2 mmol/L, $P < 0.001$), total cholesterol (0.39 ± 0.7 mmol/L, $P = 0.003$), serum triglycerides (0.39 ± 0.5 mmol/L, $P < 0.001$), and truncal and peripheral subcutaneous adipose tissue compartments (SCAT) ($P < 0.001$). However, no significant changes were noticed in BMI or levels of total body fat, truncal fat, lean body mass, cross-sectional skeletal muscle area of the extremities, or hsCRP levels.

CONCLUSIONS — Moderate-intensity PRT for 3 months resulted in significant improvement in insulin sensitivity, glycemia, lipids, and truncal and peripheral SCAT in patients with type 2 diabetes. Resistance training should be an integral part of exercise regimen in Asian Indians with type 2 diabetes.

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Prospective epidemiological studies across several populations have indicated that insulin resistance is the central feature of the metabolic syndrome and the primary defect in development of type 2 diabetes. It often antedates diabetes

by several years. Insulin resistance is also reported to be a risk factor for development of cardiovascular disease.

Both aerobic and resistance exercise effectively improve insulin sensitivity and lead to better glycemic control in patients

with type 2 diabetes (1). While aerobic exercise has been extensively investigated and shown to be beneficial for glucose-lipid metabolism, resistance exercise has been less researched. Interestingly, resistance training could be more effective than aerobic exercise in improving the glycemic profile (2). Further, a combination of these exercise regimens may even be more beneficial in improving insulin sensitivity and glycemic control (3,4).

Asian Indians manifest insulin resistance and the metabolic syndrome at a younger age and at a higher magnitude than many other ethnic groups (5,6). Possible determinants of insulin resistance in Asian Indians are excess overall adiposity, in particular abdominal adiposity; excess truncal subcutaneous adipose tissue (SCAT); and low skeletal muscle mass (5–7). It has been debated whether resistance exercise will be metabolically more beneficial in Asian Indians (8). However, the effects of resistance exercise on overall adiposity, truncal and peripheral SCAT, and intra-abdominal adipose tissue (IAAT) have not been properly evaluated. Further, it is not clear whether increasing the mass and augmenting the function of major skeletal muscle groups in Asian Indians could have a better effect on insulin sensitivity compared with its effect in other ethnic groups. Resistance exercise might target both excess adiposity and low skeletal muscle mass in Asian Indians. Therefore, it appears that resistance exercise could be specifically useful in improving insulin sensitivity and metabolic parameters in Asian Indians with type 2 diabetes.

We hypothesized that increasing the mass and enhancing the function of major skeletal muscle groups by use of supervised progressive resistance-exercise training (PRT) protocol for 3 months will improve insulin sensitivity in Asian Indian patients with type 2 diabetes. We also hypothesized that PRT protocol would improve the levels of fasting blood

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glucose, A1C, lipids, high-sensitivity C-reactive proteins (hsCRP), and anthropometric parameters and, specifically, decrease truncal SCAT and increase extremity skeletal muscle mass.

RESEARCH DESIGN AND METHODS

Subject characteristics

This prospective study was undertaken in the Department of Medicine, All India Institute of Medical Sciences, New Delhi, India, from April 2004 to March 2006. Thirty patients with type 2 diabetes were selected from the medical outpatient department and diabetes clinic. After ethical clearance, written informed consent was obtained. The following subjects were excluded from the study: patients on insulin or thiazolidinedione therapy and those with coronary artery disease, significant respiratory disease, orthopedics problems that would interfere with resistance exercise training, advanced diabetes-induced end-stage organ damage, or pregnancy. Patients were on stable doses of oral hypoglycemic drugs (sulfonylureas, biguanides, and meglitinides) for the previous 3 months. Most of the patients were already following an aerobic exercise regimen as prescribed by their physicians, which was further reinforced. Compliance was observed at 85% through a self-maintained diary. During the 12-week intervention, patients did not change the dose of oral hypoglycemic medications, dietary pattern, or intensity of baseline activities including aerobic exercises.

Short insulin tolerance test

Short insulin tolerance test (SITT), which has been validated against hyperinsulinemic-euglycemic clamp technique as a simple, valid, reproducible, and shorter method for the measurement of insulin sensitivity, was performed in this study (9,10). A number of investigators have used this method in clinical studies to measure whole-body insulin sensitivity (11). A scalp vein set was inserted in the antecubital vein, and venous blood samples were taken at -3 and 0 min. Subsequently, rapid-acting insulin (Huminsulin R; Eli Lilly) at an intravenous bolus dose of 0.05 units/kg body wt was given at 0 min. Venous blood was collected at 3 -, 6 -, 9 -, 12 -, and 15 -min intervals for blood glucose estimation, and the measured values were log transformed. The rate of decline of blood glucose levels was calculated by plotting the disappear-

ance of glucose per unit time (K value). Patients were monitored for signs of hypoglycemia. The initial SITT was performed in the beginning of the study before the start of PRT protocol, and the final SITT was done 72 – 96 h after the last exercise bout at the end of 12 weeks.

Biochemical measurements

Fasting venous blood samples were drawn for estimation of fasting blood glucose (FBG) and serum lipids (total, LDL, VLDL, and HDL cholesterol and serum triglycerides). Assay for hsCRP was carried out using an ELISA kit (Biocheck, CA).

Anthropometric measurements

BMI was calculated as weight in kilograms divided by the square of height in meters. Circumferences at waist, hip, midarm, midthigh, and calf were recorded to the nearest 0.1 cm. Biceps, triceps, thigh, calf, subscapular, anterior axillary, lateral thoracic, and suprailiac skinfolds were measured using Lange skinfold calipers as previously described (12).

Dual-energy X-ray absorptiometry and computerized tomography scans

Regional and global measurements of whole-body fat and lean body mass were estimated by using a whole-body dual-energy X-ray absorptiometry scan (Hologic QDR 4500A with fan beam). For studying the cross-sectional area of muscle mass, two axial sections using a helical computerized tomography (CT) scan (Somatom Plus 4; Siemens, Erlangen, Germany) were taken, one at the midpoint of the right thigh (midpoint of line joining superior rim of femoral head and inferior surface of femoral condyle) and the other at the midpoint of the right arm (midpoint of line joining superior rim of humeral head and inferior surface of the humerus condyle). Muscle bulk was mapped using a user-selectable region of interest, taking care to exclude adipose tissue and all other extraneous soft tissue. The skeletal muscle area (using CT images) was analyzed by a single observer using in-built software.

PRT protocol

The subjects were familiarized with the correct method of performing the following exercises: biceps flexion, shoulder flexion, finger grip, hip flexion, knee extension, and heel rise. They underwent onsite supervised PRT protocol for 12 weeks (3 days per week) in the physio-

therapy clinic supervised by the same physiotherapist (K.M.). The first, second, and third training sessions were performed every alternate day in a week and were within ~ 48 h of the last exercise bout. The gap between the third and fourth training session (performed at the start of the next week) was more than 48 h because of the weekend. Similar training schedules were implemented for each week until week 12. Each subject underwent warming up for 10 min by doing gentle stretching exercises of upper and lower limbs. For each subject, the repetition maximum (RM) was calculated for a particular muscle group. First, a 3 RM for that particular set of muscles was identified. Then, the patient was started on one weight less than that for a 3 RM. The subject performed 10 such repetitions using that weight and two sets (moderate intensity) in each group of muscles. If the patient was able to perform such exercise at the end of the week, 0.5 kg weight was added in the next week. Compliance was analyzed to be 100% at each visit.

Statistical analysis

For quantitative variables, arithmetic mean and SD were computed as measures of descriptive statistics. Student's t test was applied to compare the mean values before and after the protocol. The mean difference of the values at end (three months) and start (0 months) of the protocol was calculated for all the variables. A P value < 0.05 was considered statistically significant. STATA 9.0 (intercooled version; STATA, Houston, TX) was used for data analysis.

RESULTS

Sample description

The subjects were middle-aged (mean \pm SD age 40.8 ± 8.1 years [range 24–50]) with a wide range of BMI (24.1 ± 3.9 kg/m²; [17.5–30.0]). Of the 30 subjects (22 male and 8 female), 10 were hypertensive and 11 had diabetic retinopathy.

Insulin sensitivity and metabolic parameters

Insulin sensitivity (Fig. 1) improved as the K value increased (from K of SITT [K_{ITT}] 1.22 ± 0.732 to 2.13 ± 0.751 [$P < 0.0001$]) significantly after the protocol. A1C showed a significant decline, from $7.72 \pm 0.47\%$ at baseline to $7.18 \pm 0.33\%$ ($P < 0.001$). Also, FBG decreased significantly, from 10.07 ± 2.0 to 7.4 ± 1.2 mmol/l ($P < 0.001$). Significant de-

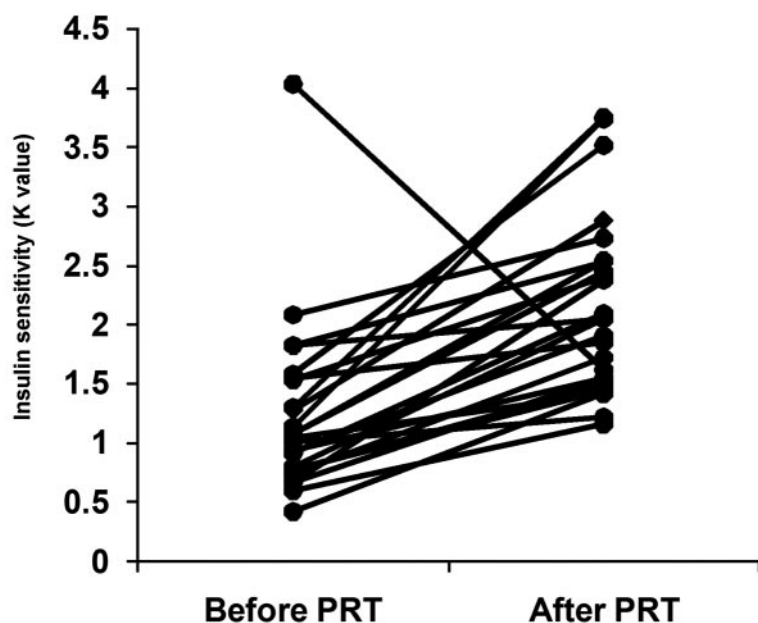


Figure 1—Insulin sensitivity as assessed by SITT and depicted as K value (see text for details) before and after intervention. Increasing value denotes improved insulin sensitivity.

creases (mean difference \pm SD) in the levels of lipids were recorded from baseline: total cholesterol (0.39 ± 0.7 mmol/l, $P = 0.003$), triglycerides (0.39 ± 0.5 mmol/l, $P < 0.001$), and VLDL cholesterol (0.34 ± 0.6 mmol/l, $P = 0.003$) (Table 1).

Anthropometric measurements

After the protocol, there was no significant change in BMI. However, a significant decrease ($P < 0.001$) in body circumference and skinfold thickness at truncal and peripheral sites was observed (Table 2).

Adiposity, lean mass, and circumferential extremity of skeletal muscle area

No significant differences were noted in the following parameters: total body fat, ratio of truncal to total body fat, regional fat in right upper arm and thigh, total-

body lean mass, and lean mass of right arm and leg. There were also no significant differences noted in midarm and midhigh skeletal muscle cross-sectional area (Table 3).

CONCLUSIONS— For the first time, we report a significant improvement in insulin sensitivity and A1C, a decrease in truncal and peripheral SCAT, and a decline in lipid values after 3 months of supervised PRT in Asian Indians with type 2 diabetes. This study is significant because it is likely that PRT may be more effective in Asian Indians than in white Caucasians because of excess overall adiposity, higher truncal SCAT, and lower skeletal muscle mass. Among the risk factors for the metabolic syndrome, waist circumference and triglyceride and FBG levels decreased significantly.

In the present study, all patients ex-

cept one had improved insulin sensitivity after 3 months as determined by SITT. Similar to our findings, those of other researchers studying disparate populations have shown an improvement in insulin sensitivity in sedentary nonobese (13) and older (14) men with type 2 diabetes using resistance exercise regimens alone. While the former study used moderate-intensity PRT, high-intensity PRT was used in the latter. However, Dunstan et al. (15) reported a minimal change in insulin sensitivity in older men and women (age 60–80 years) after a regimen of combined resistance training and weight loss. Discrepancies in the findings of different investigators could be due to variable and often inadequate duration of intervention and use of different methods to measure insulin sensitivity.

Exercise training, whether aerobic or resistance, leads to an increase in skeletal muscle GLUT4 content. Resistance training produces an increase in fat-free mass, contributing to increased glucose disposal, whereas aerobic training enhances glucose disposal independent of changes in fat-free mass, fat mass, or maximum aerobic capacity, bringing about functional changes in the muscle. It is likely that, due to different mechanisms of action, the addition of resistance exercise to aerobic training can help achieve the targets in shorter time than achievable by isolated aerobic exercise alone.

A1C and FBG values declined (0.54% and 2.7 mmol/l, respectively) from baseline, indicating a significant improvement in glycemic control. Several investigators have shown a decline of A1C ranging from 0.5 to 1.2% after resistance exercise alone (16) or resistance exercise combined with a weight loss regimen (15) spanning over a period of 3–6 months, whereas others (13,14) failed to show any improvement after 8–16 weeks of training. Balducci et al. (17) reported an im-

Table 1—Changes in metabolic parameters with PRT protocol

Variables	PRT (0 months)	PRT (1 month)	PRT (2 months)	PRT (3 months)	Mean difference	P^*
<i>n</i>	30	30	30	30	—	—
FBG (mmol/l)	10.07 ± 2.0	8.7 ± 1.3	8.2 ± 1.1	7.4 ± 1.2	2.7 ± 2.2	<0.001
Total cholesterol (mmol/l)	4.58 ± 0.7	4.35 ± 0.5	4.29 ± 0.6	4.19 ± 0.5	0.39 ± 0.7	0.003
TG (mmol/l)	1.99 ± 0.6	1.81 ± 0.5	1.63 ± 0.5	1.59 ± 0.4	0.39 ± 0.5	<0.001
HDL cholesterol (mmol/l)	1.19 ± 0.08	1.19 ± 0.06	1.19 ± 0.09	1.21 ± 0.09	-0.02 ± 0.1	0.331
LDL cholesterol (mmol/l)	1.46 ± 0.6	1.35 ± 0.4	1.34 ± 0.4	1.35 ± 0.4	0.09 ± 0.4	0.210
VLDL cholesterol (mmol/l)	1.06 ± 0.6	0.82 ± 0.3	0.75 ± 0.2	0.71 ± 0.2	0.34 ± 0.6	0.003
A1C (%)	7.7 ± 0.5	7.5 ± 0.5	7.3 ± 0.5	7.2 ± 0.3	0.54 ± 0.4	<0.001

Data are means \pm SD. $*P < 0.05$ considered significant. TG, triglyceride.

Table 2—Changes in anthropometric variables with PRT protocol

Variables	PRT (0 months)	PRT (3 months)	Mean difference	P*
n	30	30	—	—
BMI (kg/m ²)	24.1 ± 3.9	24.1 ± 3.7	0.1 ± 1.1	0.614
Circumferences (cm)				
Waist	87.9 ± 13.1	86.3 ± 12.7	−1.6 ± 1.9	<0.001
Hip	94.3 ± 10.5	92.5 ± 10.5	1.8 ± 1.2	<0.001
Mid-thigh	46.5 ± 5.9	44.9 ± 5.6	1.7 ± 1.1	<0.001
Mid-arm	29.3 ± 5.2	28.1 ± 4.6	−1.2 ± 1.0	<0.001
Waist-to-hip ratio	1.0 ± 0.2	1.0 ± 0.1	−0.0 ± 0.1	0.091
Skinfolds (mm)				
Biceps	7.2 ± 2.1	6.3 ± 1.9	−0.9 ± 0.6	<0.001
Triceps	15.4 ± 8.6	14.1 ± 8.1	−1.3 ± 1.3	<0.001
Subscapular	25.9 ± 10.3	24.3 ± 9.8	−1.6 ± 1.3	<0.001
Anterior axillary	18.4 ± 11.8	17.4 ± 11.2	−0.9 ± 1.2	<0.001
Suprailiac	27.2 ± 13.4	25.8 ± 13.1	−1.4 ± 1.3	<0.001
Thigh	23.8 ± 11.6	22.4 ± 11.3	−1.5 ± 1.1	<0.001
Calf	7.9 ± 3.9	7.1 ± 3.4	−0.9 ± 0.9	<0.001
Lateral thoracic	26.6 ± 11.0	25.6 ± 10.7	−1.3 ± 0.9	<0.001
Subscapular-to-triceps skinfold ratio	1.8 ± 0.7	1.90 ± 0.8	0.08 ± 0.2	0.075
Central skinfolds	98.1 ± 40.5	92.9 ± 38.7	5.2 ± 3.5	<0.001
Peripheral skinfolds	54.4 ± 21.6	49.8 ± 20.4	4.5 ± 3.1	0.001

Data are means ± SD. Central skinfolds: sum of values of subscapular and suprailiac skinfolds. Peripheral skinfolds: sum of values of biceps and triceps skinfolds. **P* < 0.05 considered significant.

provement of 1.2% A1C after combined aerobic and resistance exercise for 1 year. It is possible that a longer course of exercise may lead to more improvement in glycemia. The fact that glycemic control improved significantly in our study within 3 months could also mean that Asian Indians may respond better to PRT than other ethnic groups. We demonstrated a significant decline in lipid levels; however, better effect has been seen on long-term resistance exercise protocol (17). Finally, we were not able to demonstrate a significant decrease in hsCRP lev-

els, as has been reported after a 12-month study (18).

Our hypothesis was that PRT would improve insulin sensitivity by increasing the lean body mass in Asian Indians with type 2 diabetes. As skeletal muscle is the principle area of glucose disposal, increasing muscle bulk would increase insulin sensitivity, perhaps due to improved muscle physiology and vascularity. However, we did not observe any change in lean body mass and cross-sectional area of skeletal muscles of upper arm and thigh. Contradictory results have been reported

regarding the effect of resistance exercise on skeletal muscle area and mass (4,19). It is possible that a higher number of resistance exercises using more muscle groups than used in our protocol may increase muscle mass significantly. While varying duration of study and protocols may be offered as explanations, there is a possibility that resistance exercise may decrease intramyocellular triglyceride content, which may mask the increase in the muscle mass, and both effects could lead to an improvement in insulin sensitivity. Specifically, we have previously re-

Table 3—Changes in percent total body fat, regional fat, lean body mass, and cross-sectional skeletal muscle area of upper and lower extremities with PRT protocol

Variable	PRT (0 month)	PRT (3 months)	Mean difference	P*
n	30	30	—	—
Body fat (%)	27.7 ± 10.6	27.3 ± 10.3	0.3 ± 1.5	0.239
Truncal—to-total body fat ratio	0.6 ± 0.1	0.6 ± 0.1	0.0 ± 0.0	0.96
Lean body mass (kg)	42.3 ± 6.0	42.6 ± 6.2	0.2 ± 1.5	0.384
Right arm fat (%)	25.1 ± 12.5	23.9 ± 12.6	1.2 ± 6.2	0.311
Right arm regional fat (%)	23.9 ± 12.1	22.8 ± 12.5	1.2 ± 6.3	0.328
Right arm lean mass (kg)	2.8 ± 0.8	2.9 ± 0.6	0.1 ± 0.5	0.166
Right midarm muscle area (cm ²)	34.1 ± 6.7	33.6 ± 8.3	−0.5 ± 3.8	0.487
Right leg fat (%)	25.0 ± 11.8	24.7 ± 11.3	0.3 ± 1.5	0.218
Right leg regional fat (%)	23.9 ± 11.4	23.7 ± 10.9	0.2 ± 1.4	0.386
Right leg lean mass (kg)	6.8 ± 1.2	6.9 ± 1.2	0.1 ± 0.4	0.294
Right mid-thigh muscle area (cm ²)	111.4 ± 17.8	111.6 ± 19.0	−0.1 ± 6.7	0.092

Data are means ± SD. Measurements of percent total body fat, regional fat, lean body mass done by dual-energy X-ray absorptiometry. Measurements of cross-sectional skeletal muscle area of upper and lower extremities done by CT scan. **P* < 0.05 considered significant.

ported high intramyocellular triglyceride content of soleus muscle in Asian Indians with or without type 2 diabetes (20).

There was a significant decrease in all the central and peripheral skinfolds, signifying a loss of both truncal and peripheral SCAT. In contrast to that in white Caucasians, in whom IAAT is believed to be a more important determinant of insulin resistance, we believe that truncal SCAT is quantitatively greater and a better correlate of insulin sensitivity in Asian Indians (21). While most studies have demonstrated a decrease in both IAAT and SCAT with PRT alone (14,19) or combined (3) with aerobic training, Sigal et al. (4), in a case-control study, reported a significant decrease in abdominal SCAT without any alteration in IAAT after aerobic or resistance exercise alone. A significant decrease in SCAT in our patients with type 2 diabetes after short-term PRT protocol is interesting, and we speculate that decrease in SCAT may have made a significant contribution to the improved insulin sensitivity in Asian Indians seen in our study.

Regardless of how it is achieved, whether through calorie restriction, aerobic exercise, resistance training, or any combination of lifestyle factors, a reduction in truncal obesity appears to improve insulin sensitivity (19). While calorie restriction and/or aerobic exercise are effective at inducing weight loss and reducing truncal obesity, lean body mass (skeletal muscle tissue) may be sacrificed in the process. When resistance training is included as part of the weight loss regimen, lean body mass can be simultaneously maintained or even gained (22). This may prove advantageous in the long-term management of type 2 diabetes and the metabolic syndrome.

Because of their distinctive body composition and high tendency to develop insulin resistance and type 2 diabetes, Asian Indian ethnic groups constitute a population of interest with regard to studying the effects of resistance exercise. To further validate our interesting results, additional studies including the following are required: larger sample size; longer duration of study; more intensive PRT protocol involving more muscle groups; and more accurate documentation of SCAT, IAAT, and total abdominal fat measured by computed tomography/magnetic resonance imaging scan, as has been done in our previous study (23).

In conclusion, supervised PRT for 3 months leads to significant improvement in insulin sensitivity and values of A1C,

total cholesterol, triglycerides, VLDL cholesterol, and truncal and peripheral SCAT in Asian Indians with type 2 diabetes. We suggest moderate-intensity PRT for Asian Indians with type 2 diabetes to improve insulin sensitivity, glycemia, and lipid levels and to decrease SCAT.

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