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**Review**

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# The Influence of Yoga-Based Programs on Risk Profiles in Adults with Type 2 Diabetes Mellitus: A Systematic Review

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There is growing evidence that yoga may offer a safe and cost-effective intervention for Type 2 Diabetes mellitus (DM 2). However, systematic reviews are lacking. This article critically reviews the published literature regarding the effects of yoga-based programs on physiologic and anthropometric risk profiles and related clinical outcomes in adults with DM 2. We performed a comprehensive literature search using four computerized English and Indian scientific databases. The search was restricted to original studies (1970–2006) that evaluated the metabolic and clinical effects of yoga in adults with DM 2. Studies targeting clinical populations with cardiovascular disorders that included adults with comorbid DM were also evaluated. Data were extracted regarding study design, setting, target population, intervention, comparison group or condition, outcome assessment, data analysis and presentation, follow-up, and key results, and the quality of each study was evaluated according to specific predetermined criteria. We identified 25 eligible studies, including 15 uncontrolled trials, 6 non-randomized controlled trials and 4 randomized controlled trials (RCTs). Overall, these studies suggest beneficial changes in several risk indices, including glucose tolerance and insulin sensitivity, lipid profiles, anthropometric characteristics, blood pressure, oxidative stress, coagulation profiles, sympathetic activation and pulmonary function, as well as improvement in specific clinical outcomes. Yoga may improve risk profiles in adults with DM 2, and may have promise for the prevention and management of cardiovascular complications in this population. However, the limitations characterizing most studies preclude drawing firm conclusions. Additional high-quality RCTs are needed to confirm and further elucidate the effects of standardized yoga programs in populations with DM 2.

**Keywords:** blood pressure – cardiovascular disease – coagulation – glycemia – insulin resistance – lipids – lung function – oxidative stress – sympathetic activity

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## Introduction

Type 2 Diabetes mellitus (DM 2) is a leading cause of death and disability in the United States (US) and other industrialized nations (1–3) as well as in a growing number of developing countries (4–6). In the United States, newly diagnosed cases of DM 2 have increased ~50% in the past 10 years alone (2). As of 2002, DM 2 was estimated to affect ~16 million

Americans, with 1.3 million new cases diagnosed each year (2). An additional 41 million or more people have impaired glucose tolerance or impaired fasting glucose, collectively referred to as prediabetes, a powerful predictor of clinical DM 2 (1,2,7). Both diabetes and prediabetes dramatically increase risk for cardiovascular disease (CVD) and stroke, and for death due to CVD-related causes (2,7,8). Leading to premature morbidity and mortality, and to preventable disability and work loss, DM 2 is clearly of pressing clinical and economic significance, with direct medical expenditures for DM 2 in the United States totaling over \$92 billion in 2002 alone (1,2).

While diabetes is a glycemic disorder, diagnosed on the basis of elevated blood glucose levels, it is a complex

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condition characterized by multiple, underlying and inter-related metabolic abnormalities linked to insulin resistance (3,9,10). These alterations, together comprising the insulin resistance or metabolic syndrome, collectively and independently predict the development of DM 2 (1,9–11) and related vascular disorders, including atherosclerosis and CVD (1,9,11–16). Core features of the insulin resistance syndrome (IRS) are glucose intolerance, insulin resistance, atherogenic dyslipidemia, visceral adiposity and high blood pressure (12,14,16,17). Other abnormalities associated with the IRS and linked to the pathogenesis and progression of DM 2 (10,18–21) include hypercoagulation (10,14,20,21), chronic inflammation (8,14,16,17,19,21), endothelial dysfunction (8,10,14,20–22), oxidative stress (18,22) and impaired lung function (23–25). Increased sympathetic activity, enhanced cardiovascular reactivity and reduced parasympathetic tone have also been implicated in the pathogenesis of IRS (14,21,26–30) and in the development and progression of DM 2 and related cardiovascular complications (21,31,32). In addition, there is mounting evidence that chronic psychological stress and negative mood states are strongly associated, in a bidirectional manner, with insulin resistance (33–37), glucose intolerance (34,38), central obesity (39–41) dyslipidemia (34,37,42), hypertension (43–47) and other components of the IRS (33,39,48–54). Likewise, prospective studies have shown depression, a common comorbidity in diabetic populations (55,56) and a powerful predictor of CVD morbidity and mortality (45,52,57–62), to increase risk for developing DM 2 by 2- to 3-fold (56,63,64).

Clearly, there is a need to identify cost-effective prevention and management strategies for DM 2 that address the multiple interrelated factors underlying this complex, devastating and increasingly common disorder. In light of the strong influence of psychosocial factors on the development of IRS and DM 2, the role of sympathetic activation in the pathogenesis of insulin resistant states, and the bi-directional relationships of these and other IRS-related risk factors, mind–body therapies may hold particular promise for both the prevention and treatment of DM 2. Of particular interest in this regard is yoga, an ancient mind–body discipline that has been widely used in India for the management of diabetes, hypertension and related chronic insulin resistance conditions (65–69).

Originating in India over 4000 years ago, the practice of yoga has been rising steadily in the United States and other industrialized countries during recent decades (70–72). Of the seven major branches of Hindu yoga, Hatha (or forceful) yoga, Raja (Royal or classical) yoga, and Mantra yoga are perhaps the best known and most commonly practiced forms. Mantra yoga, emphasizing the use of specific sounds or chants to achieve mental and spiritual transformation, was popularized in the West by Maharishi Mahesh Yogi, the founder of Transcendental Meditation (TM). Raja yoga, Patanjali's eight limb system of meditation, contemplation and renunciation, seeks self-realization and transformation through progressive control of the mind (73). Hatha yoga, the branch of yoga most widely practiced in the Western industrialized world, approaches

self-realization and healing through the physical body and its energetic (pranic/etheric) template, with a focus on breath control (pranayama) and specific postures (asanas), including both active and relaxation poses (73). Hatha yoga also incorporates mental concentration (dharana), and meditation (dhyana), mantras or chants, cleansing exercises (kriyas), and specific hand gestures (mudras) (74). With no appreciable side effects and multiple collateral lifestyle benefits (70,72,75,76), yoga appears safe, is simple to learn, and can be practiced by even ill, elderly or disabled individuals (77). Yoga is also easy and inexpensive to maintain, requiring little in the way of equipment or professional personnel, with some studies indicating excellent long-term adherence and benefits (78–80). Notably, there is growing evidence that yoga practice may aid in the prevention and management of DM 2, reduce IRS-related risk factors associated with DM 2, and may improve the prognosis and attenuate signs of those with clinical DM 2 (69,81–85).

In this paper, we critically review the published scientific literature regarding the influence of yoga on metabolic perturbations of DM 2 and on related clinical outcomes, taking into account the major limitations and biases of these studies. Relevant findings from non-diabetic populations regarding observed effects of yoga on IRS-related risk factors for CVD and associated clinical outcomes, reviewed in depth in a previous publication (82), are also summarized, and the implications of these findings for the primary and secondary prevention of DM 2 are discussed.

## Methods

We conducted a thorough search of the published medical literature to identify studies regarding the effects of yoga in adults with diabetes. The search was restricted to English language articles published after 1970 and available in US libraries, and to original studies specifically evaluating the effects of yoga (alone or in combination with other interventions) on metabolic, anthropometric or clinical profiles of adults with DM. Because DM is so often associated with CVD (9,10), studies targeting populations with or at risk for cardiovascular disorders that explicitly included adults with DM were also evaluated. Original studies were included in the review if they reported outcome data and evaluated the effects of yoga and yoga-based interventions on clinical measures of insulin resistance, lipid profiles, body weight or composition, blood pressure, oxidative stress, coagulation/fibrinolytic profiles, lung function, or on markers of sympathetic activation and cardiovascular function. We also included studies assessing the influence of yoga and yoga-based programs on relevant clinical outcomes, including medication use, DM- or CVD-related events and hospitalizations, and measures of CVD progression.

Since the etiology and management for Type 1 diabetes differs from that of type 2 diabetes, studies targeting only populations with type 1 diabetes were excluded. Case studies, abstracts from conference proceedings and anecdotal reports were also eliminated, as were studies with intervention group

sizes of less than four subjects. Articles were identified using MEDLINE, PubMed and PsycINFO, three commercially indexed, scientific databases. Because the majority of studies investigating the effects of yoga therapy have been conducted in the Indian subcontinent and these databases offer only incomplete capture of articles published in Indian medical journals, IndMED, a bibliographic database of over 75 major Indian biomedical journals, was also searched. Search words included yoga, yogic, relaxation, mind–body and meditation. In addition, the citation sections of all identified articles, including review papers, were scanned to identify relevant papers not indexed in PsycINFO, PubMed, MEDLINE or IndMED.

Each eligible study (i.e. each study identified that met our inclusion criteria) was classified into one of three design categories: randomized controlled trials (RCTs), non-randomized controlled trials (NRCTs) and uncontrolled (pre–post) trials. In RCTs, an investigator randomly allocates a yoga or yoga-based program to one group (the experimental or yoga group) and no intervention, usual care, or another intervention to one or more other groups (controls). Both groups are then evaluated to determine change over time in specific indices of CVD risk. In NRCT, the experimental design and analytic strategy are similar to that of RCTs, but the allocation to a given treatment is not performed randomly. In uncontrolled (pre–post) studies, all subjects participate in a yoga or yoga-based program, and change over time (baseline to post-intervention) in specific indices of CVD risk is evaluated.

Study quality was evaluated using criteria based on those utilized in recent systematic reviews regarding the effects of yoga (82) and other popular mind–body therapies (86,87). Criteria included (i) adequate sample size; (ii) explicit eligibility criteria and/or adequate description of study population; (iii) single, well-defined intervention; (iv) appropriate control group(s) or comparison condition(s); (v) randomization of treatment allocation; (vi) blinding of outcome assessment; (vii) adequate accounting for confounders; (viii) statistical methods well described and appropriate; (ix) outcome measures well-defined and point estimates and measures of variability presented; (x) adequate follow-up/drop-out rate reported; and (xi) conclusions supported by findings.

Clinical measures and outcomes evaluated were categorized into several different domains (Table 2). For each domain, we summarized findings from relevant studies. Due to the heterogeneity of study designs, settings, interventions and outcomes, we did not conduct a meta-analysis.

## Results and Discussion

The literature search identified a total of 25 eligible studies investigating the influence of yoga-based interventions on physiologic/anthropometric indices of DM 2 and/or related clinical outcomes, including 15 uncontrolled clinical trials, 6 NRCTs and 4 RCTs (Table 1). Of these studies, 13 uncontrolled studies, 2 NRCTs, and 2 RCTs specifically targeted adults with DM. A majority (77%) of identified studies were

published between 1990 and 2006, and most were small in size, with over 40% having study populations numbering under 25 subjects. Seventy-nine percent of total eligible studies, and almost 90% of those specifically investigating diabetic populations were conducted in India (Table 1). Yoga-based interventions used in these studies ranged in duration from 8 days to 12 months. Some studies evaluated the effects of single ( $n = 2$ ) or multiple components of yoga practice ( $n = 12$ ) alone, while others assessed comprehensive yoga-based programs that included a special diet, lifestyle education, non-yogic exercise, stress management or other interventions ( $n = 11$ ) (Table 1). Table 2 lists the characteristics of eligible studies identified. The findings of these studies regarding the effects of yoga-based interventions on specific IRS-related physiologic and anthropometric indices and relevant clinical outcomes are reviewed below.

### Influence of Yoga on Core Indices of the IRS

Twenty-five eligible published studies from four countries have investigated the potential influence of yoga and yoga-based programs on one or more core indices of the IRS, including measures of insulin resistance and glucose metabolism, lipid profiles, body weight and composition, and blood pressure. Of these studies, 20 examined the influence of yoga-based interventions on clinical markers of insulin resistance (including 14 uncontrolled clinical trials, 3 NRCTs and 3 RCTs), 12 evaluated the influence of yoga on blood lipid profiles (including 4 uncontrolled clinical trials, 5 NRCTs and 3 RCTs), and 10 assessed the influence of yoga on body weight or composition (including 4 uncontrolled trials, 5 NRCTs and 1 RCT). In addition, we identified six eligible studies evaluating the effects of yoga on blood pressure, including three uncontrolled analyses, two non-randomized controlled studies and one RCT. Findings of these are summarized in Tables 2–4 and are discussed briefly below.

#### Markers of Insulin Resistance

Of the 20 eligible studies evaluating the effects of yoga on markers of insulin resistance, all but one documented significant, post-intervention improvement in one or more clinical measures following the practice of yoga either alone or in combination with other therapies (Tables 3 and 4). Interventions ranged in length from 8 days (88) to 12 months (89,90), and all but one (91) incorporated yoga asanas or poses. All 14 uncontrolled studies targeting adults with DM 2 (65,83,91–101), hypertension (68) and/or other chronic conditions (88) reported significant improvement post-intervention in indices of insulin resistance relative to baseline values. Documented changes included reductions in fasting (65,68,83,88,91,94–100) and post-prandial glucose (65,83,91–99), and in fasting glycated hemoglobin (83,97,98,100) (Table 2). Likewise, non-randomized controlled studies of adults with diabetes (102,103) or confirmed coronary artery disease (CAD) (89) reported reductions in fasting glucose (89,102,103) and fructosamine (102) among subjects receiving a yoga-based

**Table 1.** Characteristics of eligible studies investigating the effects of yoga-based programs in adults with Diabetes mellitus (DM)

	Uncontrolled clinical trial		Non-randomized controlled trial		Randomized controlled trial		Totals	
	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	<i>n</i>	%
Target population: adults with DM								
DM 2 only	3	2		1	1		7	41.2
DM 1 and 2	2	2			1		5	29.4
Unspecified DM	4		1	1*			5	29.4
Total targeting DM	9	4	1	1	2		17	
Sample size								
<25	7	1			1		9	52.9
25–40	2	2		1	1		6	35.3
41–60							0	0.0
>60		1	1	1*			2	11.8
Location								
India	9	2	1	1			13	76.5
US							0	0.0
Europe					2		2	11.8
Year published								
2000–05	3			1	1		5	29.4
1990–99	1	2	1	1*	1		5	29.4
1980–89	5	1					6	35.3
1970–79		1					1	5.9
							17	
Target population: adults with CAD/hypertension and/or various chronic illnesses including								
DM 2		1		1		1	3	42.9
Unspecified DM		1		3		1	5	71.4
DM N not stated				1		1	2	28.6
Total		2		4		2	8	
Sample size								
<25		1					1	14.3
25–40							0	0.0
41–60						2	2	28.6
>60		1		4			5	71.4
Location								
India		2		1		1	4	57.1
US				2		1	3	42.9
Europe				1			1	14.3
Year published								
2000–05		2		2		2	6	85.7
1990–99				2			2	28.6
1980–89							0	0.0
1970–79							0	0.0
Sample size								
<25	7	2	0	0	1	0	10	41.7
25–40	2	2	0	1	1	0	6	25.0
41–60	0	0	0	0	0	2	2	8.3
>60	0	2	1	4	0	0	7	29.2
Location								
India	9	6	1	2	0	1	19	79.2

Table 1. Continued

	Uncontrolled clinical trial		Non-randomized controlled trial		Randomized controlled trial		Totals	
	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	n	%
US	0	0	0	2	0	1	3	12.5
Europe	0	0	0	1	2	0	3	12.5
Year published								
2000–05	3	2	0	3	1	2	11	45.8
1990–99	1	2	1	2	1	0	7	29.2
1980–89	5	1	0	0	0	0	6	25.0
1970–79	0	1	0	0	0	0	1	4.2
Totals	9	6	1	5	2	2	25	

CAD, coronary artery disease; DM 1, Type 1 Diabetes mellitus; DM 2, Type 2 Diabetes mellitus.

\*Two yoga-based interventions tested within same study (100).

intervention versus controls receiving enhanced usual care (89), a low fat vegetarian diet alone (102) or a light to moderate exercise program that included walking (103). In a small RCT of British adults with DM 2, Monro *et al.* (101) demonstrated significant declines in both fasting glucose and glycated hemoglobin (HbA<sub>1c</sub>) among participants attending structured yoga classes relative to usual care controls. In a second RCT of 37 adults with poorly controlled DM, of whom 14 had type 1 diabetes, those attending biweekly yoga classes for 16 weeks demonstrated similar, but non-significant declines in HbA<sub>1c</sub> (84). In contrast, in a small RCT of American seniors, a subanalysis of those at risk for CVD did not demonstrate significant reductions in HbA<sub>1c</sub>, fasting glucose or fasting insulin in those completing a comprehensive integrative medicine program relative to controls receiving usual care or an active exercise and diet intervention. However, sample sizes in this analysis of seniors were very small ( $n = 6, 3$  and  $3$ , respectively) (90). Overall, yoga practice was associated with a 6.1–34.4% reduction in fasting glucose, 23.9–32.8% reductions in post-prandial glucose and 10.5–27.3% reduction in HbA<sub>1c</sub>, with the percentages varying by study population and design (Table 4).

While the evidence for a beneficial effect of yoga on indices of insulin resistance appears generally consistent across studies, most studies (60%) had no comparison groups (65,68,83,88,91–100), and many had small sample sizes (65,68,83,84,93–98,101) or reduced power due to stratified analyses (65,90,99,102). Others lacked detailed information on eligibility criteria or study population characteristics (65,83,92,95–98,100,102–104), including type of diabetes (90,95,96,105–107). Blinding of the outcome assessment was reported in only one (90). The study sample selection process was unclear in several studies (83,93,95–98,100, 102,103), and in others, potential selection bias (93,97), loss to follow-up (89,93–96) and uncontrolled confounding factors such as demographic, anthropometric and lifestyle characteristics (65,83,88,91,92,95–97,99,100) may have been influential. The intervention was not well-described (65,91,93,95) or appeared to vary in duration or intensity (91–94,101) in some

studies; others included multiple interventions (68,79,88–90, 94,99,100,103,105), rendering detection of the effect of a specific component difficult. Most studies did not adequately detail the analytic methods used (68,92,97–99,101,103,108), some presented no statistical analysis for some or all of the outcome measures (68,91,92,99,103), and many appeared to suffer other methodological deficiencies, including lack of adequate point estimates for key outcome measures (68,88,92,94,103,104), failure to adjust for multiple comparisons (68,83,84,88,90–92,94,97,98,100,102), confusing data presentation (65,68,91) and other potential analytic problems (65,90,95). Among the controlled studies, additional limitations included lack of randomization (89,102,103), failure to describe treatment allocation methods (89) or adjust for differing baseline characteristics (79,102) and/or absence of intergroup comparisons (103,107).

#### Blood Lipid Profiles

Of the 12 identified studies that assessed the potential effects of yoga on blood lipid concentrations, all suggested that the practice of yoga and yoga-based programs may improve lipid profiles (Table 3). Four uncontrolled studies targeting adults with diabetes (100,109) and/or other chronic conditions (68,88), demonstrated significant positive changes in blood lipid levels following yoga-based interventions that ranged from 8 days (109) to 3 months (109) in duration. Observed improvements in blood lipid fractions included reductions in cholesterol (68,88,100,109), triglycerides (88,100,109), low-density lipoprotein (LDL) (88,109), and very LDL levels (88,109), increases in high density lipoprotein (HDL) levels (68,109), and reduced LDL/HDL ratio (88) relative to baseline levels and/or control values (89,110,111). Similarly, five controlled, non-randomized studies (102,104,106,112,113) and two RCTs (79,84) investigating the effects of yoga alone (102) or in combination with diet (79,102,106,112,113), education (84), stress management (89,106,113) and other therapies (79,89,106,113) demonstrated significant improvement in lipid profiles relative to controls receiving enhanced

Table 2. Characteristics and relevant measures and outcomes of eligible studies

Reference, location	Sample size (yoga, controls)	Duration	Study population	Comparison group/condition	Intervention	Clinical measures							
						IR indices	Lipids	Body size/comp	BP	Coagulation	Oxidative stress	SNS/PSN activity	Lung function
<b>Studies targeting adults with Diabetes mellitus*</b>													
<i>Uncontrolled clinical trials</i>													
(92), India	52	6+ months, 45 min per day	Adults 17–70 years with uncomplicated DM for 3+ years (11 DM 1, 38 obese)	Ss own controls	Yoga (AS, SH); obese also on low cal diet	X+	X+	X+					X+
(93), India	14 (7 DM; 7 normal)	6 months 40 min per day	White collar men aged 25–63, white collar, 7/10 with hx of DM for 6 months to 11 years (3 drop out first 2 weeks; 6 DM 2, 1 DM 1 complete study); 7 non-DM	Ss own controls	Yoga (AS, SH, PR)	X+	X+	X+					
(109), India	32 (5–8 per group)	10–12 weeks, 45–60 min day	27 men, 5 women with DM; avg 47.5 (M), 43 years (F); randomized to 5 different yoga routines	Ss own controls	Yoga training (AS, PR, SH)		X+						
(65), India	16	28 days	Adults with DM assigned to 1 of 3 yoga routines	Ss own controls	Yoga AS	X+							X+
(91), India	35	Not stated	Adults with DM (31 DM 2, 4 DM 1)	Ss own controls	Yoga PR	X+							X+
(94), India	9 (2 DM 1, 7 DM 2)	5 weeks, 1 h 2x per day	9 hospital pts 25–50 years (DM 5–10 years) naive to yoga; 4 on insulin, others on oral drugs	Ss own controls	Resid. yoga training (AS, PR, KR, SH) +low cal, fat diet	X+		X+					X+
(95), India	20 (10 DM, 10 normal)	6 months	1. 10 non-DM men 30–35 years, 10 DM men 32–37 years, on oral meds and special diet. Analyses stratified by DM status	Ss own controls	Yoga training and practice (AS, SH/R)	X+							
(96), India	20 (10 DM, 10 normal)	6 months	1. 10 non-DM men 34–37 years, 10 non-obese DM men 34–37 years, on oral meds and special diet. Separate analyses	Ss own controls	Yoga training and practice (AS, SH/R)	X+							
(99), India	149	40 days, 2.5 h per day	149 outpatients with DM 2, avg 45.9 years, 22–23 BMI	Ss own controls	Residential (hosp-ital) yoga AS, KR, PR, SH+ veg diet	X+		X+					X+
(100), India	30	40 days	Hospitalized men with DM 2; 22 on oral drugs, mean 59.5 years, 17 years DM duration, 22.5 BMI	Ss own controls	Residential (hosp-ital) yoga AS, KR, PR, SH+ veg diet	X+	X+	X+					X+

(97), India	19	40 days, 2.5 h per day	Non-smoking adults 30–60 years w/uncomplicated DM 2?, on drug and diet control	Ss own controls	Yoga (AS, PR, M)	X+	X+	X+
(98), India	24	40 days, 30–40 min per day	Adults 30–60 years old; with un-complicated DM 2 (0–10 years)	Ss own controls	Supervised yoga AS, SH, PR	X+	X+	X+
(83), India	24	40 days	Adults 30–60 years with un-complicated DM 2 (1–10 years) on meds, diet	Ss own controls	Yoga (AS, SH): 13 poses in standard sequence	X+	X+	X+
<i>Non-randomized controlled trials</i>								
(103), India	20, 20	40 days	30–60 years; DM 2 for 0–10 years; controls similar age, DM severity	Medication, light-moderate exercise	Supervised yoga AS, PR, SH+ medication, diet	X+	X+	X+
(102), India	80 (20,20,20,20)	3 months, 2x per day, 25–35 min	60 patients from Indore diabetic clinics (intervention), 20 non-DM matched on age, sex; 40–70 years on vegetarian diet	No intervention (non-DM adults); Strict diet alone (20 DM adults)	(i) Yoga AS,SH only center(ii) Yoga +strict diet	X+	X+	X+
<i>Randomized controlled trials</i>								
(101), UK	21 (11,10)	12 weeks, 90 min 1–5x per week	Uncomplicated type 2 DM controlled with meds ( $n = 13$ ; 8 Yoga group) or diet ( $n = 8$ ); 45–67 years, avg 53 (Y), 57 (C)	Usual care (continue on medication, diet)	Yoga classes (PR, AS, SH) + usual care	X+	X+	X+
(84), UK	37*	16 weeks	Poorly controlled insulin-treated DM (14 with DM 1) from Hospital DM clinic, avg 60–61 years	Education, simple exercise	Education, Hatha yoga classes	X+	X-	X+
<b>Studies including but not targeting adults with DM 2</b>								
<i>Uncontrolled clinical trials</i>								
(68), India	20	78 sessions, 1 h per day	Adults with mild to moderate hypertension, 35–55 years. Include 4 Ss with DM (age 39–50 years)	Ss own controls	Yoga (AS, PR, M,SH) +education	X+	X+	X+
(88), India	98 (20 with DM)	8 days, 3–4 h per day with weekend off	67 male, 31 female clinic out-patients aged 20–74 (avg 46) years with CV disorders, DM, obesity or other chronic condition	Ss own controls	Yoga (AS, SH, M, PR) + education, advice, group support, stress management	X+	X+	X+
<i>Non-randomized controlled trials</i>								
(111), Germany	154 (118,36) <sup>†</sup>	3 months	Lifestyle program participants (58 men, 48 women 18–64 years); analyses incl. 36–72 Ss; Ss with DM included, N unknown	Non-participants matched on age, gender, specific risk factors	Residential program: Kriya yoga+ vegetarian diet	X+	X+	X+

Table 2. Continued

Reference, location	Sample size (yoga, controls)	Duration	Study population	Comparison group/condition	Intervention	Clinical measures								
						IR indices	Lipids	Body size/comp	BP	Coagulation	Oxidative stress	SNS/PSN activity	Lung function	Other clinical outcomes
(112), US	333 (194,139), 62 with DM	12 months, 72 4 h sessions	Adults with confirmed CAD, eligible for revascularization; 263 men, 70 women	Usual care	Usual care +Session: 1h each: stress management (incl Yoga AS, M); exercise, group support, meal	X+	X+	X+						X+
(106), US	440 (91 with DM)**; 342 complete	12 months	Adults with confirmed CAD, eligible for revascularization. 347 men, 93 women in intervention arm (68 women, 274 men complete); mean age 58 (men)-59 (F) y. 55 men, 36 women with DM at baseline	Usual care**	1 h per day stress management: Yoga AS, R, M + low fat vegetarian diet, group support 2x per week, exercise 3+h per week+usual care	X+	X+	X+		X+				
(104), India	113 (71,42)	12 months, 21 sessions	Adults 30–70 years with confirmed CAD, incl. 33 with DM 2. 71/80 in yoga group, 42/60 controls complete study	Usual care: AHA diet, moderate exercise, medication (incl statins)	Yoga + medication (except statins), low fat diet, walking, stress management	X+	X+	X+						X+
<i>Randomized controlled trials</i>														
(90), USA	43 (20,9,14) 15 high risk (6,3,6)	12 months	Adults 65+ y, avg 74 years; complete reliable data for 43 of original 57 Ss; high risk group includes Ss with DM (N not stated)	(1) Usual care; (2) Usual care+ diet, exercise, education, supplements	Yoga M, AS + walking, diet	X+		X+						X+
(79), India	42 (21,21) (7.5 with DM 2)	4 days training+ 1 year	Men with CAD & chronic stable angina, 32–72 years. Yoga and control groups similar in age, weight, lesion severity	Usual care: AHA diet, moderate exercise; regular evaluations	Yoga: (PR, AS, K, M)+ diet, exercise, regular evaluations	X+		X+						X+

Under each category, a plus indicates a beneficial change in at least one measure; a negative sign indicates no change in any of the measures in a specific category. AHA, American Heart Association; AS, yoga asanas or postures; avg, average; BF, biofeedback; BP, blood pressure; CAD, coronary artery disease; cal, calorie; Clin, clinical; comp, composition; comp, composition; d, day, DM, Diabetes mellitus; F, female; h, hour; IR, insulin resistance (markers of); KR, kriyas or cleansing exercises; M, meditation; MBSR, mindfulness-based stress-reduction program; mo, month; PMR, progressive muscle relaxation; PR, pranayama or yogic breathing exercises; R, relaxation poses (non-specified); Resid, residential; SH, shavasana or corpse pose, a traditional yoga relaxation pose; SNS/PNS, markers of sympathetic/parasympathetic activation, including heart rate and catecholamine levels; Ss, subjects; veg, vegetarian; week, week, y, year.

\*N's for each group not given.

\*\*Data for intervention group only presented in this study, number with DM 2 completing study not stated, although drop-outs similar to completers in medical risk factors.

‡36–72 analyzed in matched analyses.

**Table 3.** Summarized findings of studies (1970–2006) investigating the effects of yoga-based programs on insulin resistance, lipid profiles, and body size and composition, and blood pressure, stratified by study design and intervention (yoga alone versus in combination with other interventions)

Findings, by clinical measure	Study design					
	Uncontrolled clinical trials		Non-randomized controlled clinical trials		Randomized clinical trials	
	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions
<b>Measures of insulin resistance</b>						
Fasting glucose						
Reduced	(65,83,91,95–98)	(68,88,94,99,100)	(102)*	(103,104)†	(101)	
No change						(90)*
Post-prandial glucose						
Reduced	(65,83,91–93,95–98)	(94,99)				
No change						(90)
Reduced fructosamine			(102)			
Reduced fasting insulin						(90) (NS)
Reduced OGT maximum/AIT		(99,100)				
Fasting glycated hemoglobin						
Reduced	(83,97,98)	(100)			(101) (84) (NS)	
No change						(90)
<b>Blood lipid profiles</b>						
Total cholesterol						
Reduced	(109)	(68,88,100)	(102)	(104,106,111,112)	(84)	(79) (90) (NS)
Unchanged						
Triglycerides						
Reduced	(109)	(88,100)				(79) (90) (NS)
Unchanged				(106,112)	(84)	
Low density lipoprotein (LDL)						
Reduced	(109)	(88)		(104,106,111,112)	(84)	(79) (90) (NS)
High density lipoprotein (HDL)						
Increased	(109)	(68,88)			(84)	
Unchanged				(106,112)		(79,90)
Reduced very LDL	(109)	(88)				
Reduced cholesterol/HDL ratio					(84)	
Reduced LDL/HDL ratio		(88)				(79)
<b>Anthropometric measures</b>						
BMI						
Reduced				(111)		
Unchanged		(99,100)‡				
Body weight						
Reduced	(92,93)		(102)+	(104)¶ (106)¶¶ (112)		(79)
Unchanged		(99,100)‡				
Body composition						
Reduced waist, hip circumference/ratio		(100)				
↓% body fat, ↑% lean mass				(112)		
<b>Blood Pressure</b>						
Reduced systolic and/or diastolic pressure	(83)	(68,94)		(106)¶¶		(90)
No change in systolic or diastolic pressure					(84)	

Table 3. Continued

Findings, by clinical measure	Study design					
	Uncontrolled clinical trials		Non-randomized controlled clinical trials		Randomized clinical trials	
	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions
Systolic blood pressure						
Reduced	<b>(83)</b>	<b>(68,94)</b>		<b>(106)<sup>¶¶</sup></b>		<b>(90)<sup>††</sup></b>
Unchanged					(84)	
Diastolic blood pressure						
Reduced	<b>(83)</b>	<b>(68,94)</b>		<b>(106)<sup>¶¶</sup></b>		<b>(90)</b>
Unchanged					(84)	

Studies demonstrating beneficial effects are in boldface.

\*Described only as reduced plasma glucose.

+No statistics given; reduction greater than that with diet alone but similar to yoga + diet.

†In Ss with DM 2 ( $n = 33$ ) ‡Baseline BMI average 22–23.

¶In overweight Ss.

¶¶Data presented only for intervention group.

††  $p = 0.08$  ( $n = 6$  in yoga-based intervention).

usual care, exercise and/or dietary interventions (Tables 2 and 3). Although findings varied among studies, all documented significant changes in at least two measures of dyslipidemia. The most consistently and frequently reported improvements included reductions in total cholesterol and LDL (Table 3). Data from a third RCT of American seniors at risk for CVD also suggested improvement in several lipid indices following a yoga-based intervention. However, changes did not reach statistical significance, likely due to small sample sizes ( $n = 6$  in the yoga-based intervention group) (90).

Controlled studies ranged in length from 3 (102,112) to 12 months (79,104,106,113) and included investigations of both diabetic (84,100,102,109) and other at risk populations (68,79,88,90,104,106,112,113). Among those studies demonstrating significant changes in specific lipid indices, completion of yoga-based interventions were associated with a 5.7–25.2% decrease in total cholesterol, 8.0–23.7% reduction in triglycerides, a 5.1–26.0% reduction in LDL, a 14.5–17.7% decrease in VLDL and a 4.2–33.3% increase in HDL, with the observed magnitude of the effects differing by population and design (Table 5).

Again, published data from both uncontrolled and controlled studies suggest that the practice of yoga may have a positive influence on blood lipid profiles. However, most of the studies have methodological or other limitations that hinder interpretation of findings. These include absence of comparison groups or conditions (68,88,100,109), low power due to small sample sizes (68), stratified analyses (68,90,102,109,112) or other factors (84), lack of evidence for blinded outcome assessment [all but one study (90)], potential selection bias (88,111,113), differential loss to follow-up (89,106), lack of randomization (102,104,106,112,113) or information on the randomization process (79), multiple interventions (68,79,88–90,100,105), inadequate description of populations (89,102) or of the sampling or treatment allocation process (89). Other methodological concerns include unclear statistical

analyses (68,109,111), possible uncontrolled confounding factors (88,100,109,111) and lack of adequate point estimates (68,88,104,111), intergroup comparisons (106,107) or adjustment for multiple comparisons (68,84,88,90,100,102,109,111).

#### Anthropometric Measures

Ten published clinical trials in four countries examined the effects of yoga on anthropometric indices of CVD risk in populations that included adults with Type 2 diabetes (Table 3). All utilized interventions incorporating active yoga asanas. Three of the four uncontrolled clinical trials (92,93,100) and all five non-randomized controlled studies identified reported declines in body weight (102,104,106,112,113), reductions in waist/hip ratio (100), and/or improvements in body composition (113) following yoga-based interventions ranging from 40 days (100) to 12 months (104,106,113). Similarly, a 12 month RCT in Indian men with CAD (79) demonstrated improvement in body weight relative to usual care (79). Results reporting improvement in anthropometric characteristics included investigations targeting adults with diabetes (92,93,100,102), as well as those with CAD (79,104,106,113) and/or other chronic conditions (112). Of these, completion of yoga-based programs was associated with a 3.5–8.2% reduction in body weight (Table 4). Only two studies reported no change in body weight (99,100), likely in part reflecting the participants' low BMI values at baseline.

Limitations include lack of control groups (92,93,99,100), reduced power due to low number of subjects (93) or other factors (102,112), possible selection bias (79,93,102,105,111), uncontrolled confounding (92,99,100,111) or floor effects (99,100), lack of appropriate statistical analyses or presentation (92,99,104,111), multiple comparisons (92,102,111), inadequate description of analytic methods (92,93,99,111), population (92,93,100,102), intervention (93), treatment allocation (89), or sample selection process (93,100,102,112),

**Table 4.** Observed percent change with yoga in selected metabolic and anthropometric measures among adults with diabetes and/or other chronic disorders\*

Findings, by clinical measure and study population	Uncontrolled clinical trials	Non-randomized controlled clinical trials	Randomized clinical trials
<b>Measures of insulin resistance</b>			
Reduced fasting glucose			
Adults with diabetes/hyperglycemia	9.1–33.4% (83,88,91,94–100)	23.4–34.4% (102)	6.9% (101)††
Adults with hypertension/CVD or other chronic condition**	6.1–6.2% (68,88)		
Reduced post-prandial glucose			
Adults with diabetes	23.9–32.8% (65,83,92–94,97)		
Reduced glucose (tolerance test)			
Adults with diabetes			
1 h post-load	10.1–32% (94–96)		
2 h post-load	15.8–19.2% (94–96)		
Area under the curve (AUC)	16.5–29.5% (99,100)		
Reduced fasting insulin			
Adults at risk for CVD			19.2% (90)
Reduced fasting glycated hemoglobin			
Adults with diabetes	13.3–27.3% (83,97,98,100)		3.3–15.5% (84,101)
<b>Blood lipid profiles</b>			
Reduced total cholesterol			
Adults with diabetes	5.9–7.2% (100,109)	8.3–19.9% (102)	
Adults with hypertension/CVD or other chronic condition**	5.7†–7.5% (68,88)	8.7–25.2% (104,106,112)	5.8–21% (79,90)
Reduced triglycerides			
Adults with diabetes	8.9–11.9% (100,109)		
Adults with/at risk for hypertension/CVD or other chronic condition**	8.0%–12.4† (68,88)	8.3% (111)	14.1–23.7% (79,90)
Reduced low density lipoprotein (LDL)			
Adults with diabetes	7.5% (109)		
Adults with hypertension/CVD or other chronic condition**	5.1%† (88)	13.7–26.0% (104,106,111,112)	6.8–24.4% (79,90)
Reduced very LDL (VLDL)			
Adults with diabetes	14.5% (109)		
Adults with DM, HT, or other chronic condition**	17.7%† (88)		
Increased high density lipoprotein			
Adults with diabetes	4.2% (109)		
Adults with/at risk for hypertension/CVD or other chronic condition**	3.5†–5.7% (68,88)	33.3% (111)	
<b>Anthropometric markers</b>			
Reduced body weight			
Adults with diabetes	8.2% (93)	3.5% (102)	
Adults with hypertension/CVD**		3.4–5.0% (106,112)	7.8% (79)
<b>Blood pressure</b>			
Reduced diastolic BP			
Adults with diabetes	6.7–12.9% (83,94)		
Adults with or at risk for CVD**	15.8% (68)	5.8% (106)	9.3% (90)
Reduced systolic BP			
Adults with diabetes	11.1–11.3% (83,94)		
Adults with or at risk for CVD**	13.9% (68)	3.9% (106)	4.4% (90)

Table 4. Continued

Findings, by clinical measure and study population	Uncontrolled clinical trials	Non-randomized controlled clinical trials	Randomized clinical trials
Reduced baseline heart rate			
Adults with diabetes	10.2% (83)		
Adults with hypertension/CVD**		5.7% (106)	

CVD, Cardiovascular disease

\*Including studies reporting improvement in these indices; studies not reporting point estimates or presenting insufficient data to allow reliable calculation of point estimates were excluded.

\*\*Including adults with diabetes mellitus †Ss with cholesterol  $\geq 200$  mg dl<sup>-1</sup> ( $n = 43$ ) (88).

††18.9% mean difference relative to controls (101).

loss to follow-up (89,93) and multiple interventions (79,89,99,100,105). Among controlled studies, additional limitations included failure to compare control and intervention groups (106,107) and lack of randomization (102,104,112,113) or description of randomization methods (79). Blinded outcome assessment was not detailed in any of the 10 studies.

### Blood Pressure

We identified seven eligible studies that assessed the effects of yoga-based interventions on blood pressure. Six of these studies reported significant improvement in both systolic and diastolic blood pressure as compared to baseline values (68,83,94,106,112), or to controls receiving enhanced usual care (90). One study, a small British RCT of poorly controlled insulin-treated diabetic adults, showed no change in blood pressure despite significant improvement in other indices of CVD risk (Table 3) (84). Research reporting positive results included three uncontrolled trials targeting Indian adults with diabetes (83,94) or hypertension (68), one NRCT in US adults with CAD (106), one NRCT of German community-dwelling adults (112) and one RCT in US seniors (90). Interventions ranged from 40 days (83) to 1 year (90,106) in duration, and all incorporated active asanas. Reductions in systolic and diastolic blood pressures varied from 3.9 to 13.9% and 5.8 to 15.8%, respectively, depending on design and population (Table 4).

However, the potential biases and limitations characterizing most of these studies again hinder interpretation of findings. These include absence of comparison groups (68,83,94), small sample sizes (68,83,94), reduced power due to stratified analyses (68,90) or other factors (84), possible selection bias or confounding by lifestyle or other factors (83,94), absence of detailed information regarding the population (83), statistical methods (68,83,94,111) or subject selection process (83,112), potential uncontrolled variation in exposure to the intervention (94) or loss to follow-up (94). Only one reported blinding of outcome assessment (90), and most studies used yoga in combination with other interventions (68,89,90,106,112), making it difficult to isolate an effect specific to yoga. Other methodological limitations are lack of randomization (106,111) and inadequacies in statistical analyses or presentation, including lack of appropriate point estimates (68,94,111),

adjustment for multiple comparisons (68,83,84,90,94,111) and appropriate comparisons between (106) or within (68) groups.

### Influence of Yoga on Other Indices

Eligible data suggest that yoga-based interventions may also have beneficial effects on coagulation profiles and oxidative stress, sympathetic activation and lung function in adults with DM 2, although investigations including diabetic populations are few. For example, recent uncontrolled trials targeting Indian adults with uncomplicated diabetes mellitus (97) or hypertension (68) reported significant reductions in malonyl-dialdehyde (MDA), an estimate of lipid oxidative damage, following a 40 day yoga training course (97) and a 12 week yoga lifestyle intervention (68). These findings suggest a decrease in oxidative damage with yoga. Data from a non-randomized controlled study of German adults (including an unspecified number with diabetes) suggest that yoga may also improve coagulation profiles. Compared to relative to community controls matched on age, gender and baseline fibrinogen levels, participants who completed a 3 month residential Kriya yoga program showed a significant decline in fibrinogen among participants ( $n = 76$  subjects, including 38 controls) (111). These findings are consistent with those of uncontrolled (114–116) and controlled studies (117,118) in healthy adults (114–116,118) and in adults with other related chronic disorders (115,117). Recently, reviewed by Innes *et al.* (82), these reports showed significant improvement in measures of oxidative damage (115–118) and coagulopathy (114) following yoga-based interventions ranging from 10 weeks (118) to 5 months (116). Procoagulant changes and damage due to oxidative stress are thought to mediate many of the atherosclerotic and thrombotic changes associated with IRS (119–123) and to play a central role in the pathogenesis and progression of diabetes (18) and CVD (119–121,123).

Although many investigations have examined the effect of yoga on markers of sympathetic/parasympathetic activation and cardiovagal function (82), our search identified only four that included adults with diabetes, including two uncontrolled studies (68,83) and two NRCTs (106,112); only one of them specifically targeted patients with DM 2 (83) (Table 2). Relative to baseline (68,83,106) or to controls receiving no intervention (112), participants who completed a yoga program showed significant reductions in heart rate (83,106) and

**Table 5.** Clinical trials investigating the effects of yoga and yoga-based programs on specific clinical outcomes, stratified by study design and intervention (yoga, including yoga-based meditation, alone versus in combination with other interventions)

Findings, by outcome	Study design					
	Uncontrolled clinical trials		Non-randomized controlled trials		Randomized controlled trials	
	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions	Yoga alone	Multiple interventions
<b>Clinical outcomes</b>						
Reduced need for medication						
Hypertension/CAD		<b>(68)</b>		<b>(104)</b>		
Diabetes	<b>(65,83,92,93)</b>	<b>(99) (68)</b>			<b>(84,101)</b>	
<b>Studies targeting adults with CVD</b>						
Reduced revascularization procedures related complications				<b>(112)</b>		<b>(79)</b>
Reduction in anginal episodes				<b>(112)</b>		<b>(79)</b>
Reduced carotid intimal media thickness						<b>(90)</b>
Reduced progression of CAD				<b>(104)</b>		<b>(79)</b>
Increased regression of CAD				<b>(104)</b>		<b>(79)</b>
Reduced number of serious coronary events				<b>(112)</b>		
Reduced number of hospitalizations				<b>(104)</b>		

Studies reporting beneficial effects are in boldface. CAD, coronary artery disease; CVD, cardiovascular disease.

catecholamine levels (68,112). In agreement with these findings, results from over 35 in other populations, including healthy and hypertensive adults, suggest that yoga promotes a reduction in sympathetic activation, enhancement of cardio vagal function and a shift in autonomic nervous system balance from primarily sympathetic to parasympathetic (82). Documented changes have included significant reductions in respiratory and heart rate, in cortisol concentrations, catecholamine levels, and renin activity, in skin conductance, and in cardiovascular response to stress, as well as significant increases in heart rate variability and baroreflex sensitivity (82).

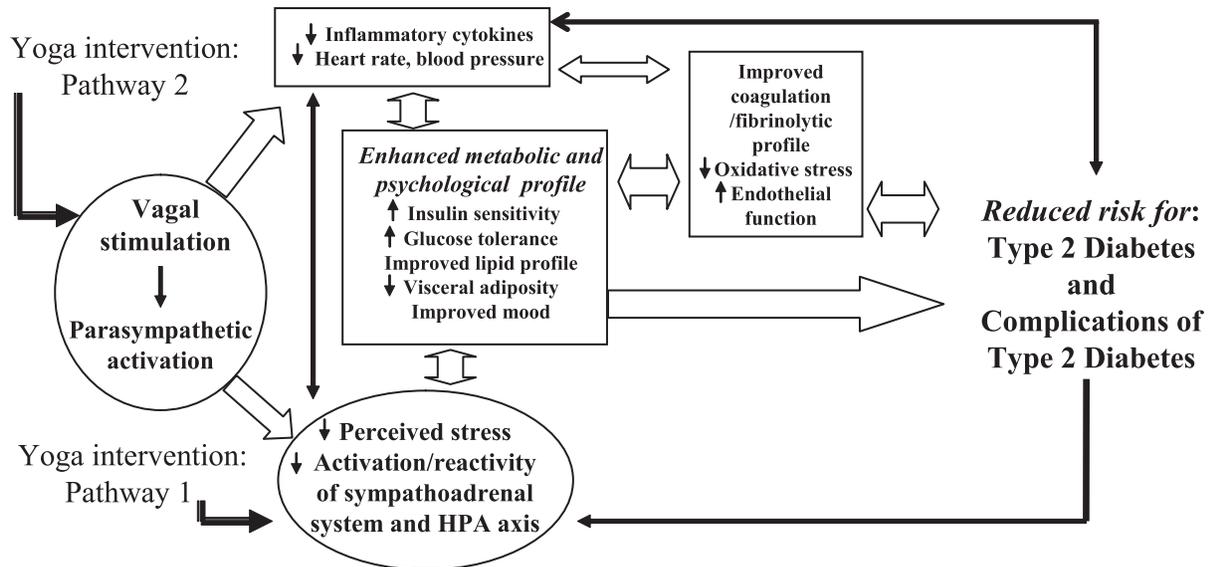
Impaired lung function is both an important complication (23,24) and a significant predictor (25) of type 2 diabetes, and has been inversely associated with insulin resistance (23) and glycemic exposure (24,124). Recent research in adults with DM 2 suggests that yoga may improve pulmonary function in this population (98). In an uncontrolled (pre–post) study of 24 Indian adults with an established diagnosis of DM 2, participants demonstrated significant increases in forced expiratory volume, forced vital capacity, peak expiratory flow rate and maximum voluntary ventilation following completion of a 40 day yoga program (98). Other research using healthy adults have yielded similar findings (125–129), although only one of them included controls (128).

While limited, available data support a possible beneficial influence of yoga on oxidative stress and coagulation profiles, sympathetic activation and pulmonary function in adults with DM 2. Limitations of existing research include lack of appropriate comparison groups (68,97,98,106), small sample sizes (68,97,98), possible selection bias or uncontrolled confounding by lifestyle and other factors (97,111), lack of randomization (111), inadequate information regarding the

population (97,98), subject selection (97,98,112), or analytic methods (68,97,98,111), multiple interventions (68,101,111), and problems with data analysis or presentation (68,97,98,111). In addition, blinding of outcome assessment was not well-reported in any identified studies.

### Influence of Yoga on Clinical Outcomes

Several studies in Indian (68,79,89,92,99), European (84,101) and American populations (90) have suggested that yoga may also improve specific clinical outcomes in patients with type 2 diabetes and other IRS-related chronic conditions. Twelve eligible studies evaluated the influence of yoga and yoga-based interventions on medication use and cardiovascular outcomes, including six uncontrolled trials, two non-randomized controlled studies and four RCTs (Table 5). In uncontrolled studies of Indian adults with hypertension (68) and/or diabetes (65,68,83,92,93,99), completion of a simple (65,83,92,93) or comprehensive yoga program (68,99) was associated with a reduced need for medication relative to baseline. In agreement with these findings, controlled studies of adults with diabetes (84,101) and/or CAD (89) showed a decline in medication requirements among those enrolled in a yoga-based intervention compared to controls receiving usual care (101), usual care plus intensive education and exercise (84), or usual care plus a diet and exercise program (89). Controlled studies in Indian (79) and American (90,113) populations also suggest that yoga may help reduce complications and improve the prognosis of those with frank or underlying disease. For example, in an RCT of Indian men with CAD, those enrolled in a 12 month comprehensive yoga program showed retardation of coronary atherosclerosis, increased regression and reduced progression of vascular lesions, and reduced anginal episodes



**Figure 1.** Hypothesized pathways by which yoga intervention may reduce risk for Type 2 Diabetes mellitus (DM 2) and for complications related to DM 2.

relative to usual care controls (79). Two other non-randomized controlled studies of CAD patients in India (89) and the United States (113) yielded similar results (Table 5). In an RCT in American seniors, participants completing a 12 month comprehensive yoga-based program demonstrated a decline in carotid intimal media thickness, an indicator of carotid atherosclerosis, relative to those receiving usual care or a comprehensive medical, diet and exercise intervention (90). The reduction was inversely correlated with adherence to the yoga program, suggesting a direct relation between practice of this program and atherosclerotic change.

Although promising, several of these studies have methodological and other limitations, including absence of control groups (65,68,83,92,93,99), small sample sizes (65,68,93,101), lack of randomization (89,113), loss of participants at follow-up (89), possible uncontrolled confounding factors (92,99,101), unclear statistical analyses (65,68,83,92) or absence of intergroup comparisons (101), lack of adjustment for multiple comparisons (68,90,92) and multiple interventions (68,79,83,89,90,99,101,113). Several lacked adequate descriptions of the study population (83,89,92,93), sample selection process (83,93), intervention (65,93,101), treatment allocation (89) or statistical methods (68,92,99,101). Only one study presented information of blinding with outcome assessment (90). In addition, reporting bias may have resulted in omission of negative findings, possibly inflating the apparent positive effect of yoga on clinical outcomes.

### Yoga, Psychosocial Risk Factors for Diabetes and CVD, and Possible Underlying Mechanisms

While methodological and other limitations preclude drawing firm conclusions, the published research reviewed above nonetheless offer evidence that yoga may improve risk profiles and clinical outcomes in adults with type 2 diabetes. In

addition, although studies that specifically target diabetic populations are lacking, investigations in healthy adults (66,130–134) and in other chronically ill populations (135–142) suggest that yoga therapy may reduce psychosocial risk factors for the development and progression of diabetes as well. Yoga has been reported to decrease perceived stress (134,143,144) and reactivity to stressors (133), enhance stress-related coping (137,138), reduce symptoms of depression (130,132,136,140,142,145) and anxiety (66,88,130,132,135,137,138,141), decrease anger, tension and fatigue (130,135), enhance psychological well-being (66,68,88,94,130–133,137,138), and reduce sleep disturbance (134,139).

Mechanisms underlying the beneficial effects of yoga practice on diabetes-related risk profiles are not yet well understood. However, the observed changes may occur via at least two major pathways. First, by reducing the activation and reactivity of the sympathoadrenal system and the hypothalamic pituitary adrenal (HPA) axis and promoting feelings of well-being, yoga may alleviate the effects of stress and foster multiple positive downstream effects on neuroendocrine status, metabolic function and related systemic inflammatory responses (Fig. 1, Pathway 1) (74,146,147). Second, by directly stimulating the vagus nerve, yoga may enhance parasympathetic activity and lead to positive changes in cardiovascular function, in mood and energy state, and in related neuroendocrine, metabolic and inflammatory responses (Fig. 1, Pathway 2) (74,146,147). In addition, yoga may both indirectly (by encouraging healthy lifestyle changes) and directly lead to weight loss and reduced visceral adiposity. Weight loss itself lowers risk for DM 2 and CVD complications (148,149).

In addition to physiologic improvements, yoga may provide a positive source of social support, a factor strongly associated with reduced risk for CVD (34,58), and may aid in improving health-related attitudes and lifestyle choices, in part by enhancing psychological well-being (34), and in this way

also play an important role in diabetes management and prevention of cardiovascular complications (34).

## Summary and Conclusions

In summary, a growing number of studies suggest that yoga may improve indices of risk in adults with type 2 diabetes, including glucose tolerance and insulin sensitivity, lipid profiles, anthropometric characteristics and blood pressure. Limited data also indicate that yoga may reduce oxidative damage, improve coagulation profiles and pulmonary function, and decrease sympathetic activation in adults with diabetes and related chronic disorders. Yoga may also be useful in reducing medication requirements in patients with diabetes and could help prevent and manage cardiovascular complications in this population.

However, despite the apparent therapeutic promise of yoga for diabetes management, rigorous, systematic studies regarding the effects of yoga on physiological, anthropometric and psychological profiles in adults with diabetes are few, and those in western populations are even fewer. Over 85% of published clinical trials (1970–2006) investigating the therapeutic applications and psychophysiological effects of yoga practice in diabetic populations have been conducted in India, where yoga forms a central part of long-standing spiritual and cultural traditions. Interpretation of existing studies is limited by small sample sizes, selection bias, lack of appropriate control groups, failure to adjust for baseline anthropometric characteristics, lifestyle factors, and other potential confounders, exposure to multiple interventions, and other methodological limitations. In addition, considerable variation in design, duration, intensity and delivery methods of yoga-based interventions renders comparison across studies problematic. Publication bias may also contribute to the selective reporting of positive results (150), particularly in non-Western countries, where yoga is more widely accepted and more likely to be incorporated into medical care. While existing RCTs have produced results consistent overall with those of non-randomized and uncontrolled studies, suggesting that the positive findings of these latter studies do not simply reflect poor study design, clearly, additional high-quality RCTs are warranted. Specifically, rigorous studies are needed to clarify the effects of specific yoga therapies on measures of DM 2 risk and related clinical outcomes, especially in American and other Western populations that remain under-represented in existing research.

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