International Journal of Cardiology 173 (2014) 170–183

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Effects of yoga on cardiovascular disease risk factors: A systematic review and meta-analysis

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ARTICLE INFO

Article history:
Received 23 September 2013
Received in revised form 28 January 2014
Accepted 13 February 2014
Available online 25 February 2014

Keywords:
Cardiovascular diseases
Hypertension
Metabolic syndrome
Type 2 diabetes
Yoga
Meta-analysis

ABSTRACT

Background: The aim of this review was to systematically assess and meta-analyze the effects of yoga on modifiable biological cardiovascular disease risk factors in the general population and in high-risk disease groups.
Methods: MEDLINE/PubMed, Scopus, the Cochrane Library, and IndMED were screened through August 2013 for randomized controlled trials (RCTs) on yoga for predefined cardiovascular risk factors in healthy participants, non-diabetic participants with high risk for cardiovascular disease, or participants with type 2 diabetes mellitus. Risk of bias was assessed using the Cochrane risk of bias tool.
Results: Forty-four RCTs with a total of 3168 participants were included. Risk of bias was high or unclear for most RCTs. Relative to usual care or no intervention, yoga improved systolic (mean difference (MD) = −5.85 mm Hg; 95% confidence interval (CI) = −8.81, −2.89) and diastolic blood pressure (MD = −4.12 mm Hg; 95%CI = −6.55, −1.69), heart rate (MD = −6.59 bpm; 95%CI = −12.89, −0.28), respiratory rate (MD = −0.93 breaths/min; 95%CI = −1.70, −0.15), waist circumference (MD = −1.95 cm; 95%CI = −3.01, −0.89), waist/hip ratio (MD = −0.02; 95%CI = −0.03, −0.00), total cholesterol (MD = −13.09 mg/dl; 95%CI = −19.60, −6.59), HDL (MD = 2.94 mg/dl; 95%CI = 0.57, 5.31), VLDL (MD = −5.70 mg/dl; 95%CI = −7.36, −4.03), triglycerides (MD = −20.97 mg/dl; 95%CI = −28.61, −13.32), HbA1c (MD = −0.45%; 95%CI = −0.87, −0.02), and insulin resistance (MD = −0.19; 95%CI = −0.30, −0.08). Relative to exercise, yoga improved HDL (MD = 3.70 mg/dl; 95%CI = 1.14, 6.26).
Conclusions: This meta-analysis revealed evidence for clinically important effects of yoga on most biological cardiovascular disease risk factors. Despite methodological drawbacks of the included studies, yoga can be considered as an ancillary intervention for the general population and for patients with increased risk of cardiovascular disease.

1. Introduction

Cardiovascular diseases, namely coronary heart disease and stroke, are the most common causes of death worldwide [1,2]. About 30% of all deaths worldwide, an estimated 17.3 million people, died from cardiovascular disease in 2008 [2]. By 2030, it has been estimated that this number will increase to 23.3 million deaths [2]. Over 80% of those deaths take place in low- and middle-income countries. Cardiovascular disease is among the leading causes of morbidity, disability, and work loss worldwide [1,3–5]. Being the major non-communicable disease, cardiovascular disease constitutes a substantial socioeconomic burden in all countries worldwide [1,3]. Although several hundred cardiovascular disease risk factors have been identified, the most important ones include hypertension, hyperlipidemia, hyperglycemia, and abdominal obesity. About 80% of cardiovascular disease is mainly caused by modifiable risk factors [6].

Yoga is rooted in Indian philosophy and has been a part of traditional Indian spiritual practice for millennia [7]. Traditional yoga's ultimate goal has been described as quieting one's mind to achieve the union of mind, body and spirit [7,8]. Regardless of its spiritual origins, yoga has become a popular route to physical and mental well-being [7,8] and has been adapted for use in complementary and alternative medicine in North America and Europe [9]. In the latter setting, yoga is most often associated with physical postures (‘*Asana*’), breath control (‘*Pranayama*’), and meditation (‘*Dhyana*’); and different yoga schools have emerged that put varying focus on physical and mental practices [7,9]. In Western societies, yoga is gaining increased popularity as a therapeutic method. About 14 million adult Americans (6.1% of the population) reported that yoga had been recommended to them by a physician or therapist [10]. Indeed, about half of American yoga

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http://dx.doi.org/10.1016/j.ijcard.2014.02.017
0167-5273/

practitioners (more than 13 million people) reported that they had started practice explicitly to improve their health [11,12]. In the United Kingdom, yoga is even promoted by the National Health Service as a safe and effective approach to improve health in both the general population and diseased patients [13]. Worldwide, it is estimated that yoga is regularly practiced by about 30 million people [14]. However, this number might still underestimate the actual prevalence of yoga practice.

Yoga has been shown to reduce important psychological cardiovascular disease risk factors such as stress [15,16] and depression [17]. Being a combination of exercise, controlled breathing, and relaxation, it is commonly thought to also improve biological cardiovascular disease risk factors [18,19]. The aim of this review was to systematically assess and meta-analyze the effects of yoga on modifiable biological cardiovascular disease risk factors (blood pressure, heart rate, respiratory rate, abdominal obesity, blood lipid levels, insulin resistance, oxidative stress, inflammatory markers, and atherosclerosis) in the general population and in high-risk disease groups (hypertension, metabolic syndrome, and type 2 diabetes).

2. Materials

The review was planned and conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [20] and the recommendations of the Cochrane Collaboration [21].

2.1. Eligibility criteria

2.1.1. Types of studies

Randomized controlled trials (RCTs) and randomized cross-over studies were eligible. No language restrictions were applied.

2.1.2. Types of participants

Studies including the following participants were eligible: 1) healthy participants; 2) non-diabetic participants with high risk for cardiovascular disease (including participants with hypertension, prehypertension, metabolic syndrome, obesity, dyslipidemia, or impaired insulin resistance); and 3) participants with type 2 diabetes mellitus. Differences between the 3 types of participants were investigated in subgroup analyses.

2.1.3. Types of interventions

Studies that compared yoga with no treatment, usual care, or any active treatment were eligible. Studies were excluded if yoga was not the main intervention but a part of a multimodal intervention. Since in North America and Europe, physical exercise is perceived as a main component of yoga [7,9], studies examining meditation or yogic lifestyle without physical component were also excluded. No further restrictions were made regarding yoga tradition, length, frequency, or duration of the program. Co-interventions were allowed. Head-to-head comparisons of different types of yoga without a non-yoga control group were excluded.

2.1.4. Types of outcome measures

For inclusion, RCTs had to assess at least 1 of the following primary outcomes: 1) blood pressure (systolic, diastolic); 2) heart rate; 3) respiratory rate; 4) abdominal obesity (assessed as e.g. waist circumference, waist–hip ratio, index of central obesity); 5) blood lipid levels (e.g. levels of cholesterol, LDL, HDL, VLDL, triglycerides); 6) insulin resistance (assessed as e.g. fasting blood insulin levels, fasting blood glucose, HbA1c, adiponectin levels, glucose tolerance test, or the Homeostatic Model Assessment [HOMA-IR]); 7) oxidative stress (assessed as e.g. blood levels of glutathione, superoxide dismutase, or catalase); 8) inflammatory markers (such as high-sensitivity C-reactive protein, interleukin-6 or homocysteine); and 9) atherosclerosis (assessed as e.g. intima-media thickness). Safety (assessed as adverse events and severe adverse events) was defined as secondary outcome.

2.2. Search methods

Four electronic databases were searched from their inception through August 08, 2013: Medline/PubMed, Scopus, the Cochrane Library, and IndMED. The literature search was constructed around search terms for “yoga” and search terms for “cardiovascular disease risk factors” and adapted for each database as necessary. The complete search strategy for PubMed/Medline is shown in Additional file 1.

Additionally, reference lists of identified original articles or reviews and the tables of contents of the International Journal of Yoga Therapy and the Journal of Yoga & Physical Therapy were searched manually.

Two review authors independently screened abstracts identified during literature search and read potentially eligible articles in full to determine whether they met the eligibility criteria (HC and RL). Disagreements were discussed with a third review author until consensus was reached.

2.3. Data extraction and management

Pairs of 2 authors (HC and HH, RL and NS) independently extracted data on design (e.g. origin, setting), participants (e.g. condition, age, gender, race), interventions (e.g. yoga type, components, duration), control interventions (e.g. type, duration), outcomes (e.g. outcome measures, assessment time points), and results using an a priori developed data extraction form. Discrepancies were discussed with a third review author until consensus was reached.

2.4. Risk of bias in individual studies

Pairs of 2 authors (HC and HH, RL and NS) independently assessed risk of bias using the Cochrane risk of bias tool [21]. This tool assesses risk of bias on the following domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias.

Selection bias includes the criteria ‘random sequence generation’ and ‘allocation concealment’. Adequate random sequence generation should produce comparable random groups; and adequate allocation concealment means that the intervention allocations could not have been foreseen before or during enrolment. Performance bias describes blinding of participants and personnel. Adequate blinding means that neither participants nor personnel (therapists or other healthcare providers) had knowledge of which intervention a participant received. While blinding of participants and personnel might be difficult or even impossible in yoga trials, inadequate blinding still remains a possible risk of bias. Detection bias describes adequate blinding of outcome assessors from knowledge of which intervention a participant received. Attrition bias due to incomplete outcome data includes inadequate exclusion of participants from the study or analysis; and/or drop-out rates beyond 20% in the short-term if not addressed by intention-to-treat analysis. Reporting bias due to selective reporting means that not all predefined outcomes were reported; and other bias includes all sources of potential bias not covered by any other criterion [21].

For each criterion, risk of bias was assessed as 1) low risk of bias (adequate fulfillment of the respective criterion), 2) unclear (insufficient information to judge about fulfillment or non-fulfillment of the respective criterion), and 3) high risk of bias (inadequate fulfillment or non-fulfillment of the respective criterion) [21]. Discrepancies were rechecked with a third reviewer and consensus achieved by discussion.

2.5. Data analysis

2.5.1. Assessment of overall effect size

Effects of yoga compared to different control interventions were analyzed separately. Meta-analyses were conducted using Review Manager 5 software (Version 5.1, The Nordic Cochrane Centre, Copenhagen) using a random effects model if at least 2 studies assessing this specific outcome were available.

For continuous outcomes, mean differences (MD) between groups and their 95% confidence intervals (CI) were calculated from means, standard deviations, and group sizes using the inverse-variance method of meta-analysis [21]. Where no standard deviations were reported, they were calculated from standard errors, confidence intervals, or t-values [21], or attempts were made to obtain the missing data from the trial authors by email. If none of these strategies was successful, standard deviations were imputed from other RCTs with comparable characteristics. Where no means were reported, attempts were made to obtain the missing data from the trial authors by email.

Where outcomes were assessed in different measurement units (e.g. cholesterol assessed in mmol/l and mg/dl), means and standard deviations were converted into a common measurement unit to allow for calculating MDs.

2.6. Assessment of heterogeneity

Statistical heterogeneity between studies was analyzed using the I^2 statistics, a measure of how much variance between studies can be attributed to differences between studies rather than chance. The magnitude of heterogeneity was categorized as 1) I^2 =0–24%: low heterogeneity; 2) I^2 =25–49%: moderate heterogeneity; 3) I^2 = 50–74%: substantial heterogeneity; and 4) I^2 = 75–100%: considerable heterogeneity [21,22]. The Chi^2 test was used to assess whether differences in results are compatible with chance alone. Given the low power of this test when only few studies or studies with low sample size are included in a meta-analysis, a p-value ≤ 0.10 was regarded to indicate significant heterogeneity [21].

2.7. Subgroup and sensitivity analyses

Subgroup analyses were conducted for type of participants (healthy, non-diabetic participants with high risk for cardiovascular disease, type 2 diabetes) and for length of the intervention (below median length, exactly at median length, above median length). Subgroup differences were assessed by testing for heterogeneity across subgroups [21] using the I^2 statistics as a measure of the percentage of variability in effect estimates from the different subgroups that is due to genuine subgroup differences rather than chance. The Chi^2 test was further used and a p-value ≤ 0.10 was regarded to indicate significant heterogeneity [21].

To test the robustness of significant results, sensitivity analyses were conducted for studies with high versus low risk of bias at the domains selection bias, detection bias, and attrition bias.

If statistical heterogeneity was present in the respective meta-analysis, subgroup and sensitivity analyses were also used to explore possible reasons for heterogeneity.

2.8. Risk of publication bias

Risk of publication bias was assessed for each meta-analysis that included at least 10 studies. Funnel plots – scatter plots of the intervention effect estimates from individual studies against the studies' standard error – were generated using Review Manager 5 software [21,23]. As the precision of effect estimates normally increases with sample size, effect estimates from studies with larger standard errors will scatter more widely than those of studies with smaller standard errors. Unpublished smaller studies with non-significant results will therefore result in asymmetrical funnel plots [21,23]. Publication bias was assessed by visual analysis with roughly symmetrical funnel plots regarded to indicate low risk and asymmetrical funnel plots regarded to indicate high risk of publication bias [21,23].

3. Results

3.1. Literature search

The literature search yielded 1510 records; 4 additional records were retrieved from reference lists of identified original articles; and 1 additional record was retrieved from the Journal of Physical Therapy and Yoga. After exclusion of duplicates, 956 records were screened and 857 records were excluded because they were not RCTs, participants had ineligible conditions, and/or yoga was not an intervention. Out of 99 full-texts assessed for eligibility, 46 were excluded because they were not randomized [24–57], participants included patients with type 1 diabetes [58], yoga was not an intervention [59], the yoga intervention did not include physical postures [60–65], yoga was part of a multimodal intervention [66,67], no relevant outcomes

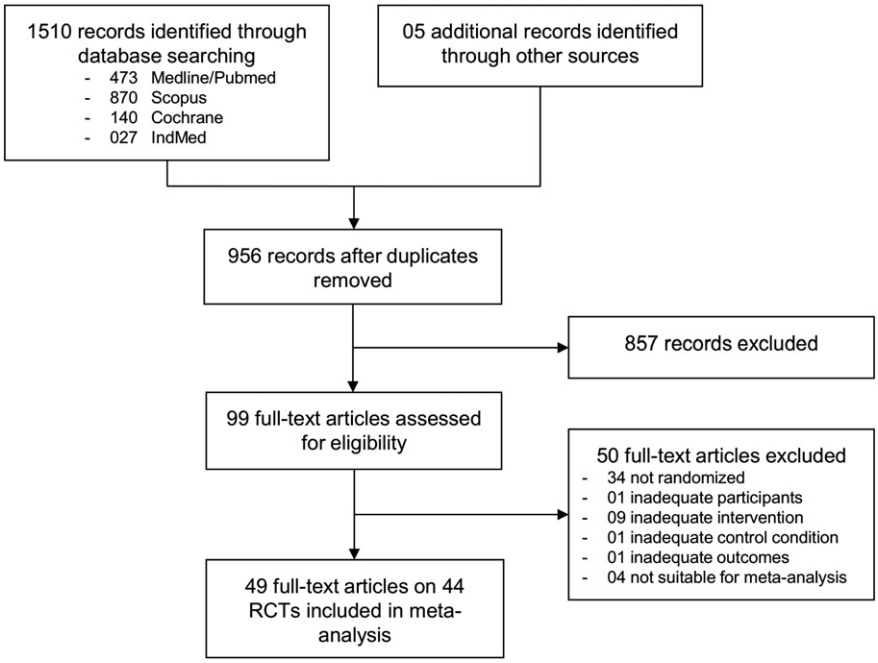

Fig. 1. Flowchart of the results of the literature search.

were assessed [68], or the study compared different yoga interventions without an adequate control group [69]. Fifty-three full-text articles on 48 RCTs were finally eligible [70–122]. Of those, 4 RCTs did not provide sufficient data to be included in the meta-analysis [91,119–121]. Missing data could be obtained from the authors of 1 of the RCTs by email [91]. The remaining 3 RCTs were excluded. One further RCT compared yoga to an ayurvedic herbal drug. As this was the only RCT with this specific comparison group, it could not be included in meta-analysis and hence had to be excluded [122]. Finally, 49 full-text articles on 44 RCTs with a total of 3168 participants were included in the analysis [70–118] (Fig. 1).

3.2. Participant and setting characteristics

Origin and setting of the included studies, characteristics of the sample, interventions, and outcome assessment are shown in Table 1. Detailed information on inclusion and exclusion criteria is given in Additional file 2.

Of the 44 RCTs that were included, 21 included healthy participants [70–92]. Twelve RCTs included non-diabetic participants with high risk of cardiovascular disease [93–105] including hypertension [94,96,98,100–103,105]; metabolic syndrome [93,95,99]; obesity [97,104,105]; dyslipidemia [98,105], or impaired fasting glucose [105]. Eleven RCTs included patients with type 2 diabetes [106–118]. The RCTs included a total of 3168 participants; sample size ranged from 16 to 420 with a median of 49. Participant's mean age ranged from 10.8 years to 75.4 years with a median of 48.2 years; 11 RCTs did not report mean age. Four RCTs included children [70,80,90,104]. Between 0% and 100% of participants were female (median 53.5%; 4 RCTs did not report gender of participants).

Nineteen of the included RCTs originated from India (43.2%); 8 from the USA (18.2%); 3 each from the UK and South Korea (6.8%); 2 each from Australia and Iran (4.5%); and 1 each from Taiwan, China, Japan, Thailand, Sweden, Cuba, and Jamaica (2.3%). Study participants were patients that were recruited from hospitals, outpatient clinics, or practices; healthy participants were students that were recruited from universities or schools, or were recruited from their workplace, the army, children's homes, retirement homes, or by advertisement.

3.3. Intervention characteristics

Of the 44 included RCTs, 24 did not define the specific style of yoga used; 7 stated that Hatha Yoga (an umbrella term for yoga styles that mainly focus on physical postures) was used; and 13 RCTs used a specific yoga style (Iyengar Yoga, Sudarshan Kriya Yoga, Kundalini Yoga, Restorative Yoga, Silver Yoga, Ashtanga Yoga, Viniyoga, Vinyasa Yoga, Yoga Synergy Water Sequence). All RCTs included physical postures in their yoga intervention; 33 RCTs included yogic breathing exercises; 36 RCTs included relaxation; 18 RCTs included meditation; and 9 RCTs included advice on yogic lifestyle. The reported yoga interventions ranged in length from 3 days to 1 year with a median length of 12 weeks (Table 1).

Thirty RCTs compared yoga to usual care or no treatment; 12 RCTs used exercise interventions as their control intervention; and 6 used psychological or educational interventions.

3.4. Outcome measures

Blood pressure was assessed in 28 RCTs, heart rate in 19 RCTs, and respiratory rate in 6 RCTs. Abdominal obesity was assessed in 10 RCTs, blood lipid levels in 16 RCTs, and measures of insulin resistance in 17 RCTs. Only 1 RCT each assessed measures of oxidative stress, or atherosclerosis. Hence, these measures could not be included in meta-analysis. No RCT assessed inflammatory markers.

Outcomes were only assessed immediately after the end of the intervention in most RCTs; only 3 RCTs reported longer-term follow-up that were assessed after the end of the intervention [80,111,115].

Safety-related data were reported in 11 RCTs (Table 1).

3.5. Risk of bias in individual studies

Risk of bias in individual studies is shown in Additional file 3, risk of bias across all included studies is shown in Fig. 2. Six RCTs reported adequate random sequence generation and allocation concealment [75,80,95,115,117,118]; and 6 RCTs reported adequate blinding of outcome assessment [75,80,83,95,105,115]. No RCT reported adequate blinding of participants and personnel and only 2 studies had low risk of bias in all other criteria [95,115].

3.6. Analyses of overall effects

Thirteen RCTs did not provide means and/or standard deviations for at least 1 outcome [70–74,76,77,86,91,96,108–110,117,119–121]. Original raw data were provided by the authors of 2 RCTs upon request [91,117]. For 4 further RCTs, standard deviations could be imputed from other RCTs with comparable means and sample size [70–73,86,96].

Effects of yoga compared to usual care or no treatment, exercise, and psychological interventions are shown in Tables 2, 3, and 4, respectively. Forests plot are presented in Additional files 4, 5, 6.

Relative to usual care or no treatment, yoga was associated with significant improvements in both systolic (MD = −5.85 mm Hg) and diastolic blood pressure (MD = −4.12 mm Hg), heart rate (MD = −6.59 bpm), respiratory rate (MD = −0.93 breaths/min), waist circumference (MD = −1.95 cm), waist/hip ratio (MD = −0.02), total cholesterol (MD = −13.09 mg/dl), HDL (MD = 2.94 mg/dl), VLDL (MD = −5.70 mg/dl), triglycerides (MD = −20.97 mg/dl), HbA1c (MD = −0.45%) and insulin resistance (HOMA-IR; MD = −0.19) (Table 2; Additional file 4). Relative to exercise, yoga improved blood levels of HDL (MD = 4.24 mg/dl) (Table 3; Additional file 5).

3.7. Subgroup analyses

3.7.1. Type of participants

In RCTs that included healthy participants, effects of yoga compared to usual care or no treatment were found for respiratory rate (MD = −0.93 breaths/min), triglycerides (MD = −27.84 mg/dl) (Table 2; Additional file 4); and effects of yoga compared to exercise were found for systolic blood pressure (MD = −5.42 mm Hg) (Table 3; Additional file 5). In RCTs that included non-diabetic participants with high risk of cardiovascular disease, effects of yoga compared to usual care or no treatment were found for systolic (MD = −10.00 mm Hg) and diastolic blood pressure (MD = −7.45 mm Hg), waist circumference (MD = −1.45 cm), triglycerides (MD = −10.92 mg/dl), and insulin resistance (MD = −0.19) (Table 2; Additional file 4). Subgroup analysis of RCTs of patients with type 2 diabetes revealed effects of yoga compared to usual care or no treatment for waist/hip ratio (MD = −0.02), total cholesterol (MD = −16.59 mg/dl), HDL (MD = 5.51 mg/dl); VLDL (MD = −4.81 mg/dl), triglycerides (MD = −23.60 mg/dl), fasting blood glucose (MD = −25.56 mg/dl) (Table 2; Additional file 4); and effects of yoga compared to exercise for HDL (MD = 4.24 mg/dl), and LDL (MD = −9.24 mg/dl) (Table 3; Additional file 5).

No further significant group differences were found in subgroup analyses (Tables 2, 3, and 4; Additional files 4, 5, 6).

3.7.2. Length of intervention

In RCTs with less than 12 weeks of intervention duration, effects of yoga compared to usual care or no treatment were found for heart rate (MD = −11.93 bpm), and triglycerides (MD = −30.09 mg/dl) (Additional file 7). In RCTs with exactly 12 weeks of intervention duration, effects of yoga compared to usual care or no treatment were found for systolic (MD = −5.47 mm Hg) and diastolic blood pressures

Table 1
Characteristics of the included studies.

Condition Reference	Origin; setting; recruited from	Participants condition; sample size; mean age; gender; ethnicity	Duration (intervention/ latest follow-up)	Intervention	Control intervention(s)	Outcomes	Safety
Healthy							
Bera 1993 [70]	India; school hostel; school	Healthy; n = 40; mean age NR; gender NR; ethnicity NR	12 months	Yoga (P, B, R) 3 × 45 min/week	No treatment	Waist circumference	Not reported
Blumenthal 1989 [71–73]	USA; setting NR; advertisement	Healthy; n = 101; 67 y; 50.5% female; 96% Caucasians	16 weeks	Yoga (P) 2 × 60 min/week	1. Aerobic exercise 3 × 60 min/week 2. No treatment	Blood pressure, heart rate, total cholesterol, triglycerides, HDL, LDL	Not reported
Bowman 1997 [74]	UK; setting NR; advertisement	Healthy; n = 40; 67 y; 42.5% female; ethnicity NR	6 weeks	Hatha yoga (P, B, R) 2 × 90 min/week	Aerobic exercise 2 × 40 min/week	Blood pressure, heart rate	Not reported
Cheema 2013 [75]	Australia; university campus; university	Healthy; n = 37; 38 y; 81.08 female; ethnicity NR	10 weeks	Yoga Synergy Water Sequence (P, B, R) 3 × 50 min/week	No treatment	Heart rate	No AE in either group
Chen 2010 [76]	Taiwan; retirement homes; retirement homes	Healthy; n = 69; 75.4 y; 52.7% female; ethnicity NR	24 weeks	Silver Yoga (P, B, R, M) 3 × 70 min/week	No treatment	Blood pressure[a], heart rate[a], respiratory rate	No signs or symptoms of discomfort
Cusumano 1992 [77]	Japan; private university; university	Healthy; n = 95; mean age NR; 100% female; ethnicity NR	3 weeks	Hatha Yoga (P) 1 × 80 min/week	Progressive muscle relaxation 1 × 80 min/week	Blood pressure[a], heart rate	Not reported
Gopal 2011 [78]	India; university campus; university	Healthy; n = 60; mean age NR; 100% female; ethnicity NR	12 weeks	Yoga (P, B, M) 35 min/daily	No treatment	Blood pressure, heart rate, respiratory rate	Not reported
Granath 2006 [79]	Sweden; company financial sector; workplace	Healthy; n = 37 mean age NR; 73% female; 100% Caucasians	4 months	Kundalini Yoga (P, R, M, LS) 10 sessions	Cognitive behavior therapy 10 sessions	Blood pressure, heart rate	Not reported
Hagins 2013 [80]	USA; public middle school; school	Healthy; n = 31; 10.8 y; 43.3% female; 50% Caucasians	15 weeks	Yoga (P, R, M) 3 × 50 min/week	Physical education, moderate physical activity 3 × 50 min/week	Blood pressure, heart rate	Not reported
Harinath 2004 [81]	India; army unit; army	Healthy; n = 30; 29.6 y; 0% female; ethnicity NR	3 months	Hatha yoga (P, B, R, M) 2 h/daily	Exercise 2 h/daily	Blood pressure, heart rate, respiratory rate	Not reported
Hovsepian 2013 [82]	Iran; university department; university	Healthy; n = 60; 19.02 y; 100% female; ethnicity NR	8 weeks/ 3 months	Yoga (P, B, R, M) 2 ×60 min/week	Aerobic exercise 2 × 60 min/week	Respiratory rate	Not reported
Innes 2012 [83]	USA; university research center; advertisement	Healthy; n = 20; 58 y; 100% female; 75% Caucasians	8 weeks	Iyengar yoga (P, R, M, LS) 2 × 90 min/ week + 30 min home practice	Educational film program 2 × 90 min/week	Blood pressure, heart rate, waist circumference[a], fasting glucose level[a]	3 AE (muscle soreness) in yoga
Kim 2012 [84]	USA; university campus; advertisement	Healthy; n = 47; 44.4 y; 100% female; ethnicity NR	8 months	Ashtanga Yoga (P, R) 2 × 60 min/week	No treatment	Blood pressure, heart rate	6 AE in yoga (migraine, high blood pressure, hyperthyroidism, tumor, menopausal symptoms, chronic fatigue)
Lu 2007 [85]	China; university campus; university	Healthy; n = 63; 26.2 y; 100% female; ethnicity NR	10 weeks	Yoga (P, R) 3 × 60 min/week	Aerobic exercise 3 × 60 min/week	Heart rate, W/H ratio[a]	Not reported

Malathi 1998 [86]	India; university campus; university	Healthy; n = 75; 18.5 y; 48% female; ethnicity NR	12 weeks	Yoga (P, B, R) 3 × 60min/week	1. Relaxation 3 × 60 min/week 2. No treatment	Blood pressure, heart rate	Not reported
Ray, Mukhopadhyaya 2001 [87]	India; university campus; university	Healthy; n = 54; 22.8 y; 18.5% female; ethnicity NR	5 months	Hatha Yoga (P, B, R) 3 × 60min/week	No treatment	Blood pressure, heart rate	Not reported
Ray, Sinha 2001 [88]	India; army unit; army	Healthy; n = 40; 22 y; 0% female; ethnicity NR	6 months	Hatha Yoga (P, B, R, M) 6 × 60min/week	Exercise 6 × 60min/week	Heart rate	Not reported
Subramanian 2012 [89]	India; university campus; university	Healthy; n = 43 mean age NR; 53.5% female; ethnicity NR	6 weeks	Sudarshan kriya and pranayam (P, B, M)	No treatment	Total cholesterol, HDL, LDL, VLDL, triglycerides	Not reported
Telles 1997 [90]	India; community home; community home	Healthy; n = 28; 15 y; 100% female; ethnicity NR	6 months	Yoga (P, R) 5 × 60 min/week	Aerobic exercise 5 × 60 min/week	Heart rate, respiratory rate	Not reported
Vogler 2011 [91]	Australia; setting NR; retirement home	Healthy; n = 40; 73.2 y; 84.2% female; ethnicity NR	8 weeks	Iyengar Yoga (P, R) 2 × 90 min/week +3 × 15–20 min/week home practice	No treatment	Blood pressure	1 drop out in control due to illness
Wolever 2012 [92]	USA; company insurance sector; workplace	Healthy; n = 239; 42.9 y; 76.6% female; 78.2% Caucasians	12 weeks	Viniyoga (P, B, R) 1 × 60 min/week	1. Mindfulness meditation 2. No treatment	Blood pressure, respiratory rate	Not reported
Non-diabetic high-risk							
Cohen 2008 [93]	USA; setting and recruitment NR	Metabolic syndrome; n = 26; 52 y; 84% female; 46% Caucasians	10 weeks	Restorative Yoga (P, B, R) 15 × 90 min/10 weeks	Usual care	Blood pressure, waist circumference, total cholesterol, HDL, LDL, triglycerides, fasting blood glucose, fasting blood insulin	Not reported
Cohen 2011 [94]	USA; university research center; advertisement	Prehypertension or hypertension; n = 78; 48.2 y; 50% female; 47.4% Caucasians	12 weeks	Iyengar Yoga (P, B) 2 × 70 min/week for 6 weeks + 1 × 70 min/week for 6 weeks	Enhanced usual care 4 × 60 min/week	Blood pressure, heart rate	3 AE in yoga
Kim 2013 [95]	South Korea; hospital; hospital	Metabolic syndrome; n = 41; 49.3 y; 100% female; ethnicity NR	12 weeks	Hatha Yoga (P, B, R) 2 × 60 min/week	Usual care	Blood pressure, waist circumference, fasting blood glucose, HDL, triglycerides	Not reported
Latha 1991 [96]	India; hospital; hospital	Hypertension; n = 23; mean age NR; gender NR; ethnicity NR	6 months	Yoga (P, B, R) 17x, twice weekly	Attention control (talk) 1x/week	Blood pressure	Not reported
Lee 2012 [97]	South Korea; setting and recruitment NR	Obesity; n = 16; 54.5 y; 100% female; ethnicity NR	16 weeks	Yoga exercise (P, B, R) 3 × 60 min/week	No treatment	Blood pressure, waist circumference, total cholesterol, HDL, LDL, fasting blood glucose, fasting blood insulin, insulin resistance (HOMA IR), adiponectin[a]	Not reported
Mahajan 1999 [98]	India; yoga residential camp; recruitment NR	Hypertension, smoking, or dyslipidemia; n = 53; mean age NR; 0% female; ethnicity NR	14 weeks	Yoga (P, B, R, M, LS) 4 days residential camp + 60 min/day home practice	No treatment	Total cholesterol, HDL, LDL, triglycerides	Not reported
Manchanda 2013 [99]	India; yoga center; hospital	Metabolic syndrome; n = 100; 51 y; 50% female; ethnicity NR	12 months	Yoga (P, B, R, M, LS)	Usual care (conventional lifestyle modification)	Blood pressure, waist circumference, total cholesterol, HDL, LDL, triglyceride, fasting	Not reported

(continued on next page)

Table 1 (*continued*)

Condition Reference	Origin; setting; recruited from	Participants condition; sample size; mean age; gender; ethnicity	Duration (intervention/ latest follow-up)	Intervention	Control intervention(s)	Outcomes	Safety
				1 week residential camp + 60 min/day home practice		blood glucose, HbA1c, carotid intima-media thickness[a]	
McCaffrey 2005 [100]	Thailand; yoga training centers; outpatient clinic	Hypertension; n = 61; 56.4 y; 64.8% female; ethnicity NR	8 weeks	Yoga (P, B, LS) 3 × 63 min/week	Usual care	Blood pressure, heart rate	Not reported
Murugesan 2000 [101]	India; setting NR; hospital	Hypertension; n = 33 mean age NR; gender NR; ethnicity NR	11 weeks	Yoga (P, B, R, M) 6 × 120 min/week	1. Usual Care 2. No treatment	Blood pressure, heart rate	Not reported
Saptharishi 2009 [102,103]	India; setting and recruitment NR	Prehypertension or hypertension; n = 113; 22.5 y; 33.3% female; ethnicity NR	8 weeks	Yoga (P, B, R) 5 × 30–45 min/week	1. Exercise 4 × 50–60 min/week 2. Salt intake reduction 3. Usual care	Blood pressure	Not reported
Seo 2012 [104]	South Korea; setting NR; advertisement	Obesity; n = 34; 14.7 y; 0% female; ethnicity NR	8 weeks	Yoga (P, R) 3 × 60 min/week	No treatment	Total cholesterol, HDL, LDL, triglyceride, fasting blood glucose, fasting blood insulin, insulin resistance (HOMA-IR)	Not reported
Yang 2011 [105]	USA; setting NR; workplace	Impaired fasting glucose, prehypertension, overweight/ obesity, or dyslipidemia; n = 25; 51.7 y; 91.3% female; 82.6% Caucasians	12 weeks	Vinyasa Yoga (P, B, R) 2 × 60 min/week	Health Education	Blood pressure, total cholesterol[a], HDL[a], LDL[a], triglycerides[a], fasting blood glucose[a], fasting blood insulin[a]	2 drop outs in each group due to medical reasons, no yoga related AE
Type 2 diabetes							
Agrawal 2003 [106]	India; hospitals; diabetic clinic	Type 2 diabetes; n = 200; 51.6 y; 29.9% female; ethnicity NR	3 months	Yoga (P, R, M, LS) 5–7 × 60 min/week	Usual care	Blood pressure, W/H ratio, total cholesterol, HDL, LDL, VLDL, triglycerides, fasting blood glucose, HbA1c	Not reported
Céspedes 2002 [107]	Jamaica; setting and recruitment NR	Type 2 diabetes; n = 40; mean age NR; gender NR; ethnicity NR	1 year	Yoga (P, B) 3 × 60 min/week	Aerobic exercise 3 × 60 min/week	Total cholesterol, triglycerides, HDL, LDL, fasting blood glucose[a]	Not reported
			24 weeks	Hatha yoga (P, B, R, LS)	1. Exercise		Not reported

Gordon 2008 [108–110]	Cuba; setting NR; hospital	Type 2 diabetes; n = 420; 63.8 y; 80.5% female; ethnicity NR		1 × 120 min/week	1 × 120 min/week 2. Usual Care	Blood pressure[a], total cholesterol, LDL, HDL, VLDL, triglycerides, fasting blood glucose, fasting blood insulin, HbA1c, malondialdehyde[a], protein oxidation[a], phosoholipase-A2[a], superoxide dismutase[a], catalase[a]	
Habibi 2013 [111]	Iran; setting NR; hospital	Type 2 diabetes; n = 26; mean age NR; 100% female; ethnicity NR	12 weeks	Yoga (P, B, M) 3 × 75 min/week	Usual care	Blood pressure, fasting blood glucose, fasting blood insulin	Not reported
Jyotsna 2012 [112]	India; hospital; hospital	Type 2 diabetes; n = 49; 48.2 y; 38.9% female; ethnicity NR	3 days/3 months	Sudarshan Kriya Yoga (P, B, R, M) 3 days 12 hour course	Usual care	Fasting blood glucose, HbA1c	Non-compliance in yoga due to illness (number not reported)
Jyotsna 2013 [113]	India; hospital; hospital	Type 2 diabetes; n = 64; 48 y; gender NR; ethnicity NR	3 days/6 months	Sudarshan Kriya Yoga (P, B, R, M) 3 days 12 hour course	Usual care	Fasting blood glucose, HbA1c	Not reported
Monroe 1992 [114]	UK; hospital; hospital	Type 2 diabetes; n = 21 mean age NR; gender NR; ethnicity NR	12 weeks	Yoga (P, B, R, LS)	Usual care	Fasting blood glucose, HbA1C	No AE in either group
Nagarathna 2012 [115]	India; setting and recruitment NR	Type 2 diabetes; n = 277; 52.4 y; 31.4% female; ethnicity NR	9 months	Yoga (P, B, R, M, LS) 5 × 60 min/week for 12 weeks + 1 × 120 -min/week and 1 h daily home practice for 9 months	Exercise 5 × 60 min/week for 12 weeks + 1 × 120 min/week and 1 h daily home practice for 9 months	Total cholesterol, triglycerides, HDL, LDL, VLDL, fasting blood glucose[a], HbA1C[a]	9 AE in yoga (6 minor illnesses, 3 secondary complications) 13 AE in control (4 minor illnesses, 8 secondary complications, 1 death)
Shantakumari 2013 [116]	India; outpatient clinic; outpatient clinic	Type 2 diabetes; n = 100; 45 y; 48% female; ethnicity NR	3 months	Yoga (P, B, R, M) 7 × 60 min/week	Usual care	W/H ratio, total cholesterol, HDL, LDL, triglycerides	Not reported
Skoro-Kondza 2009 [117]	UK; sports center or GP surgery; practices	Type 2 diabetes; n = 59; 60 y; 61% female; 23.7 Caucasians	3 months/9 months	Yoga (P, B, R) 2 × 90 min/week	Usual care	Blood pressure, waist circumference, W/H ratio, total cholesterol, HDL, LDL, triglycerides, HbA1c, fasting blood glucose[a]	Not reported
Vaishali 2012 [118]	India; day care center; hospital	Type 2 diabetes; n = 60; 65.8 y; 36.8% female; ethnicity NR	12 weeks	Yoga (P, B, R) 6 × 45–60 min/week	Usual care	Total cholesterol, HDL, LDL, triglycerides, fasting blood glucose, HbA1c	3 drop-outs in yoga due to co-morbid and diabetic complications

Abbreviations: AE, adverse events; B, breathing exercises; HbA1c, glycated hemoglobin; HDL, high density lipoprotein; HOMA-IR, homeostasis model of assessment — insulin resistance; LDL, low density lipoprotein; LS, lifestyle advice; M, meditation; Min, minutes; NR, not reported; P, postures; R, relaxation; VLDL, very low density lipoprotein; W/H ratio, waist/hip ratio; y, years.

[a] Outcome not included in meta-analysis.

(MD = −3.05 mm Hg), waist/hip ratio (MD = −0.02), total cholesterol (MD = −14.40 mg/dl), HDL (MD = 5.92 mg/dl), triglycerides (MD = −25.07 mg/dl), and fasting blood glucose (MD = −33.07 mg/dl) (Additional file 7). In RCTs of more than 12 weeks of intervention duration, effects of yoga compared to usual care or no treatment were found for waist circumference (MD = −2.41 cm), triglycerides (MD = −10.38 mg/dl) (Additional file 7); and effects compared to exercise for HDL (MD = 3.70 mg/dl) (Additional file 7).

No further significant group differences were found in subgroup analyses (Additional files 7, 8, 9).

3.8. Sensitivity analyses

3.8.1. Selection bias

When only RCTs that reported adequate random sequence generation were considered, an effect for yoga compared to usual care was found for HDL (MD = 5.37 mg/dl [95%CI: 4.74, 6.00 mg/dl]; $p < 0.01$; heterogeneity: $I^2 = 0\%$; $Chi^2 = 0.39$; $p = 0.53$). When only RCTs that reported adequate allocation concealment were included, an effect for yoga compared to usual care was found for HDL (MD = 5.37 mg/dl [95%CI: 4.74, 6.00 mg/dl]; $p < 0.01$; heterogeneity: $I^2 = 0\%$; $Chi^2 = 0.39$; $p = 0.53$). No other effects were found.

3.8.2. Detection bias

When only RCTs with adequate blinding of outcome assessment were considered, no more effects of yoga were found.

3.8.3. Attrition bias

When only RCTs with complete outcome data were included, effects for yoga compared to usual care or no treatment were found for systolic blood pressure (MD = −2.55 mm Hg [95%CI: −5.00, −0.11 mm Hg]; $p = 0.04$; heterogeneity: $I^2 = 0\%$; $Chi^2 = 2.20$; $p = 0.53$), respiratory rate (MD = −0.93 breaths/min [95%CI: −1.70, −0.15 breaths/min]; $p = 0.02$; heterogeneity: $I^2 = 31\%$; $Chi^2 = 2.90$; $p = 0.23$), total cholesterol (MD = −10.56 mg/dl [95%CI: −19.85, −1.26 mg/dl]; $p = 0.03$; heterogeneity: $I^2 = 68\%$; $Chi^2 = 15.55$; $p < 0.01$), and triglycerides (MD = −19.98 mg/dl [95%CI: −32.87, −7.10 mg/dl]; $p < 0.01$; heterogeneity: $I^2 = 49\%$; $Chi^2 = 11.79$; $p = 0.07$). No other effects were found.

3.9. Risk of publication bias

Funnel plots were roughly symmetrical for total cholesterol, LDL, and fasting blood glucose. Funnel plots were asymmetrical for systolic blood pressure, diastolic blood pressure, HDL, and triglycerides; indicating risk of publication bias (see Additional file 10).

4. Discussion

4.1. Summary of evidence

This meta-analysis of 44 RCTs of yoga for cardiovascular disease risk factors revealed evidence for clinically important effects of yoga compared to usual care on blood pressure, heart rate, respiratory rate, abdominal obesity, blood lipid levels, and measures of insulin resistance. Specifically, systolic blood pressure, diastolic blood pressure, and heart rate were reduced by 5.85 mm Hg, 4.12 mm Hg, and by 6.59 beats/min, respectively; reflecting meaningful improvements. Effects of yoga were comparable or superior to that of guideline-endorsed interventions for managing cardiovascular disease risk such as exercise or psychological interventions [123–126]. In subgroup analyses, evidence for effects was revealed for RCTs of non-diabetic participants with high risk for cardiovascular disease and of participants with type 2 diabetes mellitus; however, for some risk factors, evidence was also found in RCTs of healthy participants. In further subgroup analyses, effects were most prominent in RCTs with exactly 12 weeks of intervention duration; and fewer effects were found in shorter or longer interventions. Safety of the intervention was poorly described or not reported at all in most RCTs. However, in those trials that reported safety-related information [75,76,83,84,91,94,105,113–115,118], no serious adverse events occurred in the yoga group. Four RCTs reported that no adverse events at all occurred in the yoga group [75,76,114], and 3 reported only minor adverse events [83,113,115]. Therefore, yoga seems to be a relatively safe intervention in these populations. This is in line with findings of prior systematic reviews [127–131] and cross-sectional studies [132,133] on yoga in other patient populations.

4.2. Agreements with prior systematic reviews

The results of this meta-analysis are partly in line with that of prior systematic reviews: a comprehensive systematic review on yoga for cardiovascular disease risk factors associated with the insulin resistance syndrome that included both controlled and uncontrolled trials until 2004 concluded that yoga might improve glucose tolerance and insulin sensitivity, lipid profiles, anthropometric characteristics, and blood pressure in both healthy participants and inpatients with conditions related to insulin resistance syndrome [19]. However, in line with the findings of the present meta-analysis, this review concluded that relatively few of the included trials employed rigorous methodology. Another qualitative review on yoga for risk factors of chronic diseases found evidence for positive effects of yoga on blood pressure, obesity, blood lipid levels, and blood glucose levels in mainly healthy participant samples [134]. A further qualitative review on yoga for type 2 diabetes that included 4 RCTs and 21 non-randomized trials concluded that

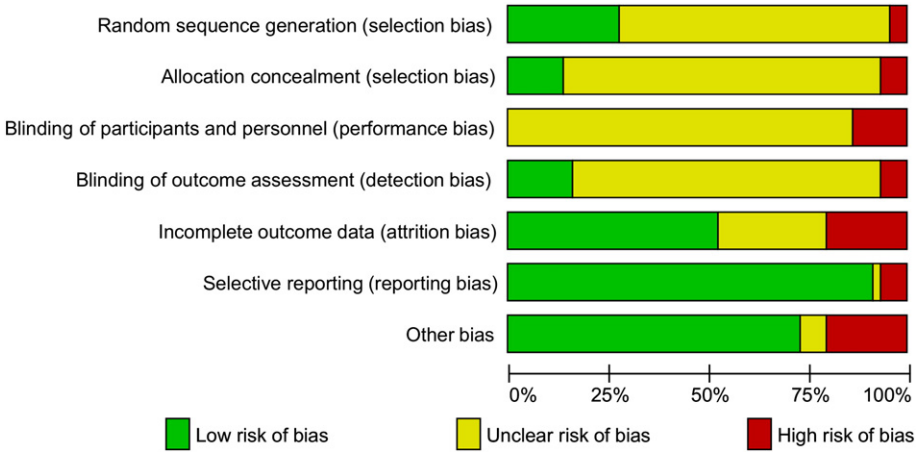

Fig. 2. Risk of bias presented as percentages across all included studies.

Table 2
Effect sizes of yoga compared to usual care or no treatment.

Outcome *Participant group*	No. of studies	No. of participants	Mean difference (95% confidence interval)	p (overall effect)	Heterogeneity I^2;Chi^2;p	Subgroup differences I^2;Chi^2;p
Systolic blood pressure, mm Hg	17	952	−5.85 (−8.81, −2.89)	<0.01	85%;107.31;<0.01	64%;5.60;0.06
Healthy	6	368	−1.53 (−5.22, 2.16)	0.42	78%;23.25;<0.01	
Non-diabetic high risk	8	347	−10.00 (−16.42, −3.59)	<0.01	90%;68.60;<0.01	
Type 2 diabetes	3	237	−6.87 (−14.68, 0.94)	0.08	80%;10.04;<0.01	
Diastolic blood pressure, mm Hg	17	991	−4.12 (−6.55, −1, 69)	<0.01	90%;160.88;<0.01	49%;3.93;0.14
Healthy	7	434	−2.06 (−6.10, 1.97)	0.32	91%;65.79;<0.01	
Non-diabetic high risk	8	347	−7.45 (−12.70, −2.21)	<0.01	92%;82.89;<0.01	
Type 2 diabetes	2	210	−0.79 (−5.22, 3.65)	0.73	83%;6.04;0.01	
Heart rate, bpm	9	422	−6.59 (−12.89, −0.28)	0.04	94%;85.77;<0.01	0%;0.74;0.39
Healthy	6	289	−4.47 (−12.85, 3.90)	0.30	95%;94.72;<0.01	
Non-diabetic high risk	3	133	−10.89 (−22.83, 1.04)	0.07	94%;33.37;<0.01	
Respiratory rate, breaths/min	3	258	−0.93 (−1.70, −0.15)	0.02	31%;2.90;0.23	–
Healthy	3	258	−0.93 (−1.70, −0.15)	0.02	31%;2.90;0.21	
Waist circumference, cm	5	214	−1.95 (−3.01, −0.89)	<0.01	32%;5.92;0.21	–
Non-diabetic high risk	3	117	−1.45 (−2.75, −0.15)	0.03	0%;1.79;0.41	
Waist/hip ratio	3	311	−0.02 (−0.03, −0.00)	<0.01	0%;0.71;0.70	–
Type 2 diabetes	3	311	−0.02 (−0.03, −0.00)	<0.01	0%;0.71;0.70	
Total cholesterol, mg/dl	12	816	−13.09 (−19.60, −6.59)	<0.01	68%;33.85;<0.01	0%;0.92;0.63
Healthy	2	109	−6.56 (−37.39, 24.27)	0.68	87%;7.45;<0.01	
Non-diabetic high risk	5	190	−10.49 (−23.33, 2.35)	0.11	63%;10.94;0.03	
Type 2 diabetes	5	517	−16.59 (−24.24, −8.95)	<0.01	64%;11.07;0.03	
HDL, mg/dl	12	815	2.94 (0.57, 5.31)	0.01	83%;63.99;<0.01	90%;20.66;<0.01
Healthy	2	109	−2.79 (−5.82, 0.24)	0.07	0%;0.02;0.88	
Non-diabetic high risk	5	190	0.85 (−6.80, 8.51)	0.83	81%;21.44;<0.01	
Type 2 diabetes	5	516	5.51 (3.56, 7.47)	<0.01	66%;11.83;0.01	
LDL, mg/dl	13	851	−6.52 (−13.74, 0.70)	0.08	79%;55.94;<0.01	0%;0.84;0.66
Healthy	2	109	0.92 (−25.05, 26.89)	0.94	82%;5.71;0.02	
Non-diabetic high risk	6	227	−5.02 (−16.10, 6.07)	0.37	68%;15.82;<0.01	
Type 2 diabetes	5	515	−10.26 (−20.85, 0.32)	0.06	84%;24.84;<0.01	
VLDL, mg/dl	3	351	−5.70 (−7.36, −4.03)	<0.01	19%;2.48;0.29	–
Type 2 diabetes	2	308	−4.81 (−6.67, −2.96)	<0.01	0%;0.37;0.54	
Triglycerides, mg/dl	13	845	−20.97 (−28.61, −13.32)	<0.01	57%;27.89;<0.01	57%;4.69;0.10
Healthy	2	109	−27.84 (−42.09, −13.58)	<0.01	29%;1.41;0.24	
Non-diabetic high risk	6	227	−10.92 (−20.36, −1.49)	0.02	0%;2.12;0.83	
Type 2 diabetes	5	509	−23.60 (−36.78, −10.43)	<0.01	73%;14.66;<0.01	
Fasting blood glucose, mg/dl	12	699	−14.11 (−30.11, 1.89)	0.08	98%;555.02;<0.01	90%;10.78;<0.01
Non-diabetic high risk	5	174	−0.74 (−5.51, 4.03)	0.76	40%;6.64;0.16	
Type 2 diabetes	7	525	−25.56 (−39.60, −11.53)	<0.01	90%;60.95;<0.01	
Fasting blood insulin, mU/l	4	216	−0.68 (−1.75, 0.38)	0.21	0%;1.51;0.68	0%;0.78;0.68
Non-diabetic high risk	2	36	−0.52 (−1.64, 0.60)	0.36	0%;0.11;0.74	
Type 2 diabetes	2	180	−2.14 (−5.55, 1.26)	0.22	0%;0.62;0.43	
HbA1c, %	8	627	−0.45 (−0.87, −0.02)	0.04	91%;81.92;<0.01	22%;1.28;0.26
Type 2 diabetes	7	550	−0.49 (−1.03, 0.05)	0.07	91%;64.36;<0.01	
Insulin resistance, HOMA-IR	2	36	−0.19 (−0.30, −0.08)	<0.01	0%;0.18;0.67	–
Non-diabetic high risk	2	36	−0.19 (−0.30, −0.08)	<0.01	0%;0.18;0.67	

yoga might improve glucose tolerance, lipid profiles, anthropometric measures, and blood pressure in type 2 diabetes [135]. The results of the present review are also in line with those of a recent meta-analysis of 8 RCTs and 9 non-randomized controlled trials of patients with hypertension (including those with metabolic syndrome) that found evidence for effects of yoga on systolic blood pressure (MD =

Table 3
Effect sizes of yoga compared to exercise.

Outcome *Participant group*	No. of studies	No. of participants	Mean difference (95% confidence interval)	p (overall effect)	Heterogeneity I^2;Chi^2;p	Subgroup differences I^2;Chi^2;p
Systolic blood pressure, mm Hg	5	141	−1.87 (−7.99, 4.26)	0.55	61%;7.74;0.05	–
Healthy	4	86	−5.42 (−10.39, −0.46)	0.03	0%;1.75;0.42	
Diastolic blood pressure, mm Hg	5	206	−2.10 (−8.06, 3.87)	0.49	83%;18.18;<0.01	–
Healthy	4	151	−3.84 (−11.21, 3.52)	0.31	79%;9.42;<0.01	
Heart rate, bpm	6	184	−0.89 (−3.25, 1.48)	0.46	0%;2.91;0.71	–
Healthy	6	184	−0.89 (−3.25, 1.48)	0.46	0%;2.91;0.71	
Respiratory rate, breaths/min	3	115	−0.89 (−2.43, 0.64)	0.25	51%;4.08;0.13	–
Healthy	3	115	−0.89 (−2.43, 0.64)	0.25	51%;4.08;0.13	
Total cholesterol, mg/dl	3	382	−1.38 (−17.61, 14.85)	0.87	75%;7.87;0.02	–
Type 2 diabetes	2	317	−8.08 (−19.20, 3.03)	0.21	38%;1.60;0.21	
HDL, mg/dl	3	382	3.70 (1.14, 6.26)	<0.01	8%;2.17;0.34	–
Type 2 diabetes	2	317	4.24 (1.75, 6.72)	<0.01	0%;0.75;0.39	
LDL, mg/dl	3	382	0.07 (−16.27, 16.42)	0.99	83%;11.75;<0.01	–
Type 2 diabetes	2	317	−9.24 (−16.55, −1.93)	0.01	21%;1.26;0.26	
Triglycerides, mg/dl	3	382	−20.60 (−49.22, 8.02)	0.16	85%;13.37;<0.01	–
Type 2 diabetes	2	317	−22.98 (−60.97, 15.00)	0.24	93%;13.35;<0.01	

Table 4
Effect sizes of yoga compared to psychological interventions.

Outcome *Participant group*	No. of studies	No. of participants	Mean difference (95% confidence interval)	p (overall effect)	Heterogeneity I^2;Chi^2;P	Subgroup differences I^2;Chi^2;P
Systolic blood pressure, mm Hg	6	321	−1.92 (−4.75, 0.91)	0.18	0%;1.59;0.90	0%;0.62;0.43
Healthy	4	285	−1.44 (−4.52, 1.63)	0.36	0%;0.95;0.81	
Non-diabetic high risk	2	36	−4.62 (−11.93, 2.69)	0.22	0%;0.03;0.86	
Diastolic blood pressure, mm Hg	6	321	−1.20 (−3.36, 0.96)	0.28	0%;1.41;0.92	0%;0.24;0.63
Healthy	4	285	−0.98 (−3.31, 1.35)	0.41	0%;1.01;0.80	
Non-diabetic high risk	2	36	−2.51 (−8.22, 3.20)	0.39	0%;0.16;0.69	
Heart rate, bpm	4	189	−0.20 (−2.67, 2.26)	0.87	0%;0.46;0.93	–
Healthy	4	189	−0.20 (−2.67, 2.26)	0.87	0%;0.46;0.93	

−7.96 mm Hg) and diastolic blood pressure (MD = −5.52 mm Hg) when compared to no treatment or usual care but not when compared to other active treatments [136].

4.3. Applicability of evidence

The RCTs of healthy participants included children, people from the working population, and elderly people from North America, Europe, and Asia. Overall, the participants in the included RCTs seem to satisfactorily represent the general population. The same was true for the RCTs on high risk patient groups. Patients were recruited from inpatient and outpatient health services from North America, Europe, and Asia. The gender ratio in the included RCTs was almost perfectly balanced. The results of this review therefore seem to be applicable to the vast majority of healthy people as well as to non-diabetic patients with high risk for cardiovascular disease, and patients with type 2 diabetes in clinical practice. As the majority of RCTs was conducted in India, the applicability to patients in North America and Europe might be limited.

4.4. Quality of evidence

Risk of bias was high or unclear for several domains in most included studies. Specifically, most studies had high or unclear risk of selection bias. Thirty RCTs insufficiently reported on random sequence generation, and 2 RCTs reported inadequate methods of random sequence generation; allocation concealment was not reported in 35 RCTs, and reported but inadequate in 3 RCTs. While blinding of participants or providers might not be possible in RCTs on behavioral interventions, adequate blinding of outcome assessors should be intended all the more. The vast majority of RCTs in this meta-analysis did not report about blinding of outcome assessment (34 RCTs) or did not blind outcome assessors (3 RCTs), though. Sensitivity analyses revealed that none of the effects found in this meta-analysis can be regarded as robust against all potential methodological biases. Moreover, the effects on systolic blood pressure, diastolic blood pressure, HDL, and triglycerides might be distorted by publication bias.

4.5. Strengths and weaknesses

This is the first meta-analysis available on yoga for the most important modifiable biological cardiovascular disease risk factors. A large number of RCTs on the general population as well as on high risk disease groups could be included. Subgroup analyses were conducted to assess the effects among these different participant groups. The applicability of the results was assessed [137]. No language restrictions were imposed.

The primary limitation of this review is the low methodological quality of the included RCTs. As prior reviews have concluded [19], the interpretation of the findings is clearly limited by the insufficient reporting of research methodology. As only 3 RCTs reported longer-term effects, the results of this review are only applicable to the short-term. Most meta-analyses had substantial to considerable heterogeneity. While subgroup analyses reduced heterogeneity for a number of subgroups and outcomes, the majority of subgroup analyses still showed large heterogeneity. This could hint at inadequate definition of subgroups, substantial differences in interventions, control conditions, and/or outcome assessment [21,22]. All potential explanations would reduce the confidence in the effects found in this meta-analysis.

4.6. Implications for further research

Given the low methodological quality of most of the included studies, future RCTs should ensure rigorous methodology and reporting, mainly adequate sample size, adequate randomization, allocation concealment, intention-to treat analysis, and blinding of at least outcome assessors [138]. Only single studies investigated the effects of yoga on oxidative stress [108–110] or atherosclerosis [99]; and no study investigated effects on inflammatory markers. As all 3 measures have been shown to be important risk factors for cardiovascular disease [139–143], future research on yoga should incorporate these risk factors in their assessment. Another important research question relates to the complexity of yoga. In its traditional definition, yoga also comprises a comprehensive lifestyle modification [5–7]. Most current yoga research focuses on yoga with an emphasis on physical postures. Highly relevant effects however have also been found in clinical trials of complex multimodal interventions that included not only yoga but also diet and lifestyle modification [144]. Future studies should aim to determine the additive value of complex yoga interventions compared to yoga interventions that primarily focus on postures and/or breathing techniques. More research is needed on which form of yoga is most effective, and whether meditation-based yoga forms are equally or even more effective than posture-based interventions. Given that only very few of the included studies investigated longer-term effects of the yoga interventions more long-term studies are needed.

4.7. Implications for clinical practice

Yoga seems to be effective in improving most modifiable biological cardiovascular disease risk factors. Therefore, yoga can play a role in the primary prevention of cardiovascular disease especially in patient populations with increased risk of cardiovascular disease but also in healthy participants. However, the implications for clinical practice are limited by the low methodological quality of the included trials. As yoga seems to a relatively safe intervention, it can be considered an ancillary intervention in the primary cardiovascular prevention until new evidence is available. Exactly 12 weeks of intervention duration seems to be more effective than shorter or longer interventions.

5. Conclusions

This meta-analysis of yoga for cardiovascular disease risk factors revealed evidence for clinically important effects of yoga on blood pressure, heart rate, respiratory rate, abdominal obesity, blood lipid levels, and measures of insulin resistance. While these effects were not clearly distinguishable from bias, based on the apparent safety and effectiveness of yoga, it can be considered as an ancillary intervention

for healthy participants and for patients with increased risk of cardiovascular disease.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ijcard.2014.02.017.

Acknowledgments

This review was supported by a grant from the Corona-Foundation, Germany. The funding source had no influence on the design or conduct of the review; the collection, management, analysis, or interpretation of the data; or in the preparation, review, or approval of the manuscript. The authors would like to express their appreciation to Dr. Petra Klose, Essen, Germany for translation of Ref. [85] as well as to Dr. Trisha Greenhalgh, London, UK, and to Dr. Lily O'Hara, Abu Dhabi, United Arab Emirates for providing the raw data of Ref. [117] and [91], respectively.

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