Tai Chi Chuan Exercise Decreases A1C Levels Along With Increase of Regulatory T-Cells and Decrease of Cytotoxic T-Cell Population in Type 2 Diabetic Patients

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Type 2 diabetes is a metabolic syndrome associated with chronic inflammation (1–3). Although exercise training has been proven beneficial in treatment of type 2 diabetes (4,5), this preventive and therapeutic modality remains underused (5). Recently, evidence (6) indicates that physical inactivity can increase proinflammatory burden independently of obesity, and exercise may induce anti-inflammatory mediators (7). Strenuous exercise has been shown to augment proinflammatory reaction (8,9) and compromise adaptive immunity with a higher risk of upper respiratory tract infections (9,10). Moreover, strenuous exercise might also potentiate hypoglycemia in elderly diabetic patients (11). In contrast, certain studies show that moderate exercise enhances T-cell function (12) and decreases respiratory infections (13), which suggests that the volume of exercise is a critical element of inducing a positive or negative immune response in diabetic patients. Tai Chi Chuan (TCC) exercise, a traditional Chinese martial art that is classified as a moderate exercise because it does not demand >55% of maximal oxygen intake (14), can benefit balance and cardiovascular and respiratory function (14–16). We have previously shown (17) that a regular TCC exercise for 12 weeks significantly enhances functional mobility and regulatory T-cell function of normal adult volunteers; however, we could not assess the effect of TCC exercise on glycemic improvement. In this study, we recruited type 2 diabetic patients to participate in the TCC program to investigate the effect of TCC exercise on the metabolism of blood glucose and lymphocyte subpopulations.

RESEARCH DESIGN AND METHODS

— This study was conducted in one group with pre- and post-TCC exercise immune tests. The study protocol was approved by the Institutional Review Board of Chang Gung Memorial Hospital, and written informed consent was obtained from all type 2 diabetic participants who had no autoimmune or immunodeficiency disorder and agreed to keep their regular diabetes medications and follow their diets over the exercise program. The estimated sample size was initially set at 30, based on the pre- and postexercise test design, with an effect size of 0.35, significant α level of 0.05, and power of 0.8. Thirty-nine diabetic patients participated in the 12-week TCC exercise program, and 32 (17 male and 15 female subjects) completed it. The mean ± SD age of the participants was 57.88 ± 14.14 years, and average length of type 2 diabetes was 5.46 ± 5.91 years. Participants performed the standardized Cheng's Tai Chi 37 Forms under the guidance of an expert TCC master, as previously described (17,18). Each TCC session included a 10-min warm-up, 40-min practice, and 10-min cooldown. Sessions were given 3 days a week from 8:00 to 9:00 A.M.

Fasting blood glucose (FBG) in serum and A1C levels, complete blood counts, and T-lymphocyte subsets in blood were measured before and 3 days after the TCC program (17). Data from this study were analyzed using descriptive analysis and Student's paired *t* test. Pearson's product moment correlation was used to analyze correlations of FBG and A1C levels to lymphocyte subpopulations. Since the data of A1C changes before and after the TCC program did not have a normal distribution, the A1C changes were transformed into standard *T*-scores before the Pearson correlation analysis. A P value ≤ 0.05 was considered statistically significant.

RESULTS

— All the participating type 2 diabetic patients had normal hemoglobin levels but higher FBG and A1C levels before the TCC exercise (Table 1). After the 12-week TCC exercise, the A1C levels revealed a significant decrease ($P = 0.026$) but were not clinically normalized. The fasting glucose levels had no significant decrease ($P = 0.080$) (Table 1). White blood cells, erythrocytes, and platelets were not significantly changed after the TCC exercise. Analysis of lymphocyte subpopulations showed that percentages of both CD4 and CD8 lymphocyte subpopulations significantly decreased after the TCC exercise, but absolute CD4 and CD8 lymphocytes had not significantly decreased after the exercise (Table 1).

Both proportional and absolute count of CD4CD25 regulatory T-lymphocytes significantly increased after the TCC ex-

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Abbreviations: FBG, fasting blood glucose; TCC, Tai Chi Chuan.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

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Table 1—*Changes in A1C, complete blood counts, and lymphocyte subsets before and after the TCC exercise program*

	Pre-exercise	Postexercise	*P*
Hemoglobin (g/dl)	14.18 ± 1.15	14.22 ± 1.05	0.84
FBG (mg/dl)	164.56 ± 53.3	150.53 ± 46.02	0.08
A1C (g/dl)*	7.74 ± 1.93	7.28 ± 1.35	0.026
Red blood cells ($\times 10^{-3}$ cells/mm^3)	4,606.55 ± 598.60	4,619.66 ± 570.27	0.75
White blood cells (cells/mm^3)	6,380.34 ± 1,731.72	6,444.38 ± 1,916.26	0.91
Lymphocytes (cells/mm^3)	2,259.13 ± 652.87	2,222.30 ± 868.83	0.56
Platelets ($\times 10^{-3}$ cells/mm^3)	231.03 ± 51.98	232.28 ± 54.20	0.84
CD4 (%)	45.93 ± 8.70	42.90 ± 9.51	0.044
CD4 (cells/mm^3)	1,004.82 ± 416.64	906.89 ± 381.06	0.130
CD8 (%)	30.56 ± 9.05	28.40 ± 9.25	0.046
CD8 (cells/mm^3)	675.82 ± 283.04	665.87 ± 405.39	0.084
CD4/CD8 ratio	1.71 ± 0.77	1.87 ± 0.99	0.222
CD4CD25 (%)	8.35 ± 2.90	12.00 ± 3.97	0.001
CD4CD25* (cells/mm^3)	176.53 ± 96.48	221.29 ± 128.35	0.029
CD8/CD28 (%)	15.38 ± 4.04	13.94 ± 4.31	0.048
CD8/CD28 (cells/mm^3)	304.81 ± 182.69	296.83 ± 174.56	0.720

Data are means ± SD; $n = 32$. *P* values were analyzed by Student's paired *t* test. *Significantly inverse correlation between decrease of A1C levels and increase of CD4CD25 regulatory T-cells ($r = 0.313$, $P = 0.004$), tested by Pearson's product moment correlation analysis.

ercise ($P = 0.001$ and $P = 0.029$, respectively). The proportional but not absolute count of CD8CD28 cytotoxic lymphocytes significantly decreased after TCC exercise ($P = 0.048$). Changes of CD4, CD8, and CD8CD28 cells before and after the TCC exercise were not correlated to changes of fasting glucose or A1C levels ($P > 0.05$), assessed by Pearson's product moment correlation. In contrast, decreases of A1C levels in the participating type 2 diabetic patients were significantly correlated to increases of CD4CD25 regulatory T-cells after the TCC exercise ($r = 0.313$, $P = 0.004$).

CONCLUSIONS — Certain exercise programs have been tried (19–22) to improve metabolic dysfunction of type 2 diabetic patients. Although these studies have been meta-analyzed for their effects on physical fitness or A1C improvement (4,22), there is no study to date demonstrating regular exercise correlated to change of lymphocyte subpopulations. Our study is the first to demonstrate that a regular TCC exercise can increase CD4CD25 regulatory T-lymphocytes correlated with decreases of A1C levels in type 2 diabetic patients. The effect of TCC exercise on the increase in regulatory T-cells may indirectly be due to better cardiopulmonary fitness after exercise. Another possibility is that a regular TCC exercise can improve glucose metabolism, resulting in less glycosylated proteins, which benefit immune regulatory function in type 2 diabetic patients. It is known that glycosylated modulation of leukocyte surface receptors (23,24) and soluble cytokines (25) can significantly change immune functions. Further studies are needed to explore the glycosylated proteins other than A1C in type 2 diabetic patients that are involved in the improvement of immune functions after the TCC exercise. Moreover, an appropriate combination of the TCC exercise program with diabetic medications may improve both glucose metabolism and immunity of type 2 diabetic patients.

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