In Brief

This review explores the available evidence for the benefits of performing conventional (cardiovascular, resistance, and combined) or alternative forms of exercise training (yoga, tai chi, and qigong) on glycemic control for individuals with impaired glucose tolerance and type 2 diabetes. Based on the available evidence, it appears that a combined cardiovascular and resistance exercise training program should be part of a comprehensive treatment program for the prevention and management of type 2 diabetes, as recommended by American Diabetes Association guidelines.

Alternative Forms of Exercise Training as Complementary Therapy in the Prevention and Management of Type 2 Diabetes

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The prevalence of type 2 diabetes has been increasing during the past decade and is projected to reach ~ 300 million individuals worldwide by 2025.[1,2] In the United States, there are > 24 million individuals living with diabetes, with an estimated additional 25% currently undiagnosed.[3] The projected prevalence of diabetes is expected to increase 165% by 2050 in the United States, primarily because of an increase in type 2 diabetes.[4]

Of particular concern are the comorbidities associated with the development of type 2 diabetes, including chronic kidney disease and macro- and microvascular disease such as cardiovascular disease (CVD), peripheral artery disease, retinopathy, and neuropathy.[5] These complications contribute to a disproportionate use of health care resources and cost to the Medicare system, approaching 10% of total Medicare expenditures.[5]

There has been a dramatic increase in the risk factors for type 2 diabetes, including obesity and physical inactivity, contributing to the increasing prevalence of impaired fasting glucose levels and pre-diabetes.[6] Pre-diabetes, or hyperglycemia that does not meet criteria for a diabetes diagnosis, is defined as a fasting blood glucose level of 100–125 mg/dl or an oral glucose tolerance test resulting in a blood glucose level of 140–199 mg/dl.[2] This population is considered to be at the highest risk for developing type 2 diabetes.[5] A complete discussion of the complex etiology and pathophysiology of type 2 diabetes is beyond the scope of this review and has been discussed extensively elsewhere.[7]

Regular moderate-intensity (50–75% of heart rate reserve) cardiovascular exercise training of at least 150 minutes per week, alone or in conjunction with resistance exercise training three times per week, has been shown to improve glucose control and glucose disposal, improve insulin sensitivity, contribute to weight loss, and improve the CVD risk factor profile in patients with impaired glucose tolerance and type 2 diabetes.[2]

The interest in alternative forms of exercise has been increasing steadily during the past few decades; however, the evidence base related to the use of these popular alternative forms of exercise in the prevention and management of chronic disease has not been widely disseminated. This review focuses on the use of alternative forms of exercise as complementary therapy in the prevention and treatment of type 2 diabetes and CVD risk factor reduction in individuals with impaired glucose tolerance and type 2 diabetes. Although regular exercise training is considered a cornerstone of complementary therapy, it is frequently underutilized as a treatment strategy for the prevention and treatment of diabetes.

Regular Exercise Training in the Prevention and Management of Type 2 Diabetes

Several epidemiological prospective studies have shown a strong association between physical inactivity,

obesity, and incidence of type 2 diabetes.[8–11] In 1991, Helmrich et al.[9] reported that an increase in leisure time physical activity was associated with a reduction in the risk of developing type 2 diabetes, as compared to no leisure time physical activity. This study was followed by the large prospective Nurses Health Study[10] and the Health Professionals' Study.[11] These studies reported a 26–38% reduction in development of diabetes, associated with increased leisure time physical activity, as compared to no leisure time physical activity. In addition, it appears that an increase in cardiovascular fitness (as measured by peak oxygen consumption) is associated with a reduced risk of developing type 2 diabetes.[12–14]

Lifestyle modification that includes increased physical activity and exercise in conjunction with diet modification has been shown to be effective in reducing the risk of developing type 2 diabetes in patients with impaired glucose tolerance, as well as improving glucose control in patients with diagnosed type 2 diabetes.[15–17] In fact, lifestyle modification is considered the initial treatment option for people with impaired fasting glucose or impaired glucose tolerance.[2]

Regular cardiovascular exercise training (generally 30–60 minutes, three to five times per week at 60–75% heart rate reserve [moderate intensity] for 12 or more weeks) has been demonstrated in multiple randomized control trials to be very beneficial in improving glucose control and preventing progression to type 2 diabetes.[16–23] Meta-analyses of moderate cardiovascular exercise training in individuals with type 2 diabetes have shown improved A1C levels (–0.6–0.7%), fasting (–0.5%) and postprandial (–9%) blood glucose levels, insulin sensitivity (28%), and fasting insulin levels (–20%).[18–21] The plausible mechanisms of a cardiovascular exercise–induced improvement in glucose control have been reviewed extensively elsewhere and are presented in Table 1.[24–26]

Regular resistance exercise training (in general, one to three sets of 10–15 repetitions at moderate intensity [70–85% of one repetition maximum], two to three times per week) has been demonstrated to improve glycemic control in individuals with impaired glucose tolerance and type 2 diabetes (reduction of A1C levels of 0.4–1.0%) similar to cardiovascular exercise training in several randomized controlled trials as well as meta-analyses.[18,20,21,23,27–29] The resistance exercise training–induced benefits on glucose control appears to be related to a muscle contraction–induced increase in insulin-independent glucose transporters, thereby facilitating and increasing glucose uptake, as well as an increase in muscle mass that occurs in response to resistance exercise training, which increases glycogen storage potential.[18,21,30,31]

Randomized, controlled trials that have investigated the combination of resistance and cardiovascular exercise training have indicated an additive effect on blood glucose control even in the presence of low A1C levels.[18,21,23] It appears that the combination of cardiovascular and resistance exercise training in individuals with type 2 diabetes results in an average improvement in A1C levels (–0.8%), fasting (–1.5%), and postprandial (–6%) blood glucose levels, insulin sensitivity (106%), and fasting insulin levels (–7%).[18,21]

These trials, in combination with meta-analyses, have led the American Diabetes Association to recommend that in order to prevent or manage type 2 diabetes, individuals with impaired glucose tolerance or type 2 diabetes should participate in cardiovascular exercise training at a minimum of 150 minutes per week of moderate-intensity exercise in combination with 3 days per week of moderate-intensity resistance exercise training.[2]

Table 1. Plausible Mechanisms for Enhanced Glucose Control With Exercise Training

Skeletal muscle biochemical adaptations
- Increased glucose transporter 4 (GLUT-4) activity
- Increased GLUT-4 content
- Increased insulin-independent glucose transporter
- Increased insulin-dependent glucose transporter
- Increased glucose metabolic enzymatic activity and content
- Increased lipid metabolism
- Decreased gluconeogensis

Skeletal muscle structural adaptations
- Increased capillary density
- Increased skeletal muscle blood flow and distribution
- Increased type IIA fiber and muscle fiber size

Systemic adaptations
- Reduced in abdominal adiposity
- Reduced in systemic inflammation
- Reduced blood pressure
- Improved lipid profile
- Increased aerobic capacity

Adapted from Refs. 24–26.

Yoga Exercise Training in the Prevention and Management of Type 2 Diabetes

Chronic stress and negative affective states can contribute significantly to the development of pre-diabetes and exacerbate the major risk factors for developing type 2 diabetes.[32] In response to these findings, the interest in mind-body therapies has increased during the past few decades. Especially accepted is the use of yoga, which has gained significant popularity among all age-groups and both sexes. Yoga is a traditional form of exercise originating from India that has been used as a therapy for many chronic conditions, including diabetes. The interest in yoga is related to the ease of use, safety, and multiple psychological benefits, including stress reduction and mental health well-being.[33,34] There are seven major branches of yoga;[33,34] for the purpose of this review, however, all branches will be referred to only as "yoga."

To our knowledge, there have been 22 randomized, controlled trials evaluating the efficacy of yoga on the impact of risk factors for type 2 diabetes. This has provided some evidence that suggests that regular practice of yoga (over 3–6 months) may attenuate the risk of developing type 2 diabetes and improve glucose control in healthy adults.[35–39] There have been only five

randomized clinical trials that have investigated the use of yoga in individuals with type 2 diabetes. There are limitations with the published studies, including great variation in intervention design, duration, and frequency; lack of randomization and control groups; and study designs that were underpowered for detection of significant treatment effects.

One nonrandomized, controlled trial reported an improvement in fasting blood glucose levels in people with hypertension and CVD after 12 months of regular yoga (21 supervised sessions), as compared to usual medical care.[35] Two randomized, controlled trials reported conflicting results in glucose control and insulin resistance in individuals with CVD after regular yoga.[36,37] The negative trial[37] consisted of 8 weeks of practice followed by a 1-year follow-up, whereas the positive trial[36] investigated the use of 14 weeks of supervised yoga. The design and duration of these interventions are clearly different and could explain the difference in outcomes.

Uncontrolled trials have reported improvements in fasting and postprandial glucose levels and A1C levels in patients with type 2 diabetes.[34] A recent uncontrolled trial by Gordon et al.[38] compared regular cardiovascular exercise to yoga and reported similar improvements in glucose control and lipid profiles. One small (n = 21), randomized, controlled trial compared 12 weeks of regular yoga class to usual medical care in people with diagnosed type 2 diabetes.[39] This study reported significant improvement in fasting glucose control and A1C levels, as compared to the usual-care control group.

The potential mechanism of the protective benefits of yoga exercise remains unknown. Yoga exercise increases parasympathetic/vagal control of the heart and reduces sympathetic activation, as well as reducing systemic inflammation.[34] In addition, yoga results in enhanced feelings of well-being and reduces stress levels, which indirectly reduces sympathetic stimulation. Other postulated mechanisms include skeletal muscle activation during yoga, which increases glucose metabolism similar to other modes of exercise, and an improvement of CVD risk factor profile.[34] Although two reviews[33,34] have attempted to quantify the efficacy of yoga in improving measures of glucose control, the paucity of randomized, controlled trials (n = 5) limits definite conclusions regarding the efficacy of yoga on risk factors for type 2 diabetes or glucose control.

Cardioprotective Effects of Yoga Exercise Training in Patients With Type 2 Diabetes

There is a paucity of studies that have investigated the effect of yoga on vascular function in participants with diabetes. Sivasankaran et al.[40] investigated the effect of 6 weeks of yoga on endothelial function measured by brachial artery flow–mediated vasodilation in healthy participants and in participants with CVD. This study reported a significant improvement in endothelial function in people with established CVD but not in individuals without known disease. The same study reported significant reductions in blood pressure, heart rate, and BMI. However, there were no improvements observed in C-reactive protein, fasting glucose, or lipid profiles.[40] This study lacked a control group and was very short in duration (6 weeks). However, it is plausible that yoga can improve endothelial function in people with impaired vascular function.

The efficacy of yoga to improve the total cholesterol and lipoprotein levels of participants with type 2 diabetes is variable, but on average it appears that 6–12 months of yoga exercise improves triglyceride levels similar to conventional exercise training. However, this observation is based on only three randomized controlled trials.[33] Yoga appears to be beneficial in reducing blood pressure levels (range 4.9–24.2%) and heart rate (8.4%) in individuals with established CVD, based on six randomized, controlled trials.[33,34] There is preliminary evidence that regular yoga exercise training reduces oxidative stress markers and fibrinogen levels in nonrandomized, controlled, and uncontrolled trials.[38,39,41] Nine randomized, controlled trials have investigated the efficacy of yoga exercise on sympathetic/parasympathetic activation, with the majority of studies reporting significant increases in heart rate variability and baroreceptor reflex sensitivity in individuals with CVD.[33,34,42–44] To our knowledge, no randomized controlled trials have investigated yoga and sympathetic/parasympathetic activation in individuals with type 2 diabetes.

Tai Chi Exercise Training in the Prevention and Management of Type 2 Diabetes

Tai chi is an ancient form of therapeutic meditative exercise that includes linked choreographed movements, which provide a fluid form of motion with a varying center of gravity. As with yoga, there are numerous different branches of tai chi; however, for the purpose of this review, all branches will be referred to only as "tai chi."

Nonrandomized and uncontrolled trials have generally been positive, reporting significant reductions in A1C levels and improvements in insulin sensitivity.[45–47] Zhang and Fu[48] reported significant improvements in fasting glucose and a reduction in insulin levels after 14 weeks of tai chi exercise (1 hour/day) in a selected group (n = 20) of people with type 2 diabetes, as compared to a control group performing no exercise. Wang et al.[49] reported similar findings after 8 weeks of tai chi exercise in an uncontrolled study.

However, randomized, controlled investigations comparing tai chi to sham exercise (e.g., stretching or light calisthenics) or usual care have reported no improvements in A1C levels or fasting blood glucose levels.[46,50] The lack of positive findings from these studies may be related to an insufficient intensity level of the specific form of tai chi performed. Recently, Lam et al.[51] performed a randomized, controlled trial investigating the efficacy of 6 months of tai chi exercise on glycemic control in 53 participants with type 2 diabetes, as compared to a group receiving usual medical care. The results of this study were largely negative with no significant differences observed between groups in any variables. The authors speculated that the lack of statistically meaningful findings was because of insufficient sample size and low power, as well as the low intensity of the tai chi exercise.

Interestingly, it appears that tai chi exercise intensity is similar to moderate-intensity cardiovascular exercise (55–67% of heart rate reserve) across sex and age-groups.[48,52] Thus, classical tai chi could be classified as a moderate-intensity cardiovascular exercise. This has been supported by cross-sectional studies as well as intervention studies that have reported higher levels of peak oxygen consumption in people who perform regular tai chi exercise.[53–55]

Cardioprotective Effects of Tai Chi Exercise Training in Patients With Type 2 Diabetes

Cross-sectional studies have indicated that regular tai chi exercise training is associated with increased arterial inflow (measured via impedance plethysmography), skin blood flow, cutaneous blood flow, and nitric oxide metabolites in plasma compared to age-matched control subjects.[53,56] Although these measures are associated with technical problems and physiological confounders, it is plausible that tai chi may improve vascular function via similar mechanisms as conventional cardiovascular endurance exercise training. Results from other nonrandomized and randomized, controlled trials have indicated reductions in blood pressure levels and submaximal heart rate similar to those from conventional cardiovascular exercise training in people with hypertension or established CVD.[54,55,57,58] However, in a randomized, controlled trial, Lam et al.[51] did not find any difference in blood pressure or lipid profile after 6 months of regular tai chi exercise training in patients with type 2 diabetes, as compared to a usual-care control group.

There appears to be a modest reduction in triglycerides and small increase in HDL cholesterol similar to that reported in the meta-analyses of conventional exercise in the few studies that have investigated changes in lipid profile, but the results have varied.[51,54] There may also be an associated improvement in parasympathetic control as evidenced by improved heart rate variability in tai chi exercisers in a cross-sectional study (published in Chinese), as reported by Wang et al.[54]

Although these preliminary results are promising, the majority of studies have lacked either randomization or control group assignment or both. In addition, the published studies have been vague about the outcomes reported and have lacked appropriate statistical analyses. The few randomized, controlled trials published have varied significantly in results, with some studies reporting improvements in CVD risk factors and others failing to identify any significant improvements in CVD risk factors.

Qigong Exercise Training in the Prevention and Management of Type 2 Diabetes

Qigong is an ancient form of therapeutic exercise practiced in China (often as part of tai chi). Qigong has been described as a movement meditation exercise, which combines a shifting center of gravity with circular and spiral movements and meditative breathing techniques.[59] There are numerous branches of qigong; however, for the purpose of this review, all branches will be referred to only as "qigong."

This form of meditative exercise has recently gained significant popularity, especially among older adults. Few trials have investigated the impact of qigong in individuals with chronic diseases. Many published studies have been conducted in China and have not been translated into English.[59]

In 1999, Iwao et al.[60] published a small pilot study (n = 10) investigating the acute impact of qigong walking (slow walking combined with circular movements and breathing techniques) on plasma glucose levels in individuals with diabetes. This study reported a decrease in blood glucose levels with qigong walking, albeit a somewhat smaller decrease than that seen with "conventional" walking exercise (7 vs. 23 mg/dl). Qigong walking can result in an increase in heart rate and blood pressure similar to moderate-intensity exercise (60–65% heart rate reserve), which theoretically should result in protective benefits similar to regular walking exercise. However, this has not been investigated in randomized, controlled trials in individuals with impaired glucose tolerance or diabetes.[59]

A small, randomized, controlled study investigated the effect of 4 months of qigong exercise on A1C levels in individuals with type 2 diabetes.[61] This study reported a significant reduction of A1C levels of 0.68%, as compared to a usual-care control group. After a 4-month crossover period during which the control group performed qigong exercise in the same manner as the intervention group, A1C levels were significantly reduced (0.94%), as compared to baseline.[61]

A review by Xin et al.[59] of the efficacy of qigong on the management of diabetes was published in 2007. This review found 69 published studies, but only 11 met inclusion criteria of a pre-post test design with measures of A1C and fasting glucose; 10 of these were published in Chinese and 1 in English. The review reported a wide variation in the style of qigong studied and the duration of study period, small sample sizes, and only one study that included a control group. Despite these major problems, it appears that qigong exercise may be beneficial in improving glucose control, with reductions in A1C levels between 0.8 and 0.94%, similar to other modes of exercise training.[59] Again, a definite conclusion cannot be made regarding the potential benefits of qigong exercise because of the lack of properly designed randomized, controlled trials.

Qigong is believed to result in reduced levels of stress and (similar to yoga and tai chi) reduced sympathetic stimulation, thereby lowering circulating catecholamines and stress hormones such as cortisol, which should result in lower glucose levels.[62] Furthermore, since qigong appears to provide a cardiovascular stimulus, it is plausible that similar benefits can be achieved with either conventional moderate walking or qigong walking.[60,63] There is also skeletal muscle activation that occurs with qigong that potentially could upregulate insulin-independent glucose transporters similar to other modes of exercise.

Cardioprotective Effects of Qigong Exercise Training in Patients With Type 2 Diabetes

There are few investigations reporting the impact of qigong exercise on CVD risk factors in patients with type 2 diabetes. Most published studies have been reported in Chinese, lacked randomized and controlled designs, and have been under-powered. The review by Xin et al.[59] in 2007 included trials that were published in Chinese and English. This review found some evidence that qigong exercise had a positive impact on blood pressure, triglyceride levels, and total cholesterol in people with type 2 diabetes. Although changes were similar to conventional cardiovascular exercise training, these findings must be viewed with caution, due to the wide variation in research design and lack of properly designed randomized, controlled trials.

Randomized, controlled trials are limited; however, Lee et al.[62] investigated the impact of 10 weeks of qigong exercise or control (randomized) on blood pressure levels in patients with essential hypertension and found a

significant reduction in both systolic and diastolic blood pressure in the qigong group. There was a significant decrease in circulating catecholamines in the qigong group, as compared to the control group, suggesting that the observed reduction in blood pressure levels may be related to a decrease in sympathetic stimulation and lower levels of circulating catecholamines. Lee et al.[64] further reported that total cholesterol, HDL cholesterol, apolipoproteins, and A1C decreased after 8 weeks of qigong exercise, as compared to a control group. A meta-analysis attempted to quantify the efficacy of qigong exercise in improving CVD risk factors using studies published in Chinese and English.[65] This review reported that blood pressure appears to be reduced after qigong exercise, as compared to no exercise based on three studies.

Limitations of Published Trials of Alternative Forms of Exercise in the Prevention and Management of Type 2 Diabetes

Although the body of literature investigating the effectiveness of alternative forms of exercise training to prevent and manage chronic diseases such as diabetes is increasing, significant challenges persist. These include the following:

1. There are numerous forms of each type of exercise, with slight variations in emphasis from style to style and in how many movements are performed and the use of additional materials (e.g., martial art weapons).
2. Numerous variations of the structure of exercise exist such as individual, group, or leader-based exercise.
3. The duration, frequency, intensity, or progression of exercise is rarely reported or standardized and has varied greatly between studies.
4. There is a lack of properly designed, randomized, controlled studies with sufficient sample size to detect either clinically or statistically meaningful differences.

Conclusion

Although many individuals enjoy yoga, tai chi, and qigong as their preferred mode of exercise training, the evidence base for its use for the prevention and management of type 2 diabetes is limited and inconclusive. Based on the presented evidence, it cannot be concluded that yoga, tai chi, or qigong are as effective as cardiovascular, resistance, or the combination of cardiovascular and resistance exercise training for the prevention and management of type 2 diabetes.

References

[1]King H, Aubert RE, Herman WH: Global burden of diabetes, 1995–2025: prevalence, numerical estimates, and projections. *Diabetes Care* 21:1414–1431, 1998

[2]American Diabetes Association: Standards of medical care in diabetes—2009. *Diabetes Care* 32:S13–S27, 2009

[3]Centers for Disease Control and Prevention: National diabetes fact sheet: general information and national estimates on diabetes in the United States, 2007. Atlanta, Ga., U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2008

[4]Boyle JP, Honeycutt AA, Narayan KM, Hoerger TJ, Geiss LS, Chen H, Thompson TJ: Projection of diabetes burden through 2050: impact of changing demography and disease prevalence in the U.S. *Diabetes Care* 24:1936–1940, 2001

[5]National Kidney Foundation: Clinical practice guidelines and clinical practice recommendations for diabetes and chronic kidney disease. *Am J Kidney Dis* 49:S13–S17, 2007

[6]Engelgau MM, Geiss LS, Saaddine JB, Boyle JP, Benjamin SM, Gregg EW, Tierney EF, Rios-Burrows N, Mokdad AH, Ford ES, Imperatore G, Narayan KM: The evolving diabetes burden in the United States. *Ann Intern Med* 140:945–950, 2004

[7]Hamman RF: Genetic and environmental determinants of non-insulin-dependent diabetes mellitus (NIDDM). *Diabetes Metab Rev* 8:287–338, 1992

[8]Bassuk SS, Manson JE: Epidemiological evidence for the role of physical activity in reducing risk of type 2 diabetes and cardiovascular disease. *J Appl Physiol* 99:1193–1204, 2005

[9]Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS Jr: Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *N Engl J Med* 325:147–152, 1991

[10]Manson JE, Rimm EB, Stampfer MJ, Colditz GA, Willett WC, Krolewski AS, Rosner B, Hennekens CH, Speizer FE: Physical activity and incidence of non-insulin-dependent diabetes mellitus in women. *Lancet* 338:774–778, 1991

[11]Hu FB, Sigal RJ, Rich-Edwards JW, Colditz GA, Solomon CG, Willett WC, Speizer FE, Manson JE: Walking compared with vigorous physical activity and risk of type 2 diabetes in women: a prospective study. *JAMA* 282:1433–1439, 1999

[12]Carnethon MR, Gidding SS, Nehgme R, Sidney S, Jacobs DR Jr, Liu K: Cardiorespiratory fitness in young adulthood and the development of cardiovascular disease risk factors. *JAMA* 290:3092–3100, 2003

[13]Bjornholt JV, Erikssen G, Liestol K, Jervell J, Erikssen J, Thaulow E: Prediction of type 2 diabetes in healthy middle-aged men with special emphasis on glucose homeostasis: results from 22.5 years' follow-up. *Diabet Med* 18:261–267, 2001

[14]Eriksson KF, Lindgarde F: Poor physical fitness, and impaired early insulin response but late hyperinsulinaemia, as predictors of NIDDM in middle-aged Swedish men. *Diabetologia* 39:573–579, 1996

[15]Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, Hu ZX, Lin J, Xiao JZ, Cao HB, Liu PA, Jiang XG, Jiang YY, Wang JP, Zheng H, Zhang H, Bennett PH, Howard BV: Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Da Qing IGT and Diabetes Study. *Diabetes Care* 20:537–544, 1997

[16]Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, Keinänen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M; Finnish Diabetes Prevention Study Group: Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 344:1343–1350, 2001

[17]Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM; Diabetes Prevention Program Research Group: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 346:393–403, 2002

[18]Thomas DE, Elliott EJ, Naughton GA: Exercise for type 2 diabetes mellitus. *Cochrane Database Syst Rev* 3:CD002968, 2006

[19]Boule NG, Haddad E, Kenny GP, Wells GA, Sigal RJ: Effects of exercise on glycemic control and body mass in type 2 diabetes mellitus: a meta-analysis of controlled clinical trials. *JAMA* 286:1218–1227, 2001

[20]Boule NG, Kenny GP, Haddad E, Wells GA, Sigal RJ: Meta-analysis of the effect of structured exercise training on cardiorespiratory fitness in type 2 diabetes mellitus. *Diabetologia* 46:1071–1081, 2003

[21]Snowling NJ, Hopkins WG: Effects of different modes of exercise training on glucose control and risk factors for complications in type 2 diabetic patients: a meta-analysis. *Diabetes Care* 29:2518–2527, 2006

[22]Sigal RJ, Kenny GP, Wasserman DH, Castaneda-Sceppa C: Physical activity/exercise and type 2 diabetes. *Diabetes Care* 27:2518–2539, 2004

[23]Sigal RJ, Kenny GP, Boule NG, Wells GA, Prud'homme D, Fortier M, Reid RD, Tulloch H, Coyle D, Phillips P, Jennings A, Jaffey J: Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. *Ann Intern Med* 147:357–369, 2007

[24]Ivy JL, Zderic TW, Fogt DL: Prevention and treatment of non-insulin-dependent diabetes mellitus. *Exerc Sport Sci Rev* 27:1–35, 1999

[25]Lund S, Holman GD, Schmitz O, Pedersen O: Contraction stimulates translocation of glucose transporter GLUT4 in skeletal muscle through a mechanism distinct from that of insulin. *Proc Natl Acad Sci U S A* 92:5817–5821, 1995

[26]Wojtaszewski JF, Nielsen JN, Richter EA: Invited review: effect of acute exercise on insulin signaling and action in humans. *J Appl Physiol* 93:384–392, 2002

[27]Nelson ME, Rejeski WJ, Blair SN, Duncan PW, Judge JO, King AC, Macera CA, Castaneda-Sceppa C: Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 39:1435–1445, 2007

[28]Dunstan DW, Daly RM, Owen N, Jolley D, De Courten M, Shaw J, Zimmet P: High-intensity resistance training improves glycemic control in older patients with type 2 diabetes. *Diabetes Care* 25:1729–1736, 2002

[29]Castaneda C, Layne JE, Munoz-Orians L, Gordon PL, Walsmith J, Foldvari M, Roubenoff R, Tucker KL, Nelson ME: A randomized controlled trial of resistance exercise training to improve glycemic control in older adults with type 2 diabetes. *Diabetes Care* 25:2335–2341 2002

[30]Gulve EA: Exercise and glycemic control in diabetes: benefits, challenges, and adjustments to pharmacotherapy. *Phys Ther* 88:1297–1321, 2008

[31]Cuff DJ, Meneilly GS, Martin A, Ignaszewski A, Tildesley HD, Frohlich JJ: Effective exercise modality to reduce insulin resistance in women with type 2 diabetes. *Diabetes Care* 26:2977–2982, 2003

[32]Vitaliano PP, Scanlan JM, Zhang J, Savage MV, Hirsch IB, Siegler IC: A path model of chronic stress, the metabolic syndrome, and coronary heart disease. *Psychosom Med* 64:418–435, 2002

[33]Aljasir B, Bryson M, Al-Shehri B: Yoga practice for the management of type II diabetes mellitus in adults: a systematic review. *Evid Based Complement Altern Med*. Electronically published ahead of print (doi:10.1093/ecam/nen027). Available at http://ecam.oxfordjournals.org/cgi/reprint/nen027v1. Accessed 7 May 2008

[34]Innes KE, Bourguignon C, Taylor AG: Risk indices associated with the insulin resistance syndrome, cardiovascular disease, and possible protection with yoga: a systematic review. *J Am Board Fam Pract* 18:491–519, 2005

[35]Yogendra J, Yogendra HJ, Ambardekar S, Lele RD, Shetty S, Dave M, Husein N: Beneficial effects of yoga lifestyle on reversibility of ischaemic heart disease: Caring Heart Project of the International Board of Yoga. *J Assoc Physicians India* 52:283–289, 2004

[36]Mahajan AS, Reddy KS, Sachdeva U: Lipid profile of coronary risk subjects following yogic lifestyle intervention. *Indian Heart J* 51:37–40, 1999

[37]van Montfrans GA, Karemaker JM, Wieling W, Dunning AJ: Relaxation therapy and continuous ambulatory blood pressure in mild hypertension: a controlled study. *BMJ* 300:1368–1372, 1990

[38]Gordon LA, Morrison YE, McGrowder DA, Young R, Frazer YT, Zamora EM, Alexander-Limo RL, Irving RR: Effect of exercise therapy on lipid profile and oxidative stress in patient with type 2 diabetes. *BMC Complement Altern Med*. Electronically published ahead of print (doi:10.1186/1472-6882-8-21). Available from http://www.biomedcentral.com/1472-6882/8/21

[39]Monro R, Power J, Coumar A, Dandona P: Yoga therapy for NIDDM: a control trial. *Complement Med Res* 6:66–68, 1992

[40]Sivasankaran S, Pollard-Quintner S, Sachdeva R, Pugeda J, Hoq SM, Zarich SW: The effect of a six-week program of yoga and meditation on brachial artery reactivity: do psychosocial interventions affect vascular tone? *Clin Cardiol* 29:393–398, 2006

[41]Chohan IS, Nayar HS, Thomas P, Geetha NS: Influence of yoga on blood coagulation. *Thromb Haemost* 51:196–197, 1984

[42]Bowman AJ, Clayton RH, Murray A, Reed JW, Subhan MM, Ford GA: Effects of aerobic exercise training and yoga on the baroreflex in healthy elderly persons. *Eur J Clin Invest* 27:443–449, 1997

[43]Panjwani U, Gupta HL, Singh SH, Selvamurthy W, Rai UC: Effect of sahaja yoga practice on stress management in patients of epilepsy. *Indian J Physiol Pharmacol* 39:111–116, 1995

[44]Patel C: Yoga and biofeedback in the management of 'stress' in hypertensive patients. *Clin Sci Mol Med* June (Suppl. 2):S171–S174, 1975

[45]Lee MS, Pittler MH, Kim MS, Ernst E: Tai chi for type 2 diabetes: a systematic review. *Diabet Med* 25:240–241, 2008

[46]Tsang T, Orr R, Lam P, Comino EJ, Singh MF: Health benefits of tai chi for older patients with type 2 diabetes: the "Move It for Diabetes" study: a randomized controlled trial. *Clin Interv Aging* 2:429–439, 2007

[47]Orr R, Tsang T, Lam P, Comino E, Singh MF: Mobility impairment in type 2 diabetes: association with muscle power and effect of tai chi intervention. *Diabetes Care* 29:2120–2122, 2006

[48]Zhang Y, Fu FH: Effects of 14-week tai ji quan exercise on metabolic control in women with type 2 diabetes. *Am J Chin Med* 36:647–654, 2008

[49]Wang JH: Effects of tai chi exercise on patients with type 2 diabetes. *Med Sport Sci* 52:230–238, 2008

[50]Tsang T, Orr R, Lam P, Comino E, Singh MF: Effects of tai chi on glucose homeostasis and insulin sensitivity in older adults with type 2 diabetes: a randomised double-blind sham-exercise-controlled trial. *Age Ageing* 37:64–71, 2008

[51]Lam P, Dennis SM, Diamond TH, Zwar N: Improving glycaemic and BP control in type 2 diabetes: the effectiveness of tai chi. *Aust Fam Phys* 37:884–887, 2008

[52]Lan C, Chen SY, Lai JS: The exercise intensity of tai chi chuan. *Med Sport Sci* 52:12–19, 2008

[53]Wang JS, Lan C, Wong MK: Tai chi chuan training to enhance microcirculatory function in healthy elderly men. *Arch Phys Med Rehabil* 82:1176–1180, 2001

[54]Wang C, Collet JP, Lau J: The effect of tai chi on health outcomes in patients with chronic conditions: a systematic review. *Arch Intern Med* 164:493–501, 2004

[55]Taylor-Piliae RE, Haskell WL, Froelicher ES: Hemodynamic responses to a community-based tai chi exercise intervention in ethnic Chinese adults with cardiovascular disease risk factors. *Eur J Cardiovasc Nurs* 5:165–174, 2006

[56]Wang JS, Lan C, Chen SY, Wong MK: Tai chi chuan training is associated with enhanced endothelium-dependent dilation in skin vasculature of healthy older men. *J Am Geriatr Soc* 50:1024–1030, 2002

[57]Yeh GY, Wang C, Wayne PM, Phillips RS: The effect of tai chi exercise on blood pressure: a systematic review. *Prev Cardiol* 11:82–89, 2008

[58]Lee MS, Pittler MH, Taylor-Piliae RE, Ernst E: Tai chi for cardiovascular disease and its risk factors: a systematic review. *J Hypertens* 25:1974–1975, 2007

[59]Xin L, Miller YD, Brown WJ: A qualitative review of the role of qigong in the management of diabetes. *J Altern Complement Med* 13:427–433, 2007

[60]Iwao M, Kajiyama S, Mori H, Oogaki K: Effects of qigong walking on diabetic patients: a pilot study. *J Altern Complement Med* 5:353–358, 1999

[61]Tsujiuchi T, Kumano H, Yoshiuchi K, He D, Tsujiuchi Y, Kuboki T, Suematsu H, Hirao K: The effect of qi-gong relaxation exercise on the control of type 2 diabetes mellitus: a randomized controlled trial. *Diabetes Care* 25:241–242, 2002

[62]Lee MS, Lee MS, Kim HJ, Moon SR: Qigong reduced blood pressure and catecholamine levels of patients with essential hypertension. *Int J Neurosci* 113:1691–1701, 2003

[63]Kjos V, Etnier JL: Pilot study comparing physical and psychological responses in medical qigong and walking. *J Aging Phys Act* 14:241–253, 2006

[64]Lee MS, Lee MS, Kim HJ, Choi ES: Effects of qigong on blood pressure, high-density lipoprotein cholesterol and other lipid levels in essential hypertension patients. *Int J Neurosci* 114:777–786, 2004

[65]Lee MS, Pittler MH, Guo R, Ernst E: Qigong for hypertension: a systematic review of randomized clinical trials. *J Hypertens* 25:1525–1532, 2007

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