



Yoga clinical research review

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A B S T R A C T

Keywords:

Yoga
Cortisol
Vagal activity
Pain

In this paper recent research is reviewed on the effects of yoga poses on psychological conditions including anxiety and depression, on pain syndromes, cardiovascular, autoimmune and immune conditions and on pregnancy. Further, the physiological effects of yoga including decreased heart rate and blood pressure and the physical effects including weight loss and increased muscle strength are reviewed. Finally, potential underlying mechanisms are proposed including the stimulation of pressure receptors leading to enhanced vagal activity and reduced cortisol. The reduction in cortisol, in turn, may contribute to positive effects such as enhanced immune function and a lower prematurity rate.

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1. Yoga research

1.1. Origins and practice of yoga

Yoga comes from Sanskrit, and means to yoke or to join together. A description of the physical yoga postures was found in the Yoga Sutras, which was apparently written in 3000 BC by Patajali, who was a Sanskrit scholar and an Indian physician.¹ Although there are many types of yoga practices, yoga typically combines stretching exercises and different poses with deep breathing and meditation. Yoga is designed to stretch and tone the muscles and to keep the spine and joints flexible. Some suggest that the bending, twisting and stretching movements also massage the internal organs and glands. Yoga poses are generally done with deep, diaphragmatic breathing that is thought to increase oxygen flow to the brain.

Yoga is typically practiced in loose clothing and bare feet on a mat. A series of poses that are called Asanas in Sanskrit are performed slowly and sequentially, concentrating each movement on the deep abdominal breathing that accompanies each movement. Movements between poses are considered as important as maintaining a pose, and typically the poses are held for 4 or 5 breaths depending on the different teaching styles of yoga that are popular today including Hatha, Ashtanga, Anasara, Iyengar and Bikram. Many of the poses are named after animals, and the real yogis suggest that you mimic the animals when in the particular pose such as feeling like a cat or a cobra while performing those poses.

Many forms of yoga involving asanas have been described including, for example, Hatha yoga (Hatha meaning sun/moon), which is considered the most relaxing form (see Table 1). Ashtanga is a programmed series of poses sometimes referred to as power yoga, and Anasara is noted for its more free-flowing movements called Vinyasa. Iyengar involves holding poses longer and some very strenuous positions such as headstands. Bikram is practiced in very high temperature rooms, a practice that is not recommended for those with elevated blood pressure.

1.2. This research review

In this paper, recent research is reviewed on psychological, pain, autoimmune and immune conditions and on physiological and physical measures as well as potential underlying mechanisms for yoga effects (see Table 2). The literature search was focused on research that primarily assessed the effects of yoga poses (asanas) as opposed to sessions that focused on breathing exercises (pranayamas) or meditation. Although, of course because yoga classes often include all 3 elements, the effects of the physical postures are often confounded.

Although very little research has been conducted on potential underlying mechanisms for the effects of yoga, they may be similar to those of massage therapy, with yoga being a kind of self-massage from the rubbing of limbs against each other and against the floor. In those ways, massage and yoga both appear to stimulate pressure receptors under the skin which, in turn, leads to enhanced vagal activity and reduced cortisol.² These physiological and biochemical changes would be expected to be accompanied by reduced depression and fewer pain syndromes and immune problems.³

Yoga has been noted to reduce anxiety and depression. Studies have also shown that yoga can improve several conditions including

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Table 1
Distinguishing features of various forms of yoga.

Hatha (meaning sun/moon) – in practice a relaxing, restorative form but sometimes used as an overarching term for all forms of yoga
Ashtanga – a strenuous series of poses sometimes referred to as power yoga
Anusara – slow free-flowing movements between poses called Vinyasa
Iyengar – holding poses and strenuous positions such as headstands emphasizing the development of strength
Bikram – yoga practiced in a high temperature room

psychological and pain syndromes, musculoskeletal and neurological disorders and autoimmune and immune syndromes. Although volumes have been written on the healing properties of yoga, the studies reviewed here are not anecdotal but empirically based studies.

1.3. Psychological effects

1.3.1. Mindfulness and reduced job stress

These are among the psychological effects reported for yoga. At least two studies have reported enhanced mindfulness following yoga.^{4,5} Although different scales were used, both studies reported enhanced mindfulness. Reductions in job stress have also followed yoga in the workplace⁶ and in fire stations with firefighters.⁷

1.3.2. Anxiety

Several studies have focused on anxiety, and several studies on various conditions have used anxiety as a measure of the condition improving (for example, see section on breast cancer). In a study focused on anxiety, females who perceived themselves as emotionally distressed attended two weekly 90-min yoga sessions.⁸ Compared to a similar group of women who were on a waitlist, those

Table 2
Conditions affected by yoga in recent research and references.

<i>Psychological symptoms and disorders</i>
Mindfulness and job stress ^{4–7}
Anxiety ^{8–10}
Depression ^{11–13}
Sleep ^{14–17}
<i>Pain syndromes</i>
Low back pain ^{18,19}
Headaches ²⁴
Osteoarthritis ^{25,26}
Rheumatoid arthritis ²⁷
<i>Cardiovascular conditions</i>
Coronary artery disease ^{29–31}
Hypertension ^{32,33}
<i>Autoimmune conditions</i>
Asthma ³⁴
Diabetes ^{35,36,38,39}
Multiple Sclerosis ⁴⁰
<i>Immune conditions</i>
Lymphoma ⁴¹
Breast Cancer ^{28,42–51}
<i>Pregnancy conditions</i>
Hypertension and preterm labor ⁵²
Stress and vagal activity ⁵³
Labor pain ⁵⁴
<i>Physiological effects</i>
Heart rate and blood pressure ^{55–58}
Pulmonary measures ^{60,62,65,67}
<i>Physical effects</i>
Weight loss ^{63–66}
Leg strength ^{70–72}

who participated in the yoga training showed decreased stress, anxiety, fatigue and depression as well as increased well-being and vigor. Physical well-being also improved, and those individuals suffering from headache or back pain reported reduced pain. Immediate effects of yoga (post-one session) have also been noted on anxiety.⁹ Performance anxiety has also been decreased in professional musicians following yoga.¹⁰

1.3.3. Depression

Yoga is also effective for alleviating depression.¹¹ Even a short trial of 2 months Vinyasa yoga (flowing poses) led to decreased depression.¹² The decreased depression may relate to the changes in brain waves and the decreased cortisol levels noted during yoga postures. For example, in one study, weekly Yoga sessions led to increased alpha waves (sign of increased relaxation) and decreased cortisol.¹³

1.3.4. Sleep

Reduced sleep problems following yoga may mediate decreased depression. In a chronic insomnia sample, yoga led to improvements on virtually every sleep measure including sleep efficiency, total sleep time, sleep onset latency, number of awakenings and sleep quality measures based on sleep-wake diaries.¹⁴

A sample of pregnant women who began prenatal Hatha yoga during the second trimester had fewer awakenings, less awake time during the night and less perceived sleep disturbance.¹⁵ Those who began yoga during the third trimester ironically had poorer sleep over time.¹⁵

Yoga also reduced sleep disturbances in a geriatric sample after 6 months of yoga practice.¹⁶ The Yoga group versus the standard control group had a significantly shorter latency to sleep as well as a significant increase in the total number of sleep hours and in the feeling of being rested in the morning.

Increasing deep sleep (restorative, quiet sleep) may reduce pain syndromes via a reduction in, for example, substance P that causes pain.¹⁷ In the Field et al study,¹⁷ when quiet sleep increased, based on activity watch monitors, both substance P (measured in saliva) and pain decreased. Similar measures might provide more confirmatory data for the sleep-enhancing and pain-reducing effects of yoga.

1.4. Pain syndromes

1.4.1. Low back pain

Low back pain has decreased after a course of yoga. Adults with chronic low back pain were randomly assigned to a yoga group (12 weekly sessions of yoga), a therapeutic exercise group or a self-care group (assigned to read and practice exercises in a book).¹⁸ After 12 weeks of yoga, back pain was reduced and back-related function was superior in the yoga group as compared to the therapeutic exercise and book-reading groups. In a more recent study by the same group of investigators the yoga participants after 12 weeks of weekly classes reported less analgesic use and less opiate use than the waitlist control group.¹⁹

Similar effects were noted for participants with non-specific chronic low back pain in a randomized controlled trial.²⁰ The yoga participants attended weekly yoga sessions for 16 weeks. The control group was given education on low back pain for the same time period. Results revealed reduced pain intensity (by 64%), functional disability (77%) and pain medication usage (88%) in the yoga group at the follow-up assessments.

In a more recent study on back pain, women were randomly assigned to yoga and control groups.²¹ The yoga program was comprised of physical postures designed for back pain, breathing and meditation. The control group practiced physical exercises and

was given didactic sessions on lifestyle change. Disability scores decreased in the yoga group compared to the control group. The yoga group also had greater increases in spinal flexion, right lateral flexion and left lateral flexion. Finally, the yoga group had fewer sleep disturbances as well as better scores on cognitive functions including long-term attention and concentration, delayed and immediate recall, verbal retention and recognition tests.

In a multi-modal yoga intervention the same group of investigators more recently reported similar effects of yoga on low back pain but this time comparing Iyengar yoga and a waitlist control group.²² The yoga group at the end of the 24-week intervention period (90 min classes twice per week) had greater reductions in functional disability, pain and depression.²³ A shorter, one-week intensive yoga program was also effective. This program included asanas (physical postures) designed for back pain, pranayamas (breathing practices), meditation, and didactic and interactive sessions on the philosophical concepts of yoga. The control group practiced physical exercises under a trained physiatrist and also had didactic and interactive sessions on lifestyle change. There was a significant reduction in disability scores in the yoga group as compared to the control group, and the yoga group had greater improvement as compared to the control group on spinal flexion, spinal extension, right lateral flexion and left lateral flexion. Once again, however, the yoga sessions were multifaceted including physical postures, breathing practices and meditation, making the effects of any of these practices confounded by the others.

1.4.2. Headaches

Individuals with migraine headaches were randomly assigned to a yoga or self-care (stress reducing) group.²⁴ After 3 months of weekly sessions, the intensity and frequency of headache pain ratings, the anxiety and depression scores and the medication use were lower in the yoga versus the self-care group.

1.4.3. Osteoarthritis

Adults with osteoarthritis of the hands were randomly assigned to either a yoga or a no therapy group.²⁵ After once weekly yoga sessions for 8 weeks, the yoga group had less pain during activity, less tenderness of the joints and greater range of motion in their fingers. Osteoarthritis of the knee has also been treated by yoga.²⁶ In this study, Iyengar yoga poses were practiced during 90-min sessions once weekly for 8 weeks. Over the course of the study, the participants experienced less pain, and their physical function improved.

1.4.4. Rheumatoid arthritis

This form of arthritis has also been effectively treated by yoga.²⁷ In this study, adults with rheumatoid arthritis were given a bi-weekly Iyengar yoga program for 6 weeks. Significant improvements were noted in pain and pain disability and related measures of depression, vitality and self-efficacy.

1.5. Potential underlying mechanisms for yoga reducing pain

The mechanism that has been most frequently used to explain massage therapy effects on pain syndromes, the Gate theory (see²⁷ for a review), might also pertain to yoga inasmuch as yoga is a form of self-massage, as in limbs rubbing against limbs and against the floor and stimulating pressure receptors. According to the gate theory, pain stimulates shorter and less myelinated (or less insulated) nerve fibers so that the pain signal takes longer to reach the brain than the pressure signal which is carried by nerve fibers that are more insulated and longer and therefore able to transmit the stimulus faster. The message from the pressure stimulation reaches the brain prior to the pain message and “closes

the gate” to the pain stimulus. This metaphor for the electrical and biochemical changes that likely occur has been commonly used in explaining the effect of grabbing your crazy bone when it has been bumped.

Another theory that is commonly referenced is the deep sleep theory. In deep sleep, less substance P is emitted and therefore less pain occurs because substance P causes pain. As already mentioned, we directly tested the “enhanced deep sleep leading to less substance P” theory in our study on massage therapy effects on fibromyalgia.¹⁷ Following a period of massage therapy, more time was spent in deep sleep, and lower levels of substance P were noted in the saliva samples taken.

Still another theory is that less pain results from increased serotonin levels,¹⁷ serotonin being the body’s natural anti-pain chemical. Serotonin also decreases cortisol and depression which are also important effects of massage therapy. And, serotonin is also noted to decrease substance P and other pain-causing chemicals, highlighting the complex interaction between massage therapy’s effects on biochemistry. Future yoga studies might use multiple physiological and biochemical measures to enhance our understanding of the mechanisms underlying the pain reduction effects of yoga.

1.6. Cardiovascular conditions

1.6.1. Coronary artery disease

Patients with advanced coronary artery disease have also benefited from yoga.²⁹ At the end of one year of yoga training cholesterol was reduced by 23% in the yoga group as compared to 4% in the standard treatment control group. And, serum low-density lipids also decreased more in the yoga group (26% versus 3% in the control group).

In a similar study on coronary artery disease, a dietary change plus yoga group was compared to a group who only made dietary changes.³⁰ After one year of weekly sessions, the yoga group had fewer anginal episodes per week, improved exercise capacity, decreased body weight and lower serum total cholesterol levels. Low-density lipoprotein, cholesterol and triglyceride levels also decreased in the yoga group. Revascularization procedures (coronary angioplasty or bypass surgery) were less frequently required in the yoga group, and coronary angiography showed that more lesions regressed (20% versus 2%) and fewer lesions progressed (5% versus 37%) in the dietary change plus yoga group. Like several other studies, however, multiple treatment procedures (dietary change plus yoga in this case) confounded the yoga effects. Dietary and exercise changes may interact to have complex effects.

In another group of heart failure patients yoga led to improved cardiovascular endurance.³¹ In addition, decreased inflammatory markers (Interleukin-6 and C- reactive protein) suggest immune effects of massage therapy.

1.6.2. Hypertension

Yoga has been effective with patients who have mild to moderate hypertension.³² In this study, yoga was practiced daily for 1 h for three months. By the end of the study, the participants had decreased blood pressure, blood glucose, cholesterol and triglycerides and improved subjective well-being and quality of life. In another group who were at risk for cardiovascular disease, resting systolic and diastolic blood pressure decreased after 20 weeks of yoga.³³

1.7. Autoimmune conditions

Autoimmune conditions seem to respond to yoga as they do to massage, again possibly via the stimulation of pressure receptors

and the resulting parasympathetic state following increased vagal activity. The autoimmune conditions recently researched include asthma, diabetes and multiple sclerosis.

1.7.1. Asthma

In a study on asthma, a yoga group and a control group who received education about asthma attended 2 h sessions once a week for 4 months.³⁴ By the end of the treatment period and again at a 2-month follow-up assessment, several measures improved for the yoga group including scores on the Asthma-Related Quality of Life Questionnaire, the Profile of Mood States, and a diary card based on the combined Asthma Score reflecting asthma symptoms, bronchodilator usage and peak expiratory flow rates.

1.7.2. Diabetes

In a study on patients with diabetes, yoga asanas were performed 30–40 min per day for 40 days.³⁵ Blood glucose levels and glycosylated hemoglobin levels decreased, as did heart rate, systolic and diastolic blood pressure. In another study on diabetes, fasting blood glucose levels and postprandial blood glucose levels decreased following yoga sessions.³⁶ In another study, participants with diabetes attended a 40-day yoga camp.³⁷ At the end of the study, body mass index and anxiety had decreased.

Still another study investigated the impact of Hatha yoga versus conventional physical training (PT) exercises on biochemical, oxidative stress indicators and oxidant status in patients with type 2 diabetes.³⁸ Biochemical parameters such as fasting blood glucose, serum total cholesterol, triglycerides, low-density lipoproteins, very low-density lipoproteins and high-density lipoproteins were determined at baseline and at two consecutive three monthly intervals. The study demonstrated positive effects of Hatha yoga on fasting blood glucose, lipid profiles, oxidative stress markers and antioxidant status, suggesting that Hatha yoga may have therapeutic effects on diabetes by decreasing oxidative stress and improving antioxidant status.

In a study on a related problem, overweight adult men and women with metabolic syndrome were randomized to attend 15 yoga sessions of 90 min each over 10 weeks or to a waitlist control group.³⁹ The results showed a significant increase in energy levels and decreased stress in the yoga versus the control group.

1.7.3. Multiple sclerosis

Patients with multiple sclerosis participated in weekly Iyengar yoga classes or exercise classes for a month or were assigned to a waitlist control group.⁴⁰ The yoga group showed significant improvement on fatigue measures.

1.8. Immune conditions

Surprisingly for all of the yoga studies on immune conditions including lymphoma and breast cancer, immune function was not studied. Instead, each of the studies measured psychological functions including sleep, anxiety and quality of life. Changes in each of these would be expected to alter immune function via the decrease of stress hormones. Nonetheless, immune measures were not collected, possibly because of the added stress of invasive blood sampling and the high costs of immune assays.

1.8.1. Lymphoma

Lymphoma patients were assigned to a yoga group or to a waitlist control group.⁴¹ After participating in 7 weekly yoga sessions, the yoga group had lower sleep disturbance scores. Although the reduction of sleep disturbances might be expected to enhance immune function, it apparently was not measured. Some disease progression markers are difficult to assay. But certainly

natural killer cells that are noted to kill bacterial, viral and cancer cells are readily measured and would provide an indirect measure of disease progression.

1.8.2. Breast cancer

Women with breast cancer have experienced less anxiety following yoga.⁴² In this study, stage II and III breast cancer outpatients were randomly assigned to yoga or brief supportive therapy prior to surgery. The yoga sessions lasted 60 min daily while the control group was given supportive therapy during their hospital visits as a part of routine care. Decreases occurred in both self-reported state anxiety and trait anxiety in the yoga group as compared to the control group. State and trait anxiety also decreased along with symptom severity and distress. Again, immune measures were missing in this study.

In another study, women with breast cancer had less pain and fatigue and increased relaxation after one year of weekly yoga.⁴³ In still other studies on women with breast cancer, weekly yoga sessions similarly led to improved quality of life and reduced anxiety.^{44–47}

Surprisingly, as already mentioned, immune function has not been measured in yoga studies. Stimulation of pressure receptors, as in the friction and stroking of massage or the friction of limbs rubbing against each other or against the floor in yoga may increase vagal activity, in turn, reducing cortisol which kills immune cells, thus enhancing immune function.⁴⁸ Natural killer (NK) cells and natural killer cell activity might be expected to increase following yoga, just as they have following massage therapy.²⁸ Improved immune function would result from natural killer cells warding off viral cells, bacterial cells and cancer cells. In our studies on massage therapy with breast cancer victims, natural killer cells and natural killer cell activity increased, suggesting improved immune function.^{49,50} The clinical condition of these women would be expected to improve as the NK cells destroyed tumor cells.⁵¹ Stimulation of pressure receptors might be the underlying mechanism for the increased NK cells.

1.9. Pregnancy conditions

1.9.1. Hypertension and preterm labor

Several studies have reported positive effects of yoga on pregnant women. In one study, physical postures, breathing and meditation were practiced by pregnant women 1 h daily from early in the second trimester until delivery.⁵² The control group walked 30 min twice a day during the study. Complications such as pregnancy-induced hypertension with associated intrauterine growth retardation as well as preterm labor and prematurity were less frequent in the yoga group. These effects are difficult to interpret as they could have derived from the physical postures, the breathing, the meditation and/or all components of the yoga sessions.

1.9.2. Stress and vagal activity

In another pregnancy study, women were recruited between the 18th and 20th week of pregnancy and were randomized to yoga and deep relaxation or standard prenatal exercises for 1 h daily.⁵³ Perceived stress decreased by 32% in the yoga group and increased by 7% in the control group. For the purposes of recording vagal activity the groups were given a guided relaxation. In the yoga group, compared with values obtained before a practice session, the high-frequency band of the heart rate variability spectrum (parasympathetic or vagal activity) increased by 64% in the 20th week and by 150% in the 36th week, and both the low-frequency band (sympathetic) and the low-frequency to high-frequency ratio were reduced. Moreover, the low-frequency band remained decreased after deep relaxation in the 36th week in the yoga group, all of these

being adaptive autonomic responses to stress. Thus, yoga reduced perceived stress and improved adaptive autonomic responses to stress in healthy pregnant women.

1.9.3. Labor pain

In still another pregnancy study, the yoga program involved six, 1-h sessions.⁵⁴ The yoga group had higher levels of maternal comfort during labor and 2 h post-labor, and they experienced less labor pain than the control group. The yoga group also had a shorter duration of the first stage of labor as well as a shorter total time spent in labor.

1.10. Physiological effects of yoga

A number of physiological effects of yoga have been examined including heartrate, heartrate variability, blood pressure, EEG, pulmonary function and oxygen consumption. Others have measured physical effects including weight loss and balance and flexibility.

1.10.1. Heartrate and blood pressure

In a recent study we conducted, physiological changes occurred following a 20-min yoga class.⁵⁵ Heartrate increased during the session, as would be expected (see Table 3). Changes from pre to post session assessments included decreased anxiety and a trend for increased EEG theta activity, suggesting greater relaxation. This may have contributed to the increased speed and accuracy noted on math computations following the yoga class.

Yoga typically leads to increased heartrate, but following prolonged training, a decrease has occurred in exercise-induced heartrate. In one prolonged yoga study, heartrate was monitored following the Harvard step test.⁵⁶ The participants were asked to step up and down the platform at a rate of 30 steps per minute for 5 min or until fatigued. Heartrate and systolic blood pressure increased and diastolic blood pressure decreased. After two months of yoga training consisting of physical postures, the exercise-induced increases in heartrate and systolic blood pressure were significantly reduced. Another group observed similar effects.⁵⁷ Following 30 days of physical postures in the yoga group, both the baseline heartrate and the lowest heartrate achieved during a 6-min exercise period were significantly lower. No changes were noted for the control group on the lowest heartrate following walking exercise.

Another study looked at the effects of yoga on heartrate and blood pressure in healthy men.⁵⁸ The men were randomly assigned to a yoga group or a control group. The yoga group practiced yoga postures for 45 min daily for three months while the control group performed flexibility exercises for 40 min and slow running for 20 min daily for 3 months. The men in the yoga group showed greater decreases in heartrate and blood pressure and greater aerobic performance than the men in the control group.

Table 3

Means for measures pre and post yoga/tai chi sessions (standard deviations in parentheses).⁵⁵

Measures	Mean		t	p (1-tailed)
	Pre	Post		
<i>Frontal EEG</i>				
Delta	8.35 (1.53)	8.46 (1.35)	NS	NS
Theta	7.07 (1.44)	7.63 (2.17)	-1.30	.10
Alpha	6.92 (1.41)	6.79 (1.60)	NS	NS
Beta	5.74 (1.71)	5.74 (1.81)	NS	NS
EKG (Pre/during)	74.02 (9.40)	91.47 (16.61)	-5.31	.000
Anxiety (STAI)	33.64 (7.01)	31.62 (7.99)	2.39	.02
<i>Math computations</i>				
Time (sec)	186.64 (107.51)	159.41 (81.96)	54.0	.000
Accuracy	3.62 (1.44)	3.97 (1.37)	-1.74	.05

1.10.2. Pulmonary measures

Two yoga practices were compared including a combined “calming and stimulating” technique called cyclic meditation (Yoga postures and resting poses) and a “calming” technique (resting poses) for their effects on pulmonary measures including oxygen consumption, heartrate and breath volume before and after the sessions.⁵⁹ The change on all 3 measures was greater after the calming and stimulating sessions versus the calming sessions. The same researchers later compared the calming and stimulating versus the calming alone sessions and found a significantly lower oxygen consumption rate following yoga (19% versus 5%).⁶⁰

In another study, healthy yoga practitioners practiced a yoga program and were compared to a control group.⁶¹ Heartrate was higher in the yoga compared to the control group. And, the increase in heartrate variability was greater for the yoga than the control group, especially for the parameters associated with vagal activity.

In still another study, oxygen consumption, breath rate and breath volume were assessed before, during and after yoga sessions and after sessions of supine rest in the corpse posture.⁶⁰ During the corpse posture, oxygen consumption, breath rate and breath volume decreased. However, the decrease in oxygen consumption after the corpse posture was less than after yoga. The results support the idea that yoga reduces oxygen consumption more than resting alone does.

Finally, antioxidants were assessed in a group that was trained in yoga for 6 months.⁶² The control group practiced routine exercise for 6 months. Antioxidants increased in the yoga group and decreased in the control group.

1.11. Physical effects

1.11.1. Weight loss

In one study, 12 weeks of yoga led to an overall reduction in food consumption, in eating speed and in food choices.⁶³ In another study, yoga practice for four years was associated with a 3-pound lower weight gain among normal weight participants and a 19-pound lower weight gain among overweight participants.⁶⁴ In a third study, a 6-day yoga program led to decreased body mass index (BMI), waist and hip circumference, fat-free mass, total cholesterol, high-density lipoprotein and fasting serum leptin levels.⁶⁵ Eating disorder symptoms have also decreased following yoga.⁶⁶ And in those diagnosed with an eating disorder, physical activity increased following yoga, and symptoms decreased, as did BMI and hip and waist measurements.⁶⁷

1.11.2. Balance and flexibility

In a study on the elderly, 6 months of weekly Hatha Yoga classes were followed by improved physical condition.⁶⁸ This included balance (as measured by one-legged standing) and flexibility. In a similar study, balance increased and lower-body flexibility increased.⁶⁹ Even grade school children have shown increased balance and flexibility following 12 weeks of 1-h yoga sessions.⁷⁰

1.11.3. Leg strength

In a study on runners, participants showed significant improvement in running performance after a brief 20-min yoga session.⁷¹ Yoga can also increase strength.⁷² A short-term yoga program of 24 yoga sessions in 8 weeks led to improved balance, and leg strength and leg muscle control increased. In a study already described, grade school children also experienced increased strength following yoga.⁷⁰

1.12. Potential underlying mechanisms for yoga effects

The positive effects of yoga may be mediated by increased vagal activity and decreased cortisol. Vagal activity has significantly

increased after yoga but not after aerobic training in the same study.⁷³ This likely happens via stimulation of dermal and/or subdermal pressure receptors that are innervated by vagal afferent fibers, which ultimately project to the limbic system including hypothalamic structures involved in cortisol secretion. These pathways are supported by anatomical studies indicating that baroreceptors and mechanoreceptors within the dermis (i.e. Pacinian corpuscles) are innervated by vagal afferent fibers.⁷⁴ Second, functional studies indicate that electrical vagal stimulation results in reduced cortisol in depressed patients.⁷⁵ And, several investigators have reported inverse relationships between vagal activity and cortisol.^{76–79} Yoga has also been noted to lead to decreased cortisol in at least two studies,^{13,80} as reviewed by Ross and Thomas.⁸¹

Although this model for potential underlying mechanisms has not yet been tested, components of the model are supported by data just reviewed and by research we have conducted including that: 1) massage therapy increases vagal activity; 2) vagal activity decreases cortisol; and 3) increased vagal activity and decreased cortisol are associated with decreased depression. Although it is not clear how yoga increases vagal activity, only moderate pressure massage (not light pressure massage) increased vagal activity in our studies, suggesting that stimulation of pressure receptors leads to increased vagal activity.⁸² Yoga, by virtue of being a form of self-massage (rubbing limbs together and against the floor) would be expected to increase vagal activity via stimulation of pressure receptors.

1.13. Limitations of studies and future directions

The studies in the yoga literature have several limitations including: 1) lack of randomization in several studies leading to groups that differ on baseline characteristics; 2) self-selection of samples that probably result from the compliance that is needed for people to participate in intensive yoga protocols over prolonged periods; 3) significant variability in the samples across studies including sample selection and sample size variables; 4) lack of good physical activity/attention control or comparison groups. For yoga to be adopted into wider practice it needs to be established as a more effective exercise as compared to other forms of exercise; A good example is the randomized controlled study showing greater effects of yoga than walking on anxiety levels⁷³; 5) dosage variability across studies in the length of classes (20–90 min), frequency (daily/weekly/monthly) and duration (weeks/months/years). This has made meta-analyses that could establish more robust effects more difficult to conduct; 6) significant variability in the measures, although most have measured self-reported anxiety and stress, as if yoga is primarily a relaxation technique. And these have been measured by a large variety of instruments; 7) often the gold standard measures for a condition have not been included e.g. immune measures for breast cancer; and 8) physical effects, e.g. weight and body mass index are rarely measured, physiological effects, e.g. heart rate and blood pressure, are rarely measured, biochemical changes are even more rarely assessed, e.g. cortisol and other hormones, even though physiological and biochemical effects are primary, and immune effects have almost never been studied even though they are critical for immune comprised samples such as women with breast cancer.

Future research on yoga effects should focus on these problems such as randomizing groups from more heterogeneous samples of sufficient size for multivariate studies. Physiological, biochemical and immune measures are needed in addition to the self-report measures. And, more practical length sessions are needed, for example 20 min instead of 90 min, so that they can be practiced at home on a daily basis. Further, underlying mechanism research is

needed for yoga to become a part of the mainstream medical community.

2. Summary

In this paper recent research is reviewed on the effects of yoga poses on psychological conditions including anxiety and depression, on pain syndromes, cardiovascular, autoimmune and immune conditions and on pregnancy. Further, the physiological effects of yoga including decreased heart rate and blood pressure and the physical effects including weight loss and increased muscle strength are reviewed. Finally, potential underlying mechanisms are proposed including the stimulation of pressure receptors leading to enhanced vagal activity and reduced cortisol. The reduction in cortisol, in turn, may contribute to positive effects such as enhanced immune function and a lower prematurity rate.

Acknowledgements

This research was supported by a merit award (MH46586) NIH grants (AT00370 and HD056036) and Senior Research Scientist Awards (MH00331 and AT001585) and a March of Dimes Grant (12-FYO3-48) to Tiffany Field and funding from Johnson & Johnson Pediatric Institute to the Touch Research Institute.

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