# Effects of Resistance Training Combined with Green Tea Treatment on Hyperglycemia and Lipid Profile in Diabetic Rats

**Khosro E (Ph.D.)[1], Hovanloo F (Ph.D.)[1], Teimoorian M (Ph.D. Student)[1], Saadati M (M.Sc.)[1], Shahvali Koohshoori Y (M.Sc.)[1], Fallah Huseini H (Ph.D.)[2*]**

1- Physical Education and Sport Science College, Shahid Beheshti University, Tehran, Iran
2- Medicinal Plants Research Center, Institute of Medicinal Plants, ACECR, Karaj, Iran.
* Corresponding author: Medicinal Plants Research Center, Institute of Medicinal Plants, ACECR, P.O.Box: 33651/66591, Karaj, Iran
Tel: +98-26-34764010-20, Fax: +98-26-34764021
E-mail: h.fallah@acecr.ac.ir

**Received:** 4 Aug. 2015 **Accepted:** 27 Feb. 2016

## Abstract

**Background: Physical exercise and herbal treatment with antioxidant property induce a favorable effect on glucose metabolism in diabetic patients.**

**Objective: The aim of the present study was to investigate the effects of resistance training combined with green tea extract consumption on blood glucose and lipid profile in diabetic rats.**

**Methods: Forty male Wistar diabetic rats aged 5 months and weights 290 ± 20 were divided into 4 groups named as: resistance training, resistance training + green tea, green tea and control. The resistance training and resistance training + green tea groups engaged in exercise for 5 weeks with three times per week moving up the ladder with weight hanging their tail. Green tea extract (100 mg/kg) was gavaged once a day for 5 weeks. Forty eight hours after the last training session and green tea gavages, the fasting blood samples was collected for determination of blood glucose, cholesterol, LDL-C, HDL-C and triglyceride levels.**

**Results: Fasting blood glucose level significantly decreased in all three groups compared with control group, where as triglyceride, cholesterol and LDL-C level significantly decrease in resistance training + green tea group compared to control group.**

**Conclusion: Green tea extract and resistance training improve hyperglycemia and in combination improve lipid profile in diabetic rats.**

**Keywords: Diabetes, Green tea, Lipid, Resistance Training**

# Introduction

Diabetes mellitus is characterized by hyperglycemia is a serious chronic metabolic disorder that has a significant impact on the health, quality of life, and life expectancy of patients, as well as on the health care system [1]. Treatment includes diet, exercise, and drug therapy [2 - 6]. Hyperglycemia along with hyperlipidemia are important cardiovascular risk factors [7]. Most people with diabetes consider using alternative treatments, including herbal medicine [8]. Green tea (*Camellia sinensis* L.) is one of the world's widely consumed beverages that used in traditional medicine for treatment of many chronic diseases including diabetes [4, 9 - 11]. Green tea contains several chemical constituent such as catechins, including epigallocatechin-3-gallate, epigallocatechin, epicatechin-3gallate and epicatechin with wide range of health promoting effects [12]. The antioxidant properties of green tea and its favorable effect on insulin resistance, lipid metabolism are key contributors for managements of hyperglycemia and hyperlipidemia [13-16]. In addition physical exercise is another important factor required for managing blood glucose levels and hyperlipidemia [17, 18], although there is controversial report over effects of different modalities of exercise such as aerobic, resistance and combined exercise on metabolic control and insulin resistance in diabetic patients [19 - 21]. Thus, in view of the joint role of physical activity and consumption of green tea in the control of diabetes and presence of controversy reports on modalities of exercise on diabetes and hyperlipidemia, this study was undertaken to find out that whether resistance training combined with green tea extract consumption can effectively improve glucose and lipid profile in diabetic rats.

# Materials and Methods

### Plant material

The green tea extract was purchased from Soha Jissa Plantation, Industries and Herbal Medicine Processing Co. (Tonekabon, Iran). According to the company product information the plant material was collected from tea farm in the Tonekabon in the Mazandaran province from 6 a.m. to 11 a.m. in May. The plants materials were identified by the company botanist and a voucher specimen of the plant (number 12) was preserved in the company herbarium unit. The plants material after processing and drying were extracted with 70% aqueous ethanol using percolation method at room temperature. The total phenol content of the green tea extract was measured by the method described by Kim et al. with some modification [22]. Briefly, an aliquot (1 ml) of the appropriately diluted extract or standard solutions of Gallic acid in water (50, 100, 150, 200 and 250 _g/ml) was added to a 25 ml volumetric flask containing 9 ml of distilled water. Reagent blank using distilled water was prepared. One milliliter of Folin & Ciocalteu's phenol reagent was added to the mixture and shaken. After 5 min, 10 ml of 7% Na2CO3 solution was added by shaking. The solution was then immediately diluted to volume (25 ml) with distilled water and mixed thoroughly. After incubation for 90 min at 23◦C, the absorbance versus prepared blank was read at 750 nm. Sample was analyzed in 3

replications.

**Animals**

Forty adult Wistar rats weighting 200-250 g purchased from Institute of Medicinal plants, ACECR, Karaj, Iran. Animals were maintained under standard environmental conditions and had access to standard rodent feed and water. Experimental diabetes was induced to overnight fasted rats by intraperitoneal injection of 50 mg/kg streptozotocin in citrate buffer. After two weeks time for the development of diabetes, the rats with blood glucose level of 150-300 mg/dl were considered as diabetic and selected for experiment. The rats were divided into 4 groups of 10 rats each as: Control, Resistance training, Green tea extract (100 mg/Kg by gavage) and Resistance training + green tea extract. The rats were housed in room maintained at 23 ± 2.0°C, with a relative humidity of 55 - 10%, and a daily photo period from 0700 to 1900 h with free access to drinking water and a standard diet. The animal care committee of Shahid Beheshti University approved the present study.

**Resistance-training protocol**

The rats in the RT and RT+GT groups were subjected to one training period per day three times per week for 8 weeks. Training was accomplished utilizing a 1-m ladder with 2-cm grid steps and inclined at 90°. Initially, rats were familiarized with the ladder by practicing climbing the ladder from the bottom to the top cage for 3 days, after which the resistance-training regimen started. A cylinder containing weights was attached to the base of the tail with foam tape (3M Conan) and a Velcro strap. The initial weight attached to each animal was 50% of its body weight. Rats were positioned at the bottom of climbing apparatus and motivated to climb the ladder by touching the tail. When the rats reached the top of the ladder, they were allowed to rest in a simulated home cage for 2 min. After the rest period, additional weights were placed in the cylinder, and the rats were returned to the bottom of the ladder for subsequent climbs. Rats climbed the ladder with 50, 75, 90, and 100% of maximal load from the previous exercise session. If a rat was able to climb the ladder with these loads, additional weights were placed in the cylinder in 30-g increments for each subsequent climb. This procedure was repeated until eight climbs were achieved or until the rat failed to climb the entire length of the ladder. The training session was stopped when the rat refused to climb up the ladder after three successive shocks to the tail.

**Biochemical analysis**

At the end of the study, after an overnight fasting, animals were anesthetized by light ether and blood samples were collected directly from the heart containing 0.1 mM EDTA. Serum was obtained by centrifuging the blood samples at 3000 rpm for 15 min for determination of glucose, cholesterol, LDL-C, HDL-C, and triglyceride levels. Serum glucose levels were determined enzymatically using standard methods by auto analyzer and all other blood serum parameters were measured by auto analyzer Hitachi 902 using commercially available kits (Pars Azmon).

**Statistical analysis**

All data were expressed as mean ± SD. The statistical significance was evaluated by one-way analysis of variance (ANOVA) using the SPSS (version 16.0) program followed by bonferroni post hoc test. Values were considered statistically significant when $p<0.05$.

## Results

Total phenol content expressed as gallic acid equivalent 703.12 ± 20.21 mg Gallic acid/g of the dried extract.

The blood glucose level and lipid profile data are summarized in table 1.

Fasting blood glucose level significantly decreased in resistance training, green tea and resistance training + green tea treated group compared with control group. Furthermore fasting blood triglyceride, cholesterol and LDL-C levels significantly decreased resistance training + green tea treated group compared with control group.

## Discussion

In present study we examine the effects of five week resistance training alone or in combination with green tea treatment on hyperglycemia and lipid profile in diabetic rats. The results suggest that resistance training and green tea treatment alone or in combination to diabetic rats improve hyperglycemia whereas and lipid profile improves in combination of resistance training + green tea treatment to diabetic rats.

The results indicate that resistance training and green tea alone improve heperglycemia but in combination improved lipid profile due to synergistic effect.

Several explanation may prposed for these finding. Type 2 diabetes is associated with increased plasma triglyceride, increased cholesterol, and decreased HDL-C concentrations [7]. Nutrition and physical activity are the key factores for management and treatment of diabetes and hyperlipidemia [8]. In this connection several studies conducted to evaluate the effects of exercises and green tea on hyperglycemia and lipid profile in experimental or clinical trial.

**Table 1- The serum glucose and lipid profile in control, aerobic exercise, green tea and aerobic exercise + green tea groups. All the values are expressed in terms of mean ± SD**

| Groups / Variables | Control | Resistance training | *P* value vs. control group | Green tea extract | *P* value vs. control group | Resistance training + green tea extract | *P* value vs. control group |
|---|---|---|---|---|---|---|---|
| FBG (mg/dl) | 334.2 ± 52.4 | 278 ± 64.6* | P=0.048 | 270.8 ± 38.8* | P=0.043 | 266.6 ± 84* | P=0.040 |
| Triglyceride (mg/dl) | 100.2 ± 13.6 | 91.1 ± 13.6 | P=0.920 | 88.1 ± 21.9 | P=0.426 | 71.2 ± 8.5* | P=0.031 |
| Cholesterol (mg/dl) | 72.5 ± 13 | 62.5 ± 13 | P=0.550 | 68.1 ± 7.1 | P=0.600 | 53.4 ± 8.6* | P=0.042 |
| LDL-C (mg/dl) | 18.2 ± 3.1 | 17.1 ± 2.2 | P=1.400 | 16.6 ± 3 | P=0.900 | 16.2 ± 1.1* | P=0.810 |
| HDL-C (mg/dl) | 34.2 ± 7.8 | 37.2 ± 10.8 | P=0.842 | 36 ± 9.4 | P=0.950 | 36.2 ± 10.25 | P=0.970 |

*P<0.05 was considered as statistically significant

It is well established that, exercise stimulate glucose uptake by muscle. Glucose uptake by muscle at rest and postprandial to exercise are insulin dependent but during exercise, glucose uptake into muscle is normal even when insulin-mediated uptake is impaired in type 2 diabetes [17, 23-25]. Muscular glucose uptake remains elevated post exercise, with the contraction-mediated pathway persisting for several hours [26]. Insulin-stimulated GLUT4 translocation is generally impaired in type 2 diabetes [17] and both aerobic and resistance exercises increase GLUT4 abundance and cellular glucose uptake, even in the presence of type 2 diabetes [27, 28]. In present study five week resistance training alone or in combination with green tea treatment improved hyperglycemia in diabetic rats. But in contrast to our study, Shahrjerdi et al. reported that, resistance training alone couldn't change the blood glucose and lipid profile in type 2 diabetic women [3, 29]. Furthermore the anti-diabetic and lipid lowering effect of green tea extract has been reported in experimental study [15]. In this connection green tea treatment to non diabetic rat induced GLUT4 increase glucose transfer into the cells without increase in insulin level [30]. Green tea also has negative effect on amylase enzyme, can reduce glucose uptake from foods [31]. Green teas catechins components increases fecal excretion of cholesterol, increases fat metabolism and increases plasma HDL-C [32]. In agreement to above finding in present study five week green tea treatment to diabetic rats improve blood glucose and in combination with resistance training improved lipid profile. The explanation for this contrast may be due to difference in green tea dosages, duration of the study, severity of diabetes or number and type animals in the study. However the favorable effects of the combination of resistance training + green tea treatment to diabetic rats on hyperglycemia and lipid profile may prove the synergistic effects of these two treatments. Of note the present study limitation were the lack of type 2 diabetic rats, severity of diabetes and single dose of green tea treatment.

## Conclusion

Resistance training and green tea each alone or in combination improve hyperglycemia whereas resistance training and green tea combination improves lipid profile in diabetic rats.

## Acknowledgement

This study was performed as a M.SC. student thesis (Shahid Beheshti University) and supported by the Medicinal Plants Research Center, Institute of Medicinal Plants, ACECR, Karaj, Iran and Physical Education and Sport Science College, Shahid Beheshti University, Tehran, Iran.

### Conflict of interest

All authors have no conflict of interest to disclose.

## References


**1.** Dey L, Attele AS and Yuan C-S. Alternative therapies for type 2 diabetes. A Textbook of Complementary and Alternative Medicine. 2003: 267.

**2.** Azar ST, Malha LP, Zantout MS, Naja M, Younes F and Sawaya MT. Management and control of patients with type 2 diabetes mellitus in Lebanon: results from the International Diabetes Management Practices Study (IDMPS). *Le Journal Medical Libanais The Lebanese Medical J*. 2013 Jul-Sep; 61 (3): 127-31. PubMed PMID: 24422361.

**3.** Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement executive summary. *Diabetes Care.* 2010 Dec; 33 (12): 2692-6. PubMed PMID: 21115771. Pubmed Central PMCID: 2992214.

**4.** Islam MS and Choi H. Green tea, anti-diabetic or diabetogenic: A dose response study. *Biofactors* 2007; 29 (1): 45 - 53.

**5.** Reaven GM, Lithell H and Landsberg L. Hypertension and associated metabolic abnormalities--the role of insulin resistance and the sympathoadrenal system. The New England journal of medicine. 1996 Feb 8; 334 (6): 374 - 81. PubMed PMID: 8538710.

**6.** Jorge MLMP, de Oliveira VN, Resende NM, Paraiso LF, Calixto A, Diniz ALD and et al. The effects of aerobic, resistance, and combined exercise on metabolic control, inflammatory markers, adipocytokines, and muscle insulin signaling in patients with type 2 diabetes mellitus. *Metabolism: Clinical and Experimental*. 2011; 60 (9): 1244 - 52.

**7.** Tomkin GH. Targets for intervention in dyslipidemia in diabetes. *Diabetes Care*. 2008 Feb; 31 Suppl 2: S241-8. PubMed PMID: 18227492.

**8.** Dey L, Attele AS and Yuan CS. Alternative therapies for type 2 diabetes. Alternative medicine review: *A Journal of Clinical Therapeutic* 2002 Feb; 7 (1): 45-58. PubMed PMID: 11896745.

**9.** Tomata Y, Kakizaki M, Nakaya N, Tsuboya T, Sone T, Kuriyama S and et al. Green tea consumption and the risk of incident functional disability in elderly Japanese: the Ohsaki Cohort 2006 Study. *The American Journal of Clinical Nutrition* 2012; 95 (3): 732 - 9.

**10.** Sueoka N, Suganuma M, Sueoka E, Okabe S, Matsuyama S, Imai K and et al. A new function of green tea: prevention of lifestyle-related diseases. *Annals of the New York Academy of Sciences* 2001 Apr; 928: 274 - 80. PubMed PMID: 11795518.

**11.** Panagiotakos DB, Lionis C, Zeimbekis A, Gelastopoulou K, Papairakleous N, Das UN and et al. Long-term tea intake is associated with reduced prevalence of (type 2) diabetes mellitus among elderly people from Mediterranean islands: MEDIS epidemiological study. *Yonsei Medical J*. 2009; 50 (1): 31 - 8.

**12.** Graham HN. Green tea composition, consumption, and polyphenol chemistry. *Preventive Medicine* 1992 May; 21 (3): 334-50. PubMed PMID: 1614995.

**13.** Patil L and Balaraman R. Effect of green tea extract on Doxorubicin induced cardiovascular abnormalities: antioxidant

action. Iranian journal of pharmaceutical research: *IJPR*. 2011 Winter; 10 (1): 89 - 96. PubMed PMID: 24363686. Pubmed Central PMCID: 3857493.

**14.** Raederstorff DG, Schlachter MF, Elste V, Weber P. Effect of EGCG on lipid absorption and plasma lipid levels in rats. *The Journal of Nutritional Biochem*. 2003 Jun; 14 (6): 326 - 32. PubMed PMID: 12873714.

**15.** Mostafa13TP0F UE-S. Effect of green tea and green tea rich with catechin on blood glucose levels, serum lipid profile and liver and kidney functions in diabetic rats. Biological. 2014, p: 17.

**16.** Li RW, Douglas TD, Maiyoh GK, Adeli K and Theriault AG. Green tea leaf extract improves lipid and glucose homeostasis in a fructose-fed insulin-resistant hamster model. *J. Ethnopharmacol*. 2006 Mar 8; 104 (1-2): 24-31. PubMed PMID: 16202550. Epub 2005/10/06. eng.

**17.** Goodyear LJ and Kahn BB. Exercise, glucose transport, and insulin sensitivity. Annual review of medicine. 1998; 49: 235-61. PubMed PMID: 9509261.

**18.** Gordon LA, Morrison EY, McGrowder DA, Young R, Fraser YT, Zamora EM and et al. Effect of exercise therapy on lipid profile and oxidative stress indicators in patients with type 2 diabetes. *BMC Complementary and Alternative Medicine* 2008; 8: 21. PubMed PMID: 18477407. Pubmed Central PMCID: 2390515.

**19.** Shahrjerdi S, Shavandi N, Sheikh Huseini R and Shahrjerdi S. Effect of resistance and endurance training on metabolic factors, life quality and psyche helth in type 2 diabetic women. *Shahrekord Science Medicine College J.* 2009; 49: 25 - 35.

**20.** Smutok MA, Reece C, Kokkinos PF, Farmer C, Dawson P, Shulman R and et al. Aerobic versus strength training for risk factor intervention in middle-aged men at high risk for coronary heart disease. *Metabolism: Clinical and Experimental*. 1993 Feb; 42 (2): 177-84. PubMed PMID: 8474314.

**21.** Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P and et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *The New England J. Medicine* 2001 May 3; 344 (18): 1343 - 50. PubMed PMID: 11333990.

**22.** Kim DO, Weon Jeong S and Lee CY. Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food Chem.* 2003; 81: 321 - 6.

**23.** Braun B, Sharoff C, Chipkin SR, Beaudoin F. Effects of insulin resistance on substrate utilization during exercise in overweight women. *Journal of Applied Physiol*. 2004 Sep; 97 (3): 991 - 7. PubMed PMID: 15133003.

**24.** Colberg SR, Hagberg JM, McCole SD, Zmuda JM, Thompson PD and Kelley DE. Utilization of glycogen but not plasma glucose is reduced in individuals with NIDDM during mild-intensity exercise. *Journal of Applied Physiol.* 1996 Nov; 81 (5): 2027 - 33. PubMed PMID: 8941525.

**25.** Richter EA, Garetto LP, Goodman MN, Ruderman NB. Muscle glucose metabolism following exercise in the rat: increased sensitivity to insulin. *The Journal of Clinical*

*Investigation* 1982 Apr; 69 (4): 785 - 93. PubMed PMID: 6804492. Pubmed Central PMCID: 370132.

**26.** Garetto LP, Richter EA, Goodman MN and Ruderman NB. Enhanced muscle glucose metabolism after exercise in the rat: the two phases. *The American Journal of Physiol*. 1984 Jun; 246 (6 Pt 1): E471-5. PubMed PMID: 6377909.

**27.** Christ-Roberts CY, Pratipanawatr T, Pratipanawatr W, Berria R, Belfort R, Kashyap S and et al. Exercise training increases glycogen synthase activity and GLUT4 expression but not insulin signaling in overweight nondiabetic and type 2 diabetic subjects. *Metabolism: Clinical and Experimental*. 2004 Sep; 53 (9): 1233 - 42. PubMed PMID: 15334390.

**28.** Cuff DJ, Meneilly GS, Martin A, Ignaszewski A, Tildesley HD and Frohlich JJ. Effective exercise modality to reduce insulin resistance in women with type 2 diabetes. *Diabetes Care*. 2003 Nov; 26 (11): 2977 - 82. PubMed PMID: 14578226.

**29.** Sano M, Tabata M, Suzuki M, Degawa M, Miyase T and Maeda-Yamamoto M. Simultaneous determination of twelve tea catechins by high-performance liquid chromatography with electrochemical detection. *Analyst* 2001 Jun; 126 (6): 816 - 20. PubMed PMID: 11445943.

**30.** Wu LY, Juan CC, Hwang LS, Hsu YP, Ho PH and Ho LT. Green tea supplementation ameliorates insulin resistance and increases glucose transporter IV content in a fructose-fed rat model. *European Journal of Nutrition* 2004; 43 (2): 116 - 24.

**31.** Tsuneki H, Ishizuka M, Terasawa M, Wu JB, Sasaoka T and Kimura I. Effect of green tea on blood glucose levels and serum proteomic patterns in diabetic (db/db) mice and on glucose metabolism in healthy humans. *BMC Pharmacol*. 2004 Aug 26; 4: 18. PubMed PMID: 15331020. Pubmed Central PMCID: 517497.

**32.** Ikeda I, Hamamoto R, Uzu K, Imaizumi K, Nagao K, Yanagita T and et al. Dietary gallate esters of tea catechins reduce deposition of visceral fat, hepatic triacylglycerol, and activities of hepatic enzymes related to fatty acid synthesis in rats. *Bioscience, Biotechnol, and Biochem*. 2005 May; 69 (5): 1049 - 53. PubMed PMID: 15914933.