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Yoga research review

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ABSTRACT

This paper is a review of empirical studies, review and meta-analysis publications on yoga from the last few years. The review includes demographics/prevalence of yoga as a practice, bibliometric analyses of the yoga publications and the use of yoga for physical fitness and cognitive function. Most of the studies reviewed here involve yoga effects on psychiatric and medical conditions. These include pregnancy, prenatal and postpartum depression; stress, PTSD, anxiety, and obesity; cardiovascular conditions including hypertension; pain syndromes including arthritis, headaches and low back pain; autoimmune conditions including asthma, type II diabetes and multiple sclerosis; immune conditions including HIV and breast cancer; and aging problems including balance, osteoporosis and Parkinson's. The methods and results of those studies are briefly summarized along with their limitations and suggestions for future research. Basically yoga has been more effective than control and waitlist control conditions, although not always more effective than treatment comparison groups such as other forms of exercise. More randomized controlled studies are needed in which yoga is compared to active exercise groups. Having established the physical and mental health benefits of yoga makes it ethically questionable to assign participants to inactive control groups. Shorter sessions should be investigated for cost-effectiveness and for daily practice. Multiple physical and physiological measures need to be added to the self-report research protocols and potential underlying mechanisms need to be further explored. In the interim, the studies reviewed here highlight the therapeutic effects of yoga, a practice that could come to be called yoga therapy.

Contents

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This paper is a review of empirical studies, review and meta-analysis papers on yoga that have been published over the past years (since our last review in 2010) [1]. The term yoga was entered into Pubmed and the selection criteria were empirical studies (single arm, randomized controlled) in which standard treatment, waitlist and treatment comparison groups were compared to yoga groups (of different styles). Systematic reviews, bibliometric analyses and meta-analyses are also included. Exclusion criteria were case studies, qualitative studies, small sample pilot studies and studies in which assessors were not blind. The review includes 2 surveys, 23 single arm trials, 52 randomized controlled trials, 11 systematic reviews and 7 meta-analyses.

Included are brief summaries of papers on the demographics/prevalence of yoga as a practice, bibliometric analyses of the yoga publications and the use of yoga for grade school, high school and university students as well as for yoga practitioners. The majority of the studies reviewed involve yoga effects on psychiatric and medical conditions. The methods and results of those studies are briefly summarized along with their limitations and suggestions for future research. The psychiatric conditions include prenatal depression, stress, anxiety, posttraumatic stress disorder and eating disorder. The medical conditions include prematurity, cardiovascular (hypertension, elevated cholesterol), pain syndromes (arthritis, low back pain, headaches, fibromyalgia), autoimmune (asthma, diabetes, irritable bowel, chronic fatigue, multiple sclerosis) and immune (HIV, breast cancer) conditions, as well as aging problems (sleep, balance, osteoporosis, Parkinson's). These and underlying mechanism studies are critically reviewed and suggestions are

given for future research.

1. Demographics/prevalence of yoga practice and bibliometric analyses of research on yoga

1.1. Yoga practice

In a recent survey, approximately 21 million Americans were noted to practice yoga during the past year [2]. Data from this national health survey suggest that 51% of this sample attended yoga classes. The reasons given for yoga were increasing energy (66%), enhancing immune function (50%) and health and disease prevention (28%). The major conditions included back pain (20%), arthritis (6%) and stress (6%). In this survey, the yoga practitioners were primarily female, young, non-Hispanic white, college–educated, living in the west and in excellent health. Again, in a systematic review of the literature on yoga practice, women were noted to be the most common practitioners and yoga was being practiced primarily for distress and physical problems as well as for better health [3].

1.2. Yoga safety

Yoga has been considered a safe practice, although in a survey from Japan on adverse events, 28% of yoga practitioners were noted to have some undesirable experience with yoga [4]. However, the yoga practitioners in this study were noted to be in poor physical condition or had chronic disease. They reported that the yoga classes were physically and mentally stressful. The adverse events were primarily among elderly practitioners and those with chronic musculoskeletal disease. In contrast, a meta-analysis of the literature on randomized controlled trials in the U.S. suggested that yoga was as safe as exercise and usual care [5]. In this meta-analysis there was reportedly no difference in non-serious or serious adverse events between yoga practitioners and those who exercised.

1.3. Yoga research trends

Regarding research trends, the number of publications on yoga since 2000 has significantly increased and since 2007 there has been a surge of publications [6] In this analysis, the author reported that more than 200 titles were added to the literature every year since 2011. Most frequently, the yoga studies have focused on pain, stress, anxiety, depression and cancer. In another bibliometric analysis that was conducted on published studies from 1967 to 2013, the authors noted that they included 486 articles that had been published in 217 different peer-review journals including 28,080 participants from 29 different countries [7]. They reported a three-fold increase in the number of publications in the last decade with 45% of the studies being randomized controlled trials, 18% being controlled trials and 37% being uncontrolled trials. Of these, notably twice as many originated from India (N = 258) followed by the U.S. (N = 122) and a very low number from Canada (N = 13). In this analysis the authors noted that the primary yoga interventions were for mental health, cardiovascular and respiratory disease.

In still another bibliometric analysis on papers published between 1975 and 2014, 366 papers were included of which 312 were randomized controlled trials and were from 23 different countries with 22,248 participants [8]. They noted that 85% of the studies were conducted with adults, 34% being with older adults and 10% with children. Only 27% were conducted with healthy participants and the other 73% had different medical conditions with the most common being breast cancer followed by depression, asthma and type 2 diabetes. Forty-six different yoga styles were used with a median sample size of 59 (and a range of 8–410) with 11% using Hatha yoga and the remaining 89% using 46 different yoga styles. The median intervention duration was 9 weeks with 78% of the studies using yoga poses. This analysis highlights the variability of these studies on every aspect of their methods. There appear to be no replication studies, probably because replication studies are often deemed insufficiently original for publication. And, failures to replicate, as in proving the null hypothesis, are less frequently published.

1.4. Comparison groups

The question of comparison groups was addressed by a systematic review of the literature [9]. This research group identified 125 randomized controlled trials that met their criteria, and of these, 65 used an active comparison group. The primary comparison groups were physical exercise (43%), relaxation/meditation (20%) and education (16%). In a study that related to dosage level of yoga, the authors reported that on average the study sessions were 30–40 min, 5 times per week for a period of 6 weeks [10].

1.5. Assessment methods

Assessment methods have also been highly variable, although most often standardized self -report measures have been used on mood, sleep, pain and quality of life. Occasionally new scales have been developed specifically for yoga. For example, the Yoga Self-Efficacy scale was developed and psychometrically evaluated in a recent study [11]. The majority of the participants were white female yoga instructors. Not surprising, the yoga teachers scored significantly higher than the non-teachers. And, the non-significant correlations with gender and income suggested that the scale has good validity and might be used in future studies.

1.6. Studies on students (see Table 1 for brief summaries studies)

Yoga studies have been conducted on several different age students including grade school, high school, and university students as well as yoga practitioners. In a bibliometric analysis, 47 publications on yoga in school settings were identified [12]. These studies were conducted primarily in the U.S. (N = 30) and India (N = 15). Of the studies conducted from 2010 onward (N = 41), about half were non-randomized controlled trials. And, significant variability was noted in the yoga styles and characteristics including the number and duration of sessions.

1.7. Grade school students

In a grade school study, a literature search revealed nine RCTs on yoga from the years 1982–2014 [13]. The results suggested that the grade school children experienced reduced tension and anxiety and improved self-esteem and mood following yoga. This may explain the reduction in cortisol levels following a 10 week yoga program in a study on grade school children [14]. In an afterschool yoga program for grade school children two sessions were held per week for 4 weeks [15]. On a mid-intervention survey 83% of the children reported positive mood changes, greater relaxation and greater strength. The children on average recalled five of the poses and stated that their favorite pose was upward facing dog (among the tree, mountain, warrior, dancer, cow, cat, boat, upward facing dog and downward facing dog poses). However, when yoga was compared to exercise, no differences were reported. For example, in a study on yoga versus physical skill training, there were no differences in movement and cognitive skills [16]. Similarly, in a study that compared yoga with physical education three times per week

Table 1
Students, physical fitness and cognitive functions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Students				
Grade school	13	REV	RCTS	<tension and anxiety
	14	Single arm		<cortisol
	15	Single arm		>strength
	16	RCT	Phys Ed	=movt. & cog. skills
	17	RCT	Phys Ed	=emot. & behav.
High school	18	RCT	Phys Ed	>Emot. Reg.
	19	RCT	PhysEd	>GPA
University	21	Single arm		>Emotional sensitivity
Graduate Sch	22	Single arm		<stress
Physical fitness				
Flexibility	24	Single arm		>Flexibility
	25	RCT	PhysTher	>Flexibility back & hamstrings
	27	RCT	Control	>Flexibility & balance
	28	RCT	Calisthenics	>Flexibility
	29	RCT	Stretching	=balance & flexibility
Spinal mobility	30	Single arm		>spinal mobility
Muscle endurance	31	RCT	Control	>Muscle endurance
Cognitive functions				
Executive function	32	RCT	Stretching	>Executive function
	33	REV		>Executive function
	34	META		>Attention & processing speed
Emotional well-being	36	RCT	Control	>Positive affect

for 12 weeks the yoga and the physical educations classes did not have a different impact on the children's emotional and behavioral functioning [17].

1.8. High school students

In a study on high school students using a randomized–controlled trial design, yoga was again compared to physical education, but this time the 16-week yoga intervention as opposed to regular physical education led to greater emotion regulation in the yoga group [18]. In another study on high school students the grade point average of the students showed a lesser decline in the yoga group as compared to a physical education group [19]. In a study on adolescents with behavior problems increased yoga participation over an eight week period (twice-weekly), led to greater sociability and a decrease in behavior problems [20]. The mixed data from the comparisons between yoga and physical education may relate to different types of yoga being used. For example, no difference was noted when Ashtanga yoga was compared to physical education, perhaps because Ashtanga is a rigorous, fast-moving yoga style that would be equivalent to a physical education class.

1.9. University students

In a study on university students, Vinyasa yoga classes were given twice-weekly for two months [21]. By self-report positive affect increased and negative affect decreased. In this study on emotional intelligence in university students 21 days of yoga led to an increase in emotional sensitivity, but this was a single arm pre-post design.

1.10. Graduate students

In a study on university graduate students, faculty and staff experiencing a 10 week yoga program (90-min sessions), stress was reduced [22]. Adherence was 88% and reenrollment for another 10 weeks was 64%. However, poses were combined with conceptual grounding, breathing and meditation exercises, making it difficult to know which aspect of yoga was effective.

1.11. Barriers to practicing yoga

Barriers to practicing yoga as well as motivators for practicing yoga have been studied in health professions students [23]. The barriers given included time, cost, lack of pragmatic information about access to yoga classes and stereotypes related to flexibility, athleticism and typical yoga practitioners. The motivators given included athleticism, health promotion, emotional well-being, seeking pain relief and sense of community.

2. Physical fitness, cognitive function and emotional well-being

Several studies have examined the effects of yoga on physical fitness including flexibility, balance, spinal mobility and muscular endurance. Cognitive functions have also been assessed including executive function, attention, processing speed and memory.

2.1. Physical flexibility

Physical flexibility has been assessed using different forms of yoga including Iyengar and Hatha yoga and using different measures including the standard sit and reach test, flexibility of the lower back and hamstrings and electromyographic signals. In an Iyengar yoga study following six weeks of 190 -minute sessions once per week lumbar and hamstring flexibility were greater on the standard sit and reach test [24]. Unfortunately this was a pre-post design with no control group. In a Hatha yoga study on flexibility, Hatha yoga was combined with physical therapy and compared to a physical therapy alone control group [25]. Following eight weeks of three 1-h sessions per week flexibility of the lower back and the hamstrings, hand grip strength and vital capacity were greater in the yoga plus physical therapy group.

At least two studies were focused on specific poses and their effects on specific muscles. In one of these studies after three months of yoga practice surface electromyographic signals during different poses suggested that downward facing dog poses are effective for strengthening abdominal muscles while chair and warrior one poses were strengthening the gluteus maximus muscles and all of these muscles could be strengthened by the upward

facing dog pose [26]. It's interesting in this light that the upward facing dog pose was the most popular pose among grade school students [15]. Another study measuring flexibility by joint angles suggested that after 10 weeks of yoga, a yoga group versus a non-yoga group of athletes showed increased flexibility and balance during different yoga poses including downward dog, upward dog, right foot lunge and the chair pose [27].

Yoga has been compared to other active exercise groups including calisthenics and stretching–strengthening exercise groups. In the calisthenics study a yoga group was compared to a calisthenics group after one year of three times per week sessions [28]. The Hatha yoga group featuring slow movements was more effective in improving flexibility than the fast movements in calisthenics. In a comparison between stretching–strengthening exercise and Hatha yoga, this randomized controlled trial of eight weeks (three times a week for 1 h) revealed equivalent performance for both groups on measures of balance, strength, flexibility and mobility [29].

2.2. Spinal mobility and muscle endurance

Other physical fitness measures have included spinal mobility and muscular endurance. Spinal mobility was measured in a Hatha yoga study that involved 90 min sessions once a week for 20 weeks [30]. Both spinal mobility and flexibility of the hamstring muscles were increased by the end of the study. Again, unfortunately, this was not a randomized controlled trial or a treatment comparison group. In a muscular endurance study yoga was compared to an inactive control group [31]. Following 18 sessions (three times per week for 1 h per session) muscular endurance was measured in the upper limbs by push-ups and in the abdomen by sit ups. The yoga group, as would be expected, showed greater improvement in both upper limb and abdominal muscle endurance.

2.3. Cognitive functioning

At least one randomized controlled study, one systematic review and one meta-analysis have been conducted on the effects of yoga on cognitive functions including executive function, attention, processing speed and memory. In a randomized controlled study a Hatha yoga group was compared to a stretching–strengthening comparison control group following an eight week period of 1 h classes three times per week [32]. The yoga group showed significantly greater improvement on the executive function measures of working memory, shorter reaction times on switching trials and greater accuracy. In a systematic review on yoga and executive function, 11 published studies met eligibility criteria [33], and, in at least half of these studies significant improvement was noted on executive function tasks following Hatha yoga. These results were surprising inasmuch as executive function is usually improved following seated meditation but has rarely been measured following Hatha yoga poses. In a meta-analysis on the effects of yoga, 15 randomized controlled trial studies were examined for the effects of yoga on cognition [34]. The strongest effect was noted for attention and processing speed followed by executive function and memory.

2.4. Emotional well-being

Yoga studies on emotional well-being have included measures of positive and negative affect and functional connectivity in the brain. In a study on 8 weeks of Vinyasa yoga with college students, positive affect scores increased and negative affect scores decreased [35]. Positive affect has increased even after one session of Hatha yoga as compared to a lecture control class. These changes in well-being may relate to greater connectivity between the caudate and other regions of the brain (basal ganglia cortical–-thalamic feedback loops) as has been noted in a study on Kripalu yoga practitioners [36].

These fitness studies have a number of limitations. They include limited sample sizes, heterogeneous samples, different yoga styles, highly variable doses of yoga and many different types of assessments. In addition, better designed, more rigorous randomized controlled trials using active controls are needed to assess the effects of yoga on physical fitness, cognitive function and emotional well-being.

2.5. Prenatal yoga studies (see Table 2)

Prenatal yoga has become increasingly popular and has raised questions regarding its safety and potential benefits on the pregnant women and their fetuses. The prenatal yoga studies reviewed here are focused on the intensity of yoga, the absence of physiological changes for the mother and the fetus during a number of poses (and therefore the safety of prenatal yoga), the beneficial effects on the mothers, and studies on alleviation of prenatal depression and anxiety and the resultant enhanced fetal growth, and the greater gestational age and birth weight of the newborn. Again the studies have ranged from randomized controlled trials to systematic reviews to meta-analyses.

2.6. Intensity and safety

In a study on the intensity level of prenatal yoga, an armband monitor was worn by healthy pregnant women who experienced different intensity yoga poses [37]. Based on energy expenditure on average 93% of the classes were categorized as sedentary and 7% were considered moderate intensity physical activity. In a study examining the safety of prenatal yoga, maternal and fetal heart rate and temperature were taken during 26 different yoga poses [38]. A comparison of the post session with the pre session data showed no change in pregnant women's heart rate, temperature or fetal heart rate and there were no falls or injuries during the total 650 poses. None of the participants reported fetal movement changes, contractions or vaginal bleeding, thus ensuring the safety of prenatal yoga even as late as 38 weeks gestation.

2.7. Beneficial effects

Turning to the beneficial effects of yoga on pregnant women, a systematic review of 10 randomized controlled trials suggested that those in the yoga groups had a lower incidence of prenatal disorders, lower levels of pain and stress, higher relationship scores and greater gestational age offspring [39]. The reviewers also concluded that yoga was a more effective exercise than walking or standard prenatal exercises. In a study on the effects of yoga on fetal growth measures and uterine artery resistance a yoga group was compared to a group who received standard care plus walking [40]. The yoga sessions were held three times a week for 1 h during the 12th to the 28th weeks of gestation. The results suggested significantly better growth measures for the fetuses of the yoga group including parietal diameter, femur length, head circumference and fetal weight, and uterine artery resistance was significantly lower in the yoga group, thus suggesting better fetal circulation.

2.8. Perinatal depression and anxiety

Perinatal depression reputedly affects approximately 20% of women and 10% of women are affected by perinatal anxiety. Because the literature is mixed on pharmacological treatment, depressed and anxious pregnant women are exploring alternatives

Table 2
Pregnancy and postpartum conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Pregnancy				
Exercise intensity	37	Single arm		93% sedentary, 7% moderate exercise
Safety	38	Single arm		No change fetal HR & contractions
Benefits	39	REV		<pain, stress & prematurity
	40	RCT	Walking	>Fetal circulation & growth
Anxiety & depression	41	REV		<anxiety & depression
	42	META	Exercise	<depression
	43	Single arm		<anxiety & cortisol
	44	RCT	Health edu	=decrease depression
	45	RCT	Support group	=decrease depression & cortisol
	46	RCT	Massage	=decrease depr & prematurity
	47	RCT	waitlist	<depression & sleep disturbance
Postpartum				
Depression & anxiety	49	RCT	Waitlist	<depression & anxiety
Depression	50	RCT	Usual care	<depression

including yoga. In a systematic review of the literature, 13 publications that met inclusion criteria suggested that yoga interventions reduced anxiety and depression [41] In a meta-analysis study six randomized controlled trials were identified, and the analysis involved comparison groups including prenatal care, exercise, social support and massage [42]. Depression was significantly lower in the yoga versus the comparison groups. A surprising finding was that integrated yoga groups experienced a greater decrease in depression than the physical–exercise–based yoga groups, suggesting that the breathing and meditation components of yoga may add to the physical exercise of yoga poses. Even a single session of yoga has been noted to decrease state anxiety as well as cortisol levels in depressed pregnant women [43].

2.9. Comparison treatment groups

When randomized controlled trials are conducted with yoga versus treatment comparison groups, the groups frequently do not differ. For example, in a comparison between prenatal yoga and perinatal–focused health education, the decreases in depression were surprisingly not statistically different between groups [44]. And, in another randomized controlled trial we compared a yoga group with an inactive social support group (leaderless discussion group) [45]. Short-term changes favored the yoga group on having less depression, anxiety, anger, back and leg pain after the first and last yoga sessions, but when comparing the last to the first day of the study, both groups had lower depression and anxiety scores as well as lower cortisol, estriol and progesterone levels. These lower levels are clinically significant given that they are inversely correlated with gestational age. In another randomized controlled study by our group, the effects of yoga were compared to those of massage therapy [46]. Following 12 weeks of twice-weekly yoga or massage therapy sessions for depressed pregnant women, both therapy groups as compared to the control group had a greater decrease in anxiety, depression, back and leg pain as well as improved relationships. Both treatment groups also had better neonatal outcomes including greater gestational age and birth weight than the control group. In still another study by our group, tai chi was combined with yoga for a 12 week period (20 min group sessions per week) for depressed pregnant women [47]. As compared to a waitlist control group the yoga group had lower depression scores, lower anxiety scores and lower sleep disturbance scores by the end of the study. The findings from both these studies are perhaps not surprising as both yoga and massage are noted to stimulate pressure receptors which, in turn, leads to greater vagal activity and to lower depression and cortisol levels as well as less sleep disturbance.

Up to 20% of women experience postpartum depression, in many cases a continuation of pre-natal depression [48]. In a study in which postpartum depressed women were randomly assigned to a yoga or waitlist control group, 16 classes over eight weeks led to a greater decrease in postpartum depression and anxiety and an increase in quality of life [49] According to the authors,78% of the women in the yoga group experienced clinically significant change. In a study that provided Hatha yoga sessions (90 min) prenatally and assessed both prenatal and postpartum depression, the yoga group as opposed to the control group surprisingly experienced less depression during the postpartum but not the prenatal period [50].

3. Stress and psychological disorders (see Table 3)

Stress and several psychological disorders including post-traumatic stress disorder, depression and anxiety are reviewed in this section. Stress has been recently studied in a couple groups of professionals including dentists and nurses.

3.1. Dentists and nurses

Stress is notably common in dentists, although only 10% of dentists practice yoga [51]. In this survey study musculoskeletal pain with stress was reported by 47% of the dentists but 53% of the dentists did not consider yoga as an alternative therapy and gave a lack of time as a reason. In the study on nurses, 120 nurses were randomly assigned to two groups, a yoga group and a non-yoga group [52]. The yoga group practiced for 20 min after work two times per week. After six months the nurses in the yoga group had better sleep quality and less work stress.

3.2. Oxidative stress

Oxidative stress has also been studied in yoga practitioners [53]. In this study practitioners of two years or more were noted to have higher levels of antioxidants than a control group. In a systematic review of mechanisms underlying stress reduction by yoga, the four biological mechanisms identified were the posterior hypothalamus (the initial point in the cortisol release pathway), elevated cortisol, increased interleukin-6 (as a pro-inflammatory cytokine), and C-reactive protein (another pro-inflammatory cytokine) [54]. In anther systematic review on yoga for stress management, 17 studies met inclusion criteria and of those 17, 12 showed positive psychological and physiological outcomes following a yoga intervention [55]. However, not all studies were randomized controlled trials, some had small sample sizes and the yoga classes were highly variable in length and style.

Table 3
Stress and psychological conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Stress & psychological conditions				
Stressed dentists	51	survey		47%muscle pain & stress-10% yoga
Stressed nurses	52	RCT	Control	>sleep quality & <stress
Oxidative stress	53	RCT	Control	>levels antioxidants
Stress	55	REV	Control	>positive psych & physiol
PTSD	56	RCT	Waitlist	<sleep disturb, stress & anxiety
	57	Single arm		<stress & anxiety
	58	RCT	Health ed	<depr & PTSD
	59	RCT	usual care	<alcohol & drug use
	60	REV		only 2 RCTs met criteria
Anxiety	61	Single arm		<anxiety, heart rate, Syst bp
Panic disorder	62	RCT	Cog behav ther	<anxiety & panic sensations
Depression	63	Survey	yoga teachers	postures & breath reg essential
	64	RCT	Yoga & antidep	both yoga groups < depr
	65	Single arm		<depr end of 1 year
Overeating	67	RCT	Waitlist	<emotional eating
	68	RCT	Instructor/DVD	prefer instructor,>activ. DVD
Obesity	69	Single arm		<BMI, glucose &pro-inflamm. cyt

3.3. Posttraumatic stress disorder

Posttraumatic stress disorder (PTSD) is a more serious form of stress most frequently noted in military veterans. In a study on yoga with military service personnel the yoga group experienced a significantly greater reduction in PTSD symptoms than a waitlist control group [56]. Surprisingly, even Kundalini yoga has reduced PTSD symptoms including sleep disturbances, stress and anxiety [57]. These results were surprising inasmuch as Kundalini yoga typically features lying down poses that would be considered restorative and inactive.

When yoga has been compared to other treatment groups for PTSD symptoms, the results are not as conclusive. For example, in a comparison between yoga and women's health education for 1 h classes for 10 weeks, both groups showed decreases in PDS symptoms during the first half of treatment, but only the yoga group showed continuing improvements [58]. The same group of investigators did a follow-up study on these women with chronic PTSD and noted that the frequency of continuing yoga predicted greater decreases in PTSD and depression symptoms as well as a loss of PTSD diagnosis. Other symptoms often associated with posttraumatic stress disorder are alcohol and drug abuse [59]. In this randomized controlled study alcohol use disorder identification tests and drug use disorder identification tests showed decreased scores on those measures following a 12 session yoga intervention. In a systematic review on randomized controlled trials from 2008 to 2014 only two randomized controlled trials were found for PTSD that were high-quality studies, highlighting the need for more conclusive studies on PTSD and yoga [60].

3.4. Anxiety and panic disorder

Anxiety and panic disorder have been similarly decreased by yoga. Before yoga training the participants in one study were distributed 6% mild anxiety, 18% moderate, and 76% severe anxiety [61]. After four weeks of yoga camp, a significant decrease in anxiety was noted with 44% being mild, 19% moderate and 37% severe. This was accompanied by decreased heart rate and systolic blood pressure. Yoga has also been used for panic disorder (anxiety and agoraphobia) [62]. In this study a yoga group was compared to a yoga plus cognitive behavioral therapy (CBT) group following 2 months of weekly 100-min sessions. Both groups experienced reduced anxiety levels and panic-related body sensations, although these changes were even greater for the yoga plus CBT group.

3.5. Depression

Recent studies on yoga and depression have included a consensus survey on the parameters of the yoga practice that are needed to lessen depression, a comparison between yoga and antidepressant effects and a study assessing the long-term effects of yoga. In the consensus survey, yoga teachers were asked for their recommendations for yoga practice [63]. The yoga teachers agreed that yoga classes should be on average 30–40 min, five times per week over six weeks. Postures and breath regulation were considered essential for reducing depression. In a study comparing yoga alone, antidepressant medication alone and yoga along with antidepressants, more patients in the yoga groups had a decrease in cortisol levels, and in the yoga alone group the cortisol decrease correlated with decreased depression scores [64]. In a longitudinal follow-up study, the effects of yoga were seen to last at least to the end of one-year [65]. Although the findings of the study may not be generalizable because the sample size was limited, the data suggest that yoga may have a sustained effect on depression and its symptoms including ruminations, stress, anxiety and quality of life.

3.6. Overeating

Low distress tolerance individuals avoid emotional experiences and often engage in overeating to reduce their distress [66]. A group of 52 females with this disorder were randomly assigned to an 8-week, twice-weekly Hatha yoga group or a waitlist control group. Participants in the yoga group experienced a greater reduction in “emotional eating”. In another study distress tolerance was related to adherence to a yoga intervention [67]. Overweight people have also participated in a 2-month yoga program and 4-month follow-up to assess the effects of an instructor versus the use of DVDs [68]. Although an instructor was preferred, the DVD group surprisingly showed higher physical activity levels, probably because the DVD facilitated more frequent yoga practice.

It is unclear why weight loss or decreased body mass index (BMI) was not reported in these studies. In a study that did report these measures, overweight/obese individuals had engaged in a yoga intervention for 10 days [69]. By the tenth day the participants showed reduced weight, BMI, waist/hip ratio, blood glucose and pro-inflammatory cytokines including interleukin-6 and neopterin. At a 30-day follow-up weight loss was sustained and systolic blood pressure was also reduced.

4. Cardiovascular conditions (see Table 4)

The recent literature on the use of yoga with cardiovascular conditions has focused on prehypertension, hypertension, and elevated cholesterol. High blood pressure is a notable risk factor for cardiovascular disease [70].

4.1. Prehypertension

In a randomized controlled study, yoga, standard lifestyle modification and lifestyle plus yoga were compared for their effects on pre-hypertension (systolic BP 120–139 and/or diastolic BP 80–89) [70]. Several potentially confounding variables were comparable between groups at the onset of the study including age, waist circumference, physical activity, blood pressure and glucose and lipids. After three months of intervention the lifestyle plus yoga group showed a significant decrease in systolic blood pressure. In addition, 13 pre-hypertensives became normotensive in the lifestyle plus yoga group as opposed to only four in the lifestyle group. In a study on mild hypertensives, a yoga group was compared to an active control group (nonaerobic exercise) [71]. The yoga group experienced a significant decrease in diastolic blood pressure, although the nonaerobic exercise group did not change.

4.2. Hypertension and blood pressure

In a systematic review of randomized clinical trials 11 of 17 of the trials that met the inclusion criteria showed a significantly greater reduction in systolic and diastolic blood pressure as compared to pharmacotherapy, no treatment or usual care [72]. The other six randomized controlled trials showed no significant yoga effects. In another systematic review and meta-analysis, yoga and exercise did not differ in their effects on systolic and diastolic blood pressure [73]. And, when Kundalini yoga was compared to usual care a three-month intervention of 15 min twice daily showed no group differences on blood pressure in patients with hypertension [74]. This result is perhaps not surprising given that Kundalini yoga only involves lying down poses. As has been noted in a study on the specific effects of yoga poses, there were only significant changes in blood pressure immediately after the standing poses as opposed to the relaxation in the supine poses [75]. The average of 10 mmHg reduction in systolic blood pressure and 8 mmHg in diastolic blood pressure has been attributed to increased parasympathetic activity and decreased sympathetic activity by increased GABA activity, counteracting the excessive activity of the sympathetic nervous system that has been associated with hypertension [76].

4.3. Cholesterol

Cholesterol altering yoga effects have also been prominent in this literature. In a randomized controlled trial attending a yoga program led to a significant increase in high density lipoprotein (HDL) as well as reduced blood pressure and glucose and an improvement in other lipid profile variables [77]. Unfortunately, yoga was not compared to an active group and the yoga program included not only poses but also breathing exercises, meditation, group discussions and advice on stress management and healthy diet, confounding the question of yoga effects. However, when yoga was compared to a physiotherapy program, the yoga group showed significantly greater improvement in HDL, low density lipoprotein (LDL) and very low density lipoprotein (VLDL) [78]. In addition, unlike most other studies this research group also assessed stress, anxiety, depression and negative affect which were also more positively affected by yoga.

In a systematic review and meta-analysis, 44 RCTs comprised of 3168 participants showed that relative to usual care or no intervention, yoga improved HDL, VLDL, triglycerides and insulin resistance [79]. When yoga was compared to exercise, a greater increase in HDL was noted in the yoga groups. This meta-analysis also showed improved systolic and diastolic blood pressure, heart rate, respiratory rate and waist circumference following yoga. In another systematic review and meta-analysis in which 37 RCTs were included, the yoga participants compared to non-exercise controls showed improved HDL, LDL, total cholesterol, triglycerides, systolic blood pressure and heart rate [80]. These systematic reviews and meta-analyses, while suggestive, have limitations. They include a number of studies not adhering to inclusion criteria, small sample sizes and high attrition rates, highlighting the need for more robust randomized controlled trials.

5. Pain syndromes (see Table 5)

Just as much as massage therapy research has focused on pain, yoga research (yoga being a form of self-massage) has focused on pain syndromes [1]. Recent research on pain reduction following yoga includes studies on arthritis, headaches, pre-menstrual syndrome, lower back pain and potential mechanisms underlying the relationship between yoga and pain reduction. This research has been primarily based on randomized controlled trials, systematic reviews and/or meta-analyses.

5.1. Arthritis

Approximately 21% of adults in the US suffer from arthritis [1]. In a systematic review on yoga for arthritis, positive psychological or physiological outcomes were noted for six of the nine studies included [81]. Unfortunately, once again, not all of the studies were randomized controlled trials, several had small sample sizes, and different yoga routines were used of varying lengths and different outcome variables. In a more recent review of the literature, this

Table 4
Cardiovascular conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Cardiovascular				
Prehypertension	70	RCT	Lifestyle program	<Systolic BP
	71	RCT	Exercise	<Diastolic BP
Hypertension	72	REV	Pharmacotherapy	<Syst & Diast BP
	73	META	Exercise	No difference
	74	RCT	Kundalini vs. usual care	No difference
	75	Single arm	Standing vs. supine poses	<BP standing
Cholesterol	77	RCT	Inactive control	<HDL
	78	RCT	Physiotherapy	>HDL & <LDL
	79	META	Exercise	>HDL & <LDL
	80	META	Non-exercise	>HDL & <LDL

Table 5
Pain syndromes that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Pain syndromes				
Arthritis	81	REV		>positive physiol outcomes
	82	REV		<pain, swelling & stiffness
Knee osteo	83	RCT	Exercise	<walking pain, > ROM
	84	RCT	Waitlist	<pain & sleep problems
	85	RCT	Waitlist	>6 min walk
Neck pain	86	RCT	Pilates	No differences
Headache	87	RCT	Medication	<headaches
	88	RCT	Usual care	<headaches &> vagal activity
Premenstrual	89	Single arm		>alpha waves & >cog. funct
Low back pain	90	RCT	Exercise	<pain
	93	Single arm		>serotonin & bone marker
	94	Single arm		>gray matter

time focused on osteoarthritis symptoms, 12 reports met inclusion criteria involving a total of 589 participants [82]. Again, the studies varied on the types of yoga and the frequencies and durations of yoga. Iyengar and Hatha were the most frequently used types, and the frequency ranged between once a week to every day and for 45–90 min per session for 6–12 weeks. In this collection of studies, yoga resulted in decreased pain, swelling and stiffness, but because of the variety of outcome measures, these results are inconclusive.

5.2. Knee osteoarthritis

In a randomized controlled study on knee osteoarthritis that focused on specific physical measures, the participants were randomly assigned to Hatha yoga or therapeutic exercises after having transcutaneous electrical stimulation and ultrasound treatment [83]. The intervention groups met for 40 min per day for three months. Although there were no significant differences between the yoga and exercise groups, there were better improvements for the yoga than the control group on walking pain, knee disability, range of knee flexion, joint tenderness, swelling, crepitus and walking time. The authors concluded that Hatha yoga practice is better than therapeutic exercise on all of these variables for patients with knee osteoarthritis. In another randomized controlled study on knee osteoarthritis in older women, the participants were randomly assigned to an eight week yoga program involving group and home sessions or to a waitlist control group [84]. The yoga group outperformed the waitlist control group on reduction in pain, stiffness, and sleep disturbances by the end of 20 weeks of treatment.

Long–term effects have been noted in at least one randomized controlled study on rheumatoid arthritis. In that study a yoga group received eight weeks of 60 min classes twice per week and was compared to a waitlist control group [85]. The yoga group showed significantly better performance on the 6 min walk, on flexibility and on quality of life variables at eight weeks and as long as nine months later. The problem with this study is that rheumatoid arthritis patients were grouped with knee osteoarthritis patients. And once again integral-based Hatha yoga was used combining poses with breathing exercises and meditation, thus confounding the treatment effect, and the poses were modified for the participants' individual needs thereby introducing treatment variability.

5.3. Neck pain

In a chronic neck pain study Pilates and yoga exercise groups were compared following 12 sessions [86]. Pilates and yoga were equally effective for decreasing pain and disability, although surprisingly there were no changes on the more objective range of motion and postural measurements. And, again, variability was introduced across individuals with modifications being made by a physiotherapist.

5.4. Headaches

In a randomized controlled study on migraine headaches a medication group was compared to a medication plus yoga group who received 12 weeks of yoga training [87]. The yoga group experienced a significant reduction in headache frequency and severity, although no changes were noted in blood nitric oxide levels. In another randomized controlled trial conventional care was compared to conventional care plus yoga with yoga practice sessions occurring five days a week for six weeks [88]. Headache frequency and intensity were reduced to a greater degree in the yoga group and an increase in vagal tone along with reduced sympathetic activity were also noted in the yoga group. This finding supports the notion that yoga is a form of self-massage that would be expected to increase vagal activity just as massage increases vagal activity and is thought to be the mediating variable for many of the therapeutic effects of yoga [1].

5.5. Premenstrual syndrome

Cognitive function and EEG recordings, but surprisingly no measures of pain, were assessed before and after a yoga session in a group of women with premenstrual syndrome [89]. Interestingly, alpha brain waves increased after yoga, suggesting that the participants felt more relaxed after yoga and they performed better with greater accuracy and shorter reaction time on attention tasks.

5.6. Low back pain

In a randomized controlled study on chronic low back pain, an Iyengar yoga group was compared to a conventional exercise group [90]. The yoga group was trained in 29 different yoga poses which are typically held for longer periods in Iyengar yoga, making it a more strenuous form of yoga and likely equivalent to exercise in its intensity. Both groups showed significant reductions in pain and improvement in quality of life measures, although the yoga group surprisingly showed almost twice the reduction in pain as compared to the exercise group.

5.7. Potential underlying mechanisms for pain reduction following yoga

Several researchers have explored potential underlying mechanisms for pain reduction following yoga. One study examined pain

perception applying a peg to the middle finger, earlobe and second toe before and after a 60–minute yoga session [91]. While 67% of the yoga participants expected to perceive less pain after a yoga session, only 40% of the participants actually experienced less pain after yoga as compared to before the session. As the authors suggested, other explanations are needed for the hypoalgesic effects of yoga.

In a study on mediators of yoga and stretching for low back pain, physical factors were explored (including hours of back exercise per week), cognitive factors (including fear avoidance, body awareness and self-efficacy), affective factors (including psychological distress, perceived stress, positive states of mind and sleep) and physiological factors (including cortisol) [92]. The findings suggested that 36% of the pain reduction following 12 weeks of yoga was mediated by increased self -efficacy, 18% by sleep disturbance, 9% by hours of back exercise and 61% by a combination of the other factors. For stretching, 23% of the effect was mediated by increased self-efficacy, 14% by days of back exercise and 61% by the combination of other mediators.

More objective measures have been assessed including serotonin and brain–derived neurotrophic factor in one study and magnetic resonance imaging techniques in another study. In the study on serotonin and brain-derived neurotrophic factor (BDNF), following 12 weeks (3 times/week) of yoga, those with low back pain showed not only increased back flexibility but also increased serotonin and serum BDNF [93]. In the magnetic resonance imaging study, yogis tolerated pain more than twice as long as individually matched controls and had more gray matter in many brain regions [94].

6. Auto-immune conditions (see Table 6)

Yoga has been used as a complementary treatment for several auto-immune conditions in recent studies. These auto-immune conditions include asthma, chronic obstructive pulmonary disease. Type II diabetes, multiple sclerosis, irritable bowel syndrome and chronic fatigue syndrome.

6.1. Asthma

Typically in the asthma studies forced vital capacity (FVC), peak expiratory flow rate (PEFR) and forced expiratory volume (FEV) have increased. In one of the asthma studies these measures increased in the short term and PEFR even increased at a 36 month follow-up following an 11 day hospital yoga program [95]. In a systematic review and meta-analysis study on 14 randomized controlled trials, asthma symptoms, PEFR and FVC improved for the yoga groups as compared with usual care. When yoga was compared with psychological interventions there was a greater PEFR increase for the yoga group [96]. Yoga has also shown better improvement on biochemical variables including a greater decrease in total leukocyte count in a randomized controlled study after six months of yoga [97].

6.2. Chronic obstructive pulmonary disease

In a systematic review and meta-analysis study on chronic obstructive pulmonary disease, five randomized controlled trials were included [98]. These suggested that yoga significantly increased forced expiratory volume in 1 s and 6 min walking distance, suggesting improved lung function and exercise capacity.

6.3. Type II diabetes

Many yoga studies have been conducted with patients with type II diabetes mellitus. Typically the fasting and postprandial blood sugar have decreased following yoga. For example, in one study fasting and postprandial blood sugar decreased in both type II diabetes and normal volunteers after six months of yoga training [99]. Another study showed a decrease in fasting and postprandial blood sugar as early as eight weeks of yoga [100]. However, the yoga sessions included not only yoga poses but also breathing exercises and meditation, thus confounding the effects of the yoga poses. And, when yoga was compared to walking, no group differences were noted on fasting postprandial blood glucose, although the yoga group had lower weight, waist circumference and body mass index [100]. In a systematic review on randomized controlled trials, 25 trials met criteria [101]. These trials that included 2170 participants suggested improved glycemic control, lipid levels, oxidative stress, blood pressure and pulmonary and autonomic function. In addition there was a reduced need for medication and improved mood and sleep. Some have argued that these yoga effects on type II diabetes derive from parasympathetic activation and decreased stress including less HPA axis activation leading to better metabolic and psychological profiles, increased insulin sensitivity and improved glucose tolerance and lipid metabolism [102].

Table 6
Auto-immune conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary reasons.

Condition	Reference	Trial	Comparison	Primary results
Auto-immune				
Asthma	95	Single arm		>FVC & FEV
	96	META	Usual care	Follow-up > PEFR
	97	RCT	Usual care	<leukocytes
COPD	98	REV		>PEFR &>6 min walk
Type ll diabetes	99	RCT	Usual care	<fasting &postprand blood sugar
	100	RCT	Walking	<weight & BMI
	101	REV		>glycemic control
Multiple sclerosis	103	Single arm		>balance & walking speed
	104	RCT	Aerobics	>quality of life
	105	META	Usual care	<fatigue
			Exercise	No differences
	106	RCT	Walking	No differences
	108	RCT	Indiv. Vs. Group	No differences
Irritable bowel	109	RCT	Waitlist	<Pain
	110	RCT	Waitlist	No differences
Chronic fatigue	111	RCT	Waitlist	<Fatigue

6.4. Multiple sclerosis

Multiple sclerosis (MS) is reputedly the most common autoimmune inflammatory disease of the central nervous system, affecting approximately 2.3 million people worldwide [103]. The onset of the disease is typically at 20–40 years, there is a greater incidence in women, and individuals with MS experience several symptoms including fatigue, imbalance, spasticity, chronic pain, bladder and bowel dysfunction and cognitive, visual and speech impairments, depression, sensory disturbance and impaired mobility.

Several studies have been conducted with multiple sclerosis. For example, in one study, after 12 weeks of biweekly yoga, significant improvement was noted in fatigue, balance, step length and walking speed [103]. However, this study did not include a control group, treatment comparison or an active comparison group. Nonetheless, when yoga was compared, for example, to an aerobics group, the mean quality of life score was higher for the yoga versus the aerobics group [104]. In a systematic review and meta-analysis, seven randomized controlled trials comparing yoga with usual care showed greater improvement for the yoga group on fatigue and mood [105]. However, no short or long-term effects of yoga were noted when yoga was compared to exercise. When yoga was compared to walking, both conditions yielded similar reductions in total mood disturbance scores [106]. When treadmill walking was compared to yoga, however, yoga had greater effects on reaction time during a cognitive task [107]. When the effectiveness of individual versus group sessions were compared there was no significant difference between the conditions on fatigue scores [108].

6.5. Irritable bowel syndrome

Irritable bowel syndrome is the most common gastrointestinal disorder [109]. In this six week twice per week Iyengar yoga study individuals with irritable bowel syndrome were compared with a waitlist control group. The attrition for this study was 24% and the attendance averaged 75%. The yoga group had a significant reduction in bowel syndrome symptoms including pain, constipation and nausea and the symptom reduction was maintained at the two month follow-up assessment. In a comparison between 16-biweekly sessions of Iyengar yoga and walking, positive effects were noted for both groups [110]. Irritable bowel syndrome severity symptoms decreased for the yoga group, while overall G.I. symptoms decreased for the walking group. However, at a six month follow-up the walking group continued to benefit, while the yoga group showed no sustained improvement, probably because the walking group reported walking more often than the yoga group practiced yoga.

6.6. Chronic fatigue syndrome

Yoga has also been effective for patients with chronic fatigue syndrome in at least one study [111]. In this study, fatigue scores decreased for the yoga versus the waitlist control group following biweekly 20 min sessions with the yoga instructor as well as daily in-home sessions for approximately two months.

7. Immune disorders (see Table 7)

Yoga has recently been studied for its immune effects mainly on the cytokines, both the pro-inflammatory and the anti-inflammatory cytokines. And several yoga studies have been conducted with groups of individuals experiencing HIV and breast cancer.

7.1. Cytokines

In a randomized controlled study yoga was provided for 90 min once a week over 12 weeks with the suggestion that it be practiced at home on a daily basis for 40 min with the help of a DVD [112]. The yoga versus the control group experienced a significant reduction in plasma levels of epinephrine and increased serotonin. The control group showed decreased immune–related (anti-inflammatory) cytokines including interleukin–12. Unfortunately the yoga group was not compared to an active treatment group and the yoga protocol included not only poses but also breathing exercises and meditation thus confounding the physical effects of yoga. In another randomized controlled trial both pro–inflammatory and anti—inflammatory cytokines were assayed [113]. By the end of the study the yoga group had a significantly lower level of the pro-inflammatory cytokine IL-1 and a higher level of the anti-inflammatory cytokine IL-10. This suggested better immune function for the yoga group. However, once again the comparison control group was not an active control.

Table 7
Immune conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Immune conditions				
Cytokines	112	RCT	Control	<Epinephrine & >Serotonin
	113	RCT	Control	<Pro-inflamm & >anti-inflamm
HIV	114	RCT	Control	>Quality of life
	115	RCT	Usual care	>Quality of life
	116	RCT	Usual care	<Depression &>CD4 cells
Pediatric cancer	117	Single arm		<Anxiety
	118	Single arm		>Physical activity
Breast cancer	119	RCT	Usual care	<Fatigue
	120	RCT	Usual care	<Pain
	121	RCT	Exercise	>Activity & <sleep disturbance
	122	RCT	Exercise	No differences
	123	RCT	Stretching	<Depression & sleep disturbance
	124	RCT	Stretching	>Phys funct & <Cortisol
	125	RCT	Aerobics	>Muscle strength
	126	Single arm		<Arm volume
	127	Single arm		No differ. arm volume
	128	RCT	Health edu	<Pro & >anti-inflamm
Colorectal cancer	129	RCT	Waitlist	<Sleep disturbance

7.2. HIV

Of the three HIV studies, two simply measured quality of life and the third study assayed the critical CD4 count variable, reflecting the progression of the disease. In the first study, individuals with HIV who also used crack cocaine attended 60 min twice per week yoga sessions for two months and were compared to a no-contact control group [114]. The yoga group showed improved quality of life and better scores on the perceived stress scale and the impact of events scale, although their cortisol levels did not change. And in the other quality of life study, yoga was compared with standard care [115]. The yoga group trained for six days to prepare for daily practice at home (30 min sessions). Significant improvements were noted on all 3 of the health-related domains-the physical, psychological and independence domains. In the study that assessed CD-4 cell counts, integrated yoga sessions were given 60 min a day, six days a week for one month and this group was compared to a usual care control group [116]. The yoga group experienced a significant decrease in depression scores and a significant increase in CD4 cell counts. In contrast, the control group experienced increased depression scores and decreased CD4 cell counts. Unfortunately, once again the integrated yoga sessions included not only poses but also breathing exercises, relaxation techniques and meditation, confounding the question of which type of intervention is effective. In addition, the control group was an inactive control group.

7.3. Cancer

The yoga for cancer data are also inconclusive. Regarding pediatric cancer, one group of researchers had difficulty recruiting children and adolescents (32% enrollment), although attendance at the 6-week program was excellent (90%) [117]. After the six week program the children had a significant decrease in anxiety scores. In the other recent study on pediatric cancer the recruitment, retention and attendance rates were good for a 12 week yoga program (two times per week) [118]. The children showed an increase in quality of life, functional mobility, hamstring flexibility and physical activity levels at the end of the program. Both of these studies were repeated measures within subjects studies as opposed to randomized controlled trials, suggesting very tentative results.

7.4. Breast cancer

The lion's share of the recent yoga for cancer research has been conducted on breast cancer. In a randomized controlled trial comparing yoga and usual care, fatigue was reduced [119] and in a similar trial, musculoskeletal pain was reduced [120]. These trials were limited given that the yoga poses were combined with breathing exercises and meditation, as in many of the other randomized controlled trials. The same confound occurred in a yoga versus exercise study in which the yoga group showed greater physical activity and less sleep disturbance [121]. In another yoga versus exercise study no group differences were noted on decreased body fat [122]. In a yoga versus a stretching versus a waitlist control group, at the end of the six treatments the yoga group showed the greatest reduction in depressive symptoms and sleep problems [123]. And in another yoga versus stretching versus waitlist control group study, at the end of the six week treatment period (3 times a week) and at a six month follow-up period the yoga group showed greater increases in physical functioning and greater decreases in cortisol levels [124]. However, when yoga was compared to an aerobics exercise program (30 min a week for six weeks) similar effects were noted for both groups [125]. These included increased muscle strength and performance on the 6 min walk test.

Yoga has also been noted to decrease lymphedema in the upper extremities of women with breast cancer [126]. This decreased arm volume was significant but the sample was small and this was a pre-posttest design without a control group. In another study that was a randomized controlled trial for yoga (again for 8 weeks), the yoga group had a greater decrease in tissue induration of the affected upper arm but there was no difference in arm volume/lymphedema ([127]. Further, at a four week follow-up period there were no longer any positive effects. This sample, however, was also small, highlighting the need for further arm volume studies. Both increased pro-inflammatory–related genes and increased anti-inflammatory related genes have resulted from a 12-week Iyengar yoga versus a health education control condition [128] which could explain the mixed results just described. Yoga, by virtue of its sustained high energy poses, and the rest periods in between, could result in mixed effects depending on the ratio of rigor to rest.

7.5. Colorectal cancer

The only other cancer publications during this recent period included a study on colorectal cancer in which fewer sleep disturbances were noted following the end of the yoga intervention (90 min once weekly for 10 weeks) suggesting long-term effects [129]. However, this study featured high attrition and low adherence. Another miscellaneous study on cancer featured laughter yoga (thought to massage the internal organs) which was noted to decrease stress from chemotherapy [130]. And, finally a survey was conducted about oncologists recommending yoga to their cancer patients [131]. Only a small number of the respondents recommended yoga, claiming that more research was needed to document positive effects of yoga.

8. Aging conditions (see Table 8)

Yoga has also been assessed for several aging problems including balance, mobility and sleep quality. The most common aging conditions have also been studied for yoga effects including osteoporosis, Parkinson's and pulmonary disease.

8.1. Mobility and gait speed

In a pretest-posttest design yoga was assessed for postural control, mobility, and gait speed following a 12 -week biweekly 60 min yoga class [132]. By the end of the 12 -week intervention improvements were seen in mobility, postural control and gait speed and 80% attendance was reported.

8.2. Balance

Several studies have been conducted on balance in older adults, as the fear of falling and balance problems are prevalent in that age group. In one study individuals were randomly assigned to yoga practice sessions or a control group that received no intervention [133]. The yoga group performed better on the fall and on the balance scale. In another randomized controlled trial, tai chi and yoga were compared [134]. Yoga was as effective as tai chi in improving balance and postural stability. In another randomized controlled trial comparing yoga and tai chi, yoga and tai chi were both effective for reducing falls, although the yoga group had a greater reduction in pain [135]. In a systematic review of balance studies, 15 studies showed positive results on at least one balance measure [136]. In a systematic review and meta-analysis six trials involving 307 participants showed positive effects for balance and for physical mobility [137].

Table 8
Aging conditions that have been improved by yoga: conditions, reference numbers, trial types, comparison groups and primary results.

Condition	Reference	Trial	Comparison	Primary results
Aging				
Mobility & gait	132	Single arm		>Mobility & gait speed
Balance	133	RCT	Control	>Balance
	134	RCT	Tai Chi	No differences
	135	RCT	Tai Chi	>Balance
	136	REVIEW		>Balance
	137	META		>Balance
Sleep	138	RCT	Waitlist	>Sleep & <Depression
Osteoporosis	139	Single arm		>Bone absorption
	140	RCT	Usual care	>Bone absorption
Parkinson's	141	Single arm		>Sit to stand
	142	RCT	Usual care	<Diastolic BP
	143	RCT	Power training	No differences
Respir. Funct.	144	RCT	Inactive	>FVC, <HR & RR

8.3. Sleep quality

In a study on sleep quality, older adults with insomnia who engaged in twice per week yoga classes for 12 weeks had better sleep quality, sleep efficiency, sleep latency and duration than an inactive control group [138] In addition, their depression, anxiety, stress and anger scores were reduced.

8.4. Osteoporosis

A couple recent studies on yoga for osteoporosis have suggested increased bone absorption based on x-ray absorptiometry (DEXA scan). In one study on osteoporotic, postmenopausal women, improvement was noted in the DEXA scan following a 6 month yoga program of weight-bearing and non-weight bearing poses, breathing exercises and meditation [139]. Not only was this study confounded by the different forms of yoga but it was also limited by its pre-post, non-control group design. When a control group design was used, an 8-month Ashtanga yoga program (60 min sessions twice per week) had a small effect on bone formation but no effects on bone resorption [140]. This result is consistent with the result of the 6-month study just mentioned, although the women in this study were not osteoporotic.

8.5. Parkinson's

A few studies on yoga with Parkinson's have recently appeared in the literature. In one study on an 8-week yoga program, improvements were noted on sit to stand tests [141]. However, this was a pre-posttest, single arm study not a randomized controlled study. In a yoga versus control group study, following a twice-weekly 12 week program, significant improvement was noted on the Parkinson's Disease Rating Scale, for diastolic blood pressure and average forced vital capacity [142]. However, this was a small sample with limited power. When two active groups (power training and high-speed yoga) were compared to a non-active control group, after 12 weeks of twice a week classes, both active groups showed significant improvement on balance, single leg stance and postural sway tests with no differences between the active groups [143].

8.6. Respiratory function

Yoga has also been assessed for improving respiratory function in the elderly [144]. In this study, 65-minute yoga sessions were held 3 times/week for 12 weeks. At the end of the 12-week period, heart rate and respiratory rate were significantly decreased in the yoga group, and tidal volume, vital capacity and 1-min ventilation were increased. Unfortunately, yoga was compared to an inactive control group in this study.

9. Potential underlying mechanisms

Potential underlying mechanisms for the general effects of yoga include enhanced vagal activity and changes in brain wave activity. Increased vagal activity has been noted in at least 4 studies. In a pre-post, single arm design yoga was practiced daily for one month under the direction of a yoga instructor [145]. At the end of the month the low-frequency (LF) power spectrum was reduced as was the LF/high-frequency (HF) ratio, suggesting greater vagal activity or parasympathetic control. Unfortunately this was not only a non-controlled study but the combination of yoga poses, breathing exercises and meditation also confounded the results of this study. In a randomized controlled trial, the yoga group versus the control group showed reduced work-related stress and a significant increase in heart rate variability (vagal activity) following a 12-week program [146]. In a five-month program (90 min per day 6 days per week) the yoga group versus a control group showed a significant increase in heart rate variability (vagal activity) and a reduction in the LF/HF ratio [147]. The yoga group also showed increased alpha, beta and theta EEG band powers and a reduction in delta band power suggesting enhanced memory and concentration and synchronization of brain activity. In a review of 15 studies on the effects of yoga on brain waves and structural changes and activation, increases in gray matter were noted along with increased amygdala and frontal cortex activation [148].

10. Limitations of studies and future directions

Surprisingly, many of the same limitations or potential confounds we reviewed in our 2010 review paper continue to be limitations/confounds of the yoga literature several years later [1]. One of the most significant continuing problems regarding the interventions is that yoga is most often an integrated practice of poses, breathing exercises and meditation. Although the poses predominate most yoga sessions, making yoga a type of physical exercise, it is difficult to parse the effects of the poses, breathing and meditation. That could be one reason why yoga, while thought to be a moderate intensity exercise, is sometimes less intense as it is coupled with still meditation resulting in lesser effects than those experienced by an active exercise group. Or to the contrary, both poses and meditation have been noted to have parasympathetic effects, so each component might have additive, positive effects. The poses, breathing and meditation may have synergistic effects

that are critical to the yoga practice, but they have not yet been deconstructed to determine their individual effects. So it remains unknown which aspects or if all aspects are leading to the positive physical, physiological, cognitive and emotional effects. But for studies to at least be replicable, more detailed descriptions of these components are needed in terms of the physical poses, breathing and meditation and the duration of each component. Oxygen consumption measures on each component might also indicate the exercise intensity of each component.

A second problem is that many different types of yoga, e.g. Hatha, Ashtanga, Vinyasa and Iyengar yoga, have been used with different conditions. Iyengar yoga is thought to be more intense, as the poses are held for longer durations, and Ashtanga yoga is characterized by continuous movements, making these more intense forms of yoga. The different yoga types need to be compared in future studies as it is conceivable that a specific type of yoga may be more beneficial for a specific condition. Yoga sessions are also highly variable including individual versus group practice sessions and the dosage including length of class (20–90 min), the frequency of classes (daily, weekly) and duration of intervention (weeks, months). Although bibliometric analyses have established medians and ranges for yoga classes, the ranges are very large, and different bibliometric analyses on different conditions on different time cohorts yield different parameters.

Several methodological problems relate to the research designs. First, samples vary in their participants with some having virtual beginners and others experienced yogis. Groups would need to be carefully balanced on self-selection factors such as these as yogis would likely be in better condition at baseline and more motivated to practice between intervention sessions. Secondly, many studies are single arm, pre-post studies, others are mixed design (experimental versus control or waitlist control), and still others are active yoga/inactive control comparisons such as educational groups. Often those comparisons have of course favored the yoga group, but when yoga is compared to an active comparison group such as an exercise group, the yoga group advantage often disappears. For yoga to be adopted into wider practice documentation is needed that it is as effective as other forms of exercise.

The methodologically better literature is comprised of randomized controlled trials (RCTs) comparing yoga with active exercise groups, systematic reviews of the RCTs and finally meta-analyses. Without random assignment, self-selection occurs especially since yoga practice requires physical activity and attention. Often meta-analyses could not be performed as there were a limited number of RCTs that met criteria and that were bias free and the RCTs had such variable protocols and assessments that they could not be grouped for meta–analyses.

The variability in assessment protocols has been problematic for grouping even RCTs in systematic reviews and meta-analyses. Stress and mood and pain have been mostly self-reported, which has problems of its own, not being thought to be as reliable as more objective measures. But different self-report measures are used for different conditions and by different cultures. In addition to lacking standardization of the less objective measures across studies, the gold standard measures for a condition have rarely been included, e.g. CD4 levels for HIV and Natural killer cells for breast cancer. Physical and physiological measures are also rarely used, e.g. body mass index, blood pressure, cortisol and other hormones (relatively easy to be assayed from saliva samples) that are often more pertinent for different conditions than mood states.

Future research should use randomized controlled studies in which yoga is compared to active exercise groups. Having established the benefits of yoga makes it ethically questionable to assign participants to inactive control groups. Shorter sessions should be investigated for cost-effectiveness and for daily practice. Multiple physical and physiological measures need to be added to the self-report research protocols and potential underlying mechanisms need to be further explored. In the interim, the studies reviewed here highlight the therapeutic effects of yoga, a practice that could come to be called yoga therapy.

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