ROOSEVELT UNIVERSITY

THE EFFECTS OF YOGA ON STRESS RESPONSE AND MEMORY: A LITERATURE REVIEW

A THESIS SUBMITTED TO THE FACULTY OF THE COLLEGE OF ARTS AND SCIENCES IN CANDIDACY FOR THE DEGREE OF MASTER OF ARTS IN PSYCHOLOGY

BY

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CHICAGO, ILLINOIS

DECEMBER, 2014

Acknowledgments

This thesis would not have been possible without the support, encouragement and guidance of my thesis chair, Dr. Lisa Lu and my committee, Dr. Kimberly Dienes.

My deepest gratitude goes out to my loving and supportive fiancé, Matthew Eland, for giving me the space and freedom to learn and grow, and for always pushing me to be the best version of myself.

A special thank you to my parents, Rick and Anne Longstreth, for their kindness, love and support throughout this process. Their influence has inspired me to accomplish each and every one of my goals, and I can't thank them enough for all they've sacrificed to help me along the way.

Finally, I have benefited greatly from the influence of my teacher and mentor, Genevieve Yellin. Genevieve's work has inspired me to utilize yoga not just as a spiritual practice, but also as a therapy for mind, body and spirit.

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Abstract

Chronic over-activity of the body's endocrine stress response system is detrimental to overall health and, over time, may have a negative impact on the structure and function of the hippocampus, a key brain area involved in episodic memory consolidation. Yoga is becoming an increasingly popular mind-body therapy used to reduce and prevent the harmful effects of stress on the body. This review presents a summary of the research investigating yoga as a therapeutic intervention to reduce both perceived and physiological stress in healthy adults. Studies looking at the effects of yoga on hippocampal-dependent memory function in children, adults, and elderly populations were also reviewed. Research investigating the stress-reducing effects of yoga has indicated that yoga may hold therapeutic value in reducing both perceived and physiological stress in healthy populations. In children, yoga has been shown to improve spatial, but not verbal, memory. In adults and elderly individuals, studies indicate improvements in both short and long-term verbal recall following yoga intervention. Elderly individuals also showed increased hippocampal volume following long-term yoga practice. Due to the shortage of empirical evidence, along with several shared methodological limitations, further investigation is still needed to fully determine the efficacy of yoga as a beneficial mind-body therapy for decreasing both perceived and physiological stress-response, improving memory, and preventing stress and age-related hippocampal volume loss.

Introduction

Evolving as a means of preparing the body for action against threat of imminent injury or death, the endocrine stress response has become chronically over-active in many individuals, leading to a wide array of physiological, emotional, and psychiatric health problems. This chronic imbalance of the body's endocrine stress response system is primarily due to the typically hectic modern lifestyle experienced by many of us today. Unfortunately, it is all too common for our days to be filled with far too much stress and far too little sleep. This cycle of self-neglect is often paired with improper nutrition and insufficient physical activity, furthering the endocrine imbalance as well as the negative impact on our physical health and psychological well-being. This type of imbalanced lifestyle does not allow for the ample time our bodies require to find and maintain homeostasis. This repeated, consistent exposure to stressful situations produces an array of detrimental effects on the body, often referred to as "allostatic load" (McEwen, 2002). Over-stimulation of the body's physiological response to stress may also expedite the normal aging processes within the brain, leading to hippocampal volume loss, cognitive impairment, and poorer memory performance. Importantly, the effects of chronic stress on hippocampal volume should be further examined to determine the long-term impact of chronic over-exposure to cortisol, an adrenal hormone playing a key role in the regulation of physiological stress response, on the brain and memory performance throughout the lifespan.

Due to the ever-increasing cost of standardized Western medicine, paired with the apparent lack of effective modern medical treatments for many chronic physical and mental health concerns, alternative therapies are becoming increasingly utilized resources to help prevent and alleviate symptoms of physiological and psychological illnesses. Mind-body therapies, such as yoga, may offer many important physical and mental health benefits. Numerous studies have indicated that yoga intervention may prove widely beneficial in improving overall health, reducing perceived stress and enhancing cognitive performance in the young as well as in the elderly. It is important to thoroughly investigate mind-body therapies such as yoga and their possible implications in the prevention and treatment of stress-related illness and age-related cognitive decline.

In this review, the potential benefits of yoga therapy intervention for stress reduction and memory improvement will be evaluated. A summary is provided reviewing relevant literature on hormonal stress response and the role of cortisol in hippocampal volume loss, memory function and cognitive impairment. A review and critique of the literature on the effects of yoga intervention on stress response and memory performance is provided to determine the effectiveness of yoga as a mind-body therapy intervention to mediate the detrimental effects of chronic stress on the brain.

Stress Response

Throughout the lifespan, the human body is in a constant struggle to maintain a state of balance, or homeostasis. The adaptive responses of the body are fine-tuned to maintain this balanced state in the midst of a wide variety of daily physiological, emotional, psychological, and social stressors. The body's innate ability to consistently adapt to changes encountered in daily life is commonly referred to as "allostasis," meaning to "achieve stability through change" (McEwen, 2002). Almost every system within the body is involved in the maintenance of allostasis, including the immune system, central nervous system (CNS), autonomic nervous system (ANS), and hypothalamo-pituitary-adrenal (HPA) axis. Even the brain itself shows evidence of involvement in allostatic maintenance through the reactive activation of nerve cell activity and appropriate release of neurotransmitters (McEwen, 2002).

In order to maintain allostasis during times when the body is under stress, physiological mediators of stress, including cytokines from immune cells, adrenalin from the adrenal medulla, and glucocorticoids from the adrenal cortex act upon receptors in various tissues throughout the body to produce short-term effects which are adaptive and helpful in regulating the body's response to stressors. In the brain, glucocorticoids and catecholamine act together to facilitate the formation of memories involving dangerous situations to aid in avoiding future threats to safety and well-being. These systems also help to protect areas of the brain, such as the hippocampus, which are particularly susceptible to damage resulting from exposure to certain environmental stressors (McEwen, 2002). While the glucocorticoid system evolved as a means of preparing the body for action to protect against threat of injury, death, or disease, the endocrine stress response has become chronically over-active in many individuals today. This allostatic load has a detrimental effect on the brain and the hippocampus in particular, eventually leading to hippocampal volume loss and memory impairment.

Stress Response and Cortisol

In response to situations perceived as stressful, the body produces and releases the stress hormone cortisol. Cortisol is a glucocorticoid hormone produced by the body in response to stress. Cortisol response to stress is meant to be an adaptive mechanism, producing appropriate physiological changes to the body and mind in response to stressful stimuli. However, chronic overproduction and exposure to cortisol in the body, often due to prolonged states of perceived stress, elicit many harmful physical, psychological, and neurological effects including suppression of the body's immune system (McEwen, 2002). Nearly every form of physical and mental illness may be attributed to stress at some level. From heart attacks to diabetes and even cancer, many of the most common illnesses plaguing our society today are either directly caused by or exacerbated by stress. In cancer patients, a dysregulation in cortisol levels has been discovered with elevated evening cortisol associated with poorer clinical outcomes (Carlson, 2013). In the case of mental disorders including depression and anxiety, mood disorders, and schizophrenia, it's been widely accepted that the onset of symptoms results from a combination of genetic predisposition and external stressors which are likely to result in increased cortisol levels in the body.

The onslaught of stress weighing on us throughout our daily lives carries with it the potential for some very dire consequences. The management and release of stress from our bodies and minds plays an incredibly crucial role in our health and overall well-being. Any intervention with the potential for providing relief from chronic stress and the effects of chronic elevation of cortisol on the body and mind deserves serious and thorough scientific investigation.

Our Thoughts and their Relationship to Stress Response

"The brain is the master controller of the interpretation of what is stressful and the behavioral and physiological responses that are produced" (McEwen, 2002, p.922). Even when physiological homeostasis remains uncompromised, an individual's interpretation of a situation as stressful or threatening often results in a hormonal or behavioral stress response. When an individual perceives a non-threatening situation as being stressful or threatening to his or her well-being, an increase in free-cortisol often occurs along with various compensatory behaviors, such as overeating, smoking cigarettes, or drinking alcohol which may further contribute to the physiological burden and allostatic load by elevating levels of glucocorticoids (McEwen, 2002). Therefore, an individual's ability to control his or her thoughts and perceptions regarding events interpreted as "stressful" may be a key aspect in preventing and reducing the damaging effects of chronic exposure to glucocorticoids and allostatic load on the body.

Stress Response, the Hippocampus and Memory

The influence of acute stress on the brain and cognition depends on the level of glucocorticoid elevation that occurs in response to the stressor. Small, short-term increases in glucocorticoids, including cortisol, enhance hippocampal-mediated learning and memory function. This process of enhanced hippocampal processing in response to an acute and immediate stressor is an adaptive response intended to increase learning and processing speeds during times of challenge and also to enhance memory of dangerous situation in order to better avoid them in the future. Larger and more long-term elevations in glucocorticoids act to impair hippocampal processing and memory function (Lupien, McEwen, Gunnar & Heim, 2009). Animal studies have shown that chronic exposure to stress and glucocorticoids in rodents causes structural and functional changes in the hippocampus, a key brain area involved in memory function (Magarinos & McEwen, 1995; Gould, McEwen, Tanapat, Galea & Fuches,1997; McEwen, 2000; McEwen, 2001). Additional animal research has shown that these glucocorticoid-induced alterations to hippocampal structure and function are reversed after a period of prolonged withdrawal from the stressor or exogenous glucocorticoid administration, indicating that it may be possible to reduce the detrimental effects of chronic stress on the hippocampus (Conrad, LeDoux, Magarinos & McEwen,1999; Luine, Villegas, Martinez & McEwen, 1994).

Four main scenarios are commonly associated with elevated or maladaptive activity of the body's stress response systems: repeated challenges, failure to habituate to repeated challenges, failure to "turn off" the body's stress response following a challenge, and lack of adequate means to cope with stress in response to challenge (McEwen, 2002). During periods of prolonged exposure to stress, or when these allostatic systems remain active after they're no longer needed, normally helpful hormonal stress mediators, such as cortisol and adrenaline, become damaging to the body. Over time this process may lead to neuronal damage, hippocampal volume loss, and impaired memory function. These damaging effects to the brain are especially evident in older individuals during aging.

Hippocampal processing is necessary for the formation of new declarative memory. The hippocampus also happens to contain a high number of cortisol receptors, causing this important brain area to become particularly susceptible to the effects of chronic stress (McEwen, 1998). While several physiological mechanisms have been posited as contributors to cortisol-mediated effects on cognitive performance, an abundance of animal research in this area has focused on the hippocampus in particular due to its crucial role in memory consolidation and spatial working memory. The

Schaffer collateral synapse is an area of particular importance to hippocampal memory encoding. Connections formed at the Schaffer collateral synapse demonstrate various forms of plasticity important for hippocampal memory consolidation. The hippocampus utilizes information from several regions in the brain with input from the neocortex arriving via the entorhinal cortex via the preforant pathway. The hippocampus processes cortical input via a trisynaptic pathway that links the second layer of the entorhinal cortex to the dentate gyrus, allowing the coding of various forms of memory. The dentate gyrus subsequently transmits the information to area CA3 (Cornu Ammonis), where the information is then processed and passed along to the stratum radiatum in area CA1 via the Schaffer collateral pathway. Area CA1 is believed to assist in translating memories into new forms that are then sent back to the entorhinal cortex for long-term storage in other brain areas (Izumi & Zorumski, 2008; Purves, Augustine, Fitzpatrick et al., 2001). Structural changes in dendritic spine density and connectivity alter the synaptic plasticity and function of the hippocampus (Wooley, 1998). Dendritic spines are the postsynaptic sites of excitatory input in all neurons including CA1 hippocampal pyramidal cells. Dendritic spine density indicates quantity of excitatory synaptic inputs (Woolley and McEwen, 1992).

Animal research has shown that prolonged exposure to stress in rodents causes dendritic atrophy in CA3 pyramidal neurons in the hippocampus and inhibits neurogenesis in the dentate gyrus (Margarinos & McEwen, 1995; Gould et al., 1997). Atrophy of this particular area within the hippocampus is associated with poorer memory consolidation, causing impairments in learning. Additionally, chronic stress in adult rats has been shown to cause hippocampal volume loss (McEwen, 2000). Animal studies have also linked stress-related changes in the hippocampus to temporary impairments in spatial learning (McEwen, 2001), indicating a link between stress-related structural changes to the hippocampus and cognitive performance.

Cognitive Correlates of Hippocampal Damage

Stress-induced changes in the hippocampus, which is a brain area known to play a crucial role in episodic and verbal memory function, have real life implications on the day-to-day functioning of humans as well as animals. In a review and meta-analysis of the literature investigating the relationship between hippocampal volume and memory function in healthy human subjects, Van Petten (2004) discovered a significant relationship between pathological and age-related hippocampal volume loss and decreased episodic memory function. While an association has been found between declining hippocampal volume and impaired memory function, it is important to note that overall the results of meta-analysis showed a negative correlation between hippocampal volume and memory in healthy children, adolescents, and young adults. This means that in young, healthy individuals, a larger hippocampus doesn’t necessarily equate to better episodic memory; however, a decline in hippocampal volume compared to baseline, due to pathology or normal aging, can have a significant impact on hippocampal-dependent episodic memory function (Van Petten, 2004).

Studies have investigated memory impairment in patients with Cushing’s syndrome (CS), a disease marked by spontaneous chronic elevations in corticosteroids, including cortisol. In patients with CS, chronic elevation in cortisol levels has been associated with below-average hippocampal volume and impairments in episodic and verbal memory consolidation and recall (Mauri et al., 1993; Starkman et al., 1999; Resmini et al., 2012) with a trend toward poorer recall and smaller hippocampal volume with longer duration of hypercortisolism (Resmini et al., 2012). Luckily, research has indicated that hippocampal volume loss related to chronic cortisol over-activation may be reversed following a reduction in cortisol levels (Starkman et al., 1999). This indicates that while chronic overexposure to cortisol in the brain decreases hippocampal volume and related memory function, these effects may be reversed using therapies aimed at cortisol reduction.

In healthy individuals, cortisol stress response has been associated with impaired memory retrieval. A study by Kuhlmann, Piel, and Wolf (2005) demonstrated that an increase in cortisol in response to a psychosocial laboratory stressor (the Trier Social Stress Test: TSST) was associated with impaired verbal memory retrieval. Upon further analyses, it was discovered that the impairment in memory retrieval was specific to emotionally charged words, whereas recall for neutral words was not effected (Kuhlmann, et al., 2005). This impairment in verbal memory recall following a psychosocial stressor has been shown to differentially effect participants based on gender. A study by Almela et al. (2011) found that in women, there was a significant impact of stress on verbal memory performance as well as a significant relationship between elevated salivary cortisol in response to stress and poorer verbal recall. The results of this study did not show a relationship between psychosocial stress (TSST), memory performance, and salivary cortisol in men (Almela et al., 2011). The results of these studies suggest a complex relationship between psychosocial stress, salivary cortisol, verbal memory performance, and gender, indicating that the physiological and psychological effects of stress can vary greatly depending on the influence of a number of different variables. The results of these studies also indicate that exposure to psychosocial stress and elevated cortisol levels may have short-term effects on the hippocampus and related verbal memory performance in healthy, younger populations. Additionally, it remains important to investigate the effects of chronic exposure to external stress and elevated levels of cortisol within the body in senior populations who are more at risk for age-related hippocampal volume loss and memory impairment.

Stress response and the aging hippocampus. Throughout the normal aging process the hippocampus, a key brain structure involved in episodic, declarative, spatial, and contextual memory as well as the regulation of autonomic, neuroendocrine, and immune response, sustains a gradual loss in both volume and function (McEwen, 2002). In healthy aging, the average person will lose approximately 1-2% hippocampal volume annually (Raz et al., 2005). Evidence shows that age-related hippocampal volume loss may be accelerated by chronic stress and subsequent over-exposure to stress hormones such as cortisol (Oitzl, Champagne, van der Veen & de Kloet, 2010; McEwen, 2002; Lupien et al., 2005). Several theories have been proposed regarding the impact of cortisol exposure on the aging of important brain structures over time. Aging has been thought to provoke the onset of hypercorticism in some individuals. Stress and hypercorticism have been proposed to facilitate cognitive aging, working to amplify individual variation in the cognitive aging process (Oitzl et al., 2010). One theory, known as the "glucocorticoid cascade hypothesis" of aging, proposes that dysregulation of the HPA axis and chronic exposure to glucocorticoids wears down the hippocampus and accelerates the brain's normal aging processes (McEwen, 2002). A study by Lupien et al. (2005) lends partial support to this theory, showing that elderly individuals with rising cortisol levels over a four-year period declined in performance in both explicit memory and attention tasks. This decline in cognitive function coincided with a 14 percent reduction in hippocampal volume. While the hippocampus is particularly vulnerable to damage by chronic exposure to stress hormones, studies indicate the hippocampus may be especially resilient and able to adapt to changes in allostatic load and its effects on the brain (McEwen, 1999; McEwen, 2002; Starkman et al., 1999; Marlatt, Potter, Lucassen & Van Praag, 2012). The hippocampus has been known to retain a substantial amount of plasticity throughout the lifespan, beyond the years of early childhood development as previously thought (McEwen, 1999; McEwen, 2002; Starkman et al., 1999; Marlatt et al., 2012). This lends hope and support to the idea that individuals suffering from age-related cognitive decline may recover from hippocampal volume reduction and memory loss through various forms of therapeutic intervention, including mind-body therapies such as yoga and meditation.

Yoga as a Therapeutic Intervention

The increase in the cost of standardized Western medical treatments along with a growing concern for the detrimental side effects associated with most modern pharmaceutical drugs are leading more and more people to turn to alternative therapies to help prevent and alleviate symptoms associated with many physiological and psychological health concerns. Alternative therapies, such as yoga therapy, are becoming an increasingly common wellness tool to be used alone or in tandem with conventional medicine to address a number of common chronic physical diseases and mental disorders. Yoga has shown promise in its ability to help improve symptoms associated with many health conditions including anxiety and depression and other psychiatric disorders along with chronic pain and headache, cardiovascular conditions, autoimmune conditions including diabetes and multiple sclerosis, pregnancy-related conditions and complications, and immune conditions including lymphoma and breast-cancer (Field, 2011; Ross & Thomas, 2010). Research has also suggested that yoga practice may be a safe and effective alternative therapy for improving both psychological and physiological markers of chronic stress in healthy adults (Chong, Tsunaka, Tsang, Chan & Cheung, 2011; Cowen & Adams, 2005; Granath, Ingvarsson, von Thiele & Lundberg, 2006; West, Otte, Geher, Johnson & Mohr, 2004; Michalsen et al., 2005; Smith, Hancock, Black-Mortimer & Eckert, 2007; Satyapriya, Nagendra, Nagarathna & Padmalatha, 2009; Li & Goldsmith, 2012; Bowden, Gaundry, An & Gruzeller, 2012; Yoshihara, Hiramoto, Sudo & Kubo, 2011). Due to the connection between chronic stress and cognitive impairment, it is also important to note that several studies have indicated that yoga may improve cognitive performance in healthy individuals (Rocha et al., 2012; Gothe, Pontifex, Hillman & McAuley, 2013; Sarang & Telles, 2007; Manjunath & Telles, 2004) as well as in elderly populations (Hariprasad et al., 2013). This thesis reviews the clinical research to investigate the stress-reducing and cognitive effects of yoga practice.

Introduction to Yoga

Yoga is an increasingly popular practice combining the use of physical postures, or *āsana*, with breathing exercises (*prānāyāma*), mental discipline and control over the senses (*pratyāhāra*), focused concentration (*dhāranā*) , and meditation (*dhyāna*) (Bryant, 2009; Iyengar, 1966). There are several variations of yoga practice here in the West, each with a slightly different focus. Increasing evidence indicates that regular yoga practice may hold value in reducing stress as well as preventing memory loss and improving cognitive function in younger individuals as well as the elderly. Because yoga reaches far beyond the physical practice, including mindfulness, breathing exercises, and meditation, research has suggested that the beneficial effects of yoga may surpass the benefits of typical physical activity (Ross & Thomas, 2010). But what exactly is yoga, and what gives it the potential to effectively stave off stress and cognitive decline?

B.K.S. Iyengar is recognized as one of the world's foremost authorities on Hatha yoga, a style of yoga focused on proper alignment in asana, incorporating various breath work and meditation practices. In his book titled *Light on Yoga*, a publication celebrated as one of the most comprehensive writings on modern yoga practice and philosophy, Iyengar writes "yoga is a timeless pragmatic science evolved over thousands of years dealing with the physical, moral, mental and spiritual well-being of man as a whole" (p.13). In ancient yoga texts, importance is placed on maintaining a state of homeostasis, or balance, within the body, mind and spirit. This state of balanced equilibrium is known as *samatvam* in Sanskrit. While much attention is given to *āsana*, *prānāyāma* and meditation in today's mainstream yoga practice, traditionally yoga also incorporates a balanced, healthy lifestyle, including a nourishing plant-based diet. Also important to yoga is the practice of identifying one's emotions and the thought patterns attached to those emotions, and modifying those thought patterns as needed (Telles, 2010). This practice of identifying and modifying negative thought patterns and belief systems (*samskaras*), put forth over 5,000 years ago in the ancient yoga texts, is reflected in modern Cognitive Behavioral Therapies (CBT) utilized by many of today's psychotherapists.

According to yoga texts, there are five main levels of existence, known as the *koshas*, meaning "sheaths" in Sanskrit: the physical level (*annamayakosha*), the level of subtle energy (*pranamayakosha*), the psycho-emotional level of the mind (*manomayakosha*), the intellectual or wisdom level of the mind (*vijnamayakosha*), and the ideal level, or "bliss body," which encompasses a balanced state of perfect unity and oneness (*anandamayakosha*). Imbalances occurring at the psycho-emotional mental level, often produced by maladaptive thinking and stress, will eventually translate into imbalances at all five levels of existence, leading to physical disease (Telles, 2010). Similarly, imbalances at the physical level (e.g. poor nutrition or lack of physical activity) will eventual translate into imbalances at the mental and subtle energy levels, leading to psychiatric illness. It is the comprehensive and holistic nature of the of yoga, combining physical strengthening and stretching exercises with controlled breathing, mindfulness, mental focus, meditation, and spiritual exploration that makes yoga an effective mind-body therapy tool for not only preventing stress-related illness and age-related cognitive decline, but also for improving memory, concentration, physical and emotional health, and overall well-being and happiness.

Yoga and Stress Response

For thousands of years, yoga has been utilized and accepted as an important tool to help alleviate the effects of chronic stress and anxiety. In recent years, research has begun to validate the use of yoga as an integrative or alternative treatment method for providing much needed relief from chronic stress and anxiety. While there is currently a lack of statistically sound randomized controlled studies on the topic, preliminary research has suggested the effectiveness of yoga in reducing both subjective and physiological response to stress while also improving immune function and overall well-being.

Evidence has suggested that long-term yoga practice may hold promise in its ability to improve mental states and decrease perceived tension and anxiety in healthy individuals. Yoshihara et al. (2011) found that female yoga practitioners with 2-3 years experience showed significantly lower scores on the tension-anxiety, depression, anger-hostility, and fatigue subscales of the Profile of Mood States (POMS) questionnaire compared to controls with no prior experience with yoga practice. Limitations of this study include self-selection bias as this was a non-randomized study, and the women who volunteered to participate had been practicing yoga for several years on their own accord. These women are likely to differ in personality, perspective, and health & wellness habits from the general population. Another limitation to the generalizability of this study is the absence of male practitioners in the sample population utilized.

In a randomized trial comparing the effects of ten weeks of yoga intervention versus progressive muscle relaxation training on stress and anxiety reduction, Smith et al. (2007) found yoga to be effective in reducing subjective levels of stress and anxiety and also improving overall quality of life. The study, using a sample of 119 middle-aged participants, showed that yoga was equally effective as progressive muscle relaxation at reducing stress as measured by the psychological stress subscale of the General Health

Questionnaire (GHQ-12). Participants in both the yoga and progressive muscle relaxation groups also showed decreased anxiety as indicated by the State Trait Personality Inventory's anxiety subscale (STPI) as well as increased physical and mental health as measured by the MOS 36 Item Short Form Health Survey (SF-36) (Smith et al., 2007). While the results of this study indicated yoga could be an effective intervention for stress and anxiety reduction, limitations of the study design included the inability to keep participants blinded as to which group they were in. Although it is not possible to conduct a study investigating yoga intervention while keeping participants blinded, the unblinded study design may result in participant bias toward positive outcomes on subjective measures of stress and mental health. Another potential limitation is due to the fact that the outcome measures utilized in this study have not been described as reliable and valid. Future research should aim to investigate the sustained stress-reduction and health effects of long-term yoga practice.

A randomized comparison study by Bowden et al. (2012) compared the effects of brain wave vibration training (BWV), Iyengar yoga, and mindfulness training. Brain wave vibration refers to a type of moving meditation designed to promote relaxation and awareness of energy flow. Iyengar yoga is a variation of Hatha yoga practice emphasizing proper postural alignment in *āsana* with the aim of building strength, concentration, and meditation. Mindfulness training promotes present-centered, nonlaborative and nonjudgmental awareness. A sample of 33 healthy young college students (21 female; 12 male) were randomized into three groups, each completing four months of regular classes in either BWV, Iyengar yoga, or mindfulness. All three groups showed improvements in overall stress as measured by the Depression, Anxiety, and

Stress Scale (DASS). Additionally, participants in both the BWV and yoga groups improved in measures of overall mood and vitality. It is possible that the mind-body aspect of both yoga and BMV, combining physical movement with mental concentration and meditation, is responsible for the superior results on outcome measures of mood and vitality across both groups. Across all three groups, however, a slight but non-significant increase was observed in salivary cortisol following therapeutic intervention (Bowden et al., 2012). This may be due in part to the study's failure to account for both menstrual cycle status and hormonal birth control use in a small sample of predominantly female participants. It has been confirmed across several studies that cortisol response to stress varies across the menstrual cycle, with an attenuated cortisol response during the follicular phase and an elevated cortisol response to stress during the luteal phase (Almela et al., 2011; Childs, Dlugos & de Wit, 2010; Kajantie & Phillips, 2006; Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999; Kudielka & Kirschbaum, 2005).

In a study investigating stress reduction programs in the workplace, Granath et al. (2006) compared the effects of Kundalini yoga versus cognitive behavioral therapy (CBT) on perceived stress, stress-related behavior, exhaustion, anger, quality of life, blood pressure, heart rate, and cortisol levels. Kundalini is a variation of yoga practice focused on exercises that stimulate the blood flow and subtle energy flow through the spinal column into the brain, the nervous system, and the glands in the endocrine nervous system. For the purpose of this study, participants were randomized into either the Kundalini yoga group or the CBT group and participated in 10 sessions of either yoga or CBT over the course of four months. Yoga was held weekly, while CBT was held weekly for 4 consecutive weeks, followed by 3 sessions held every other week and an additional 3 sessions held every third week. The results of the study indicated a reduction in perceived stress, as indicated by scores on the PSS, in both the Kundalini yoga and CBT groups. Moreover, scores for stress-related behavior and exhaustion also decreased across both groups. Scores for anger decreased significantly for the CBT group and non-significantly for the yoga group. While the yoga group showed a near-significant decrease in heart rate following treatment, heart rate was not significantly lower in either post-treatment group. Measures of salivary cortisol did not differ significantly pre and post-study across both groups. One potential explanation for this may be the study's apparent failure to control for menstrual cycle in a predominantly female mixed gender participant group (male: n=10; female: n=27). The results of this study show that yoga was as effective as CBT in decreasing subjective sense of stress, but not anger. Neither treatment types resulted in improved quantitative measures of physiological stress response, which may, in part, be due to methodological limitations to the study's design. Limitations to the study design include the differences in timing of the sessions between the two groups. While Kundalini yoga sessions were held weekly for 10 consecutive weeks, CBT sessions became increasingly spaced apart over the course of the study, which may have influenced the differences in outcome measures reported between the two groups, as extended time between study sessions may have allowed for life changes not associated with the study to influence post-treatment outcomes in the CBT group. Additional limitations were posed by the small sample size (n=37). Future studies should aim to replicate these results in using a more consistent timeline in a larger participant sample (Granath et al., 2006).

Yoga intervention has also shown promise in its ability to reduce perceived stress and improve heart rate variability in pregnant women. Pregnant women are particularly vulnerable to the effects of stress as both the woman and her unborn child may be negatively impacted by the elevation of stress hormones, such as cortisol, within the body. Prenatal maternal stress has been associated with spontaneous miscarriage, preterm labor, fetal deformities, and asymmetric growth restriction (Mulder et al., 2002). Because of this, it remains crucial that we investigate the efficacy of stress relieving interventions during pregnancy. To determine benefits of yoga on perceived stress and heart rate variability in pregnant women, Satyapriya et al. (2009) compared the effects of 16 weeks of prenatal yoga practice and guided yogic relaxation versus standard prenatal exercises in a large sample of 90 pregnant women. Standard prenatal exercise consisted of simple exercise routines, including breathing and stretching exercises, guided by instructors trained in prenatal exercise. The women were randomized into either the yoga group or standard exercise group and began the intervention between their 18th and 20th week of pregnancy. The results of this study showed that perceived stress, as measured by the Perceived Stress Scale (PSS), significantly decreased by 31.6% in the yoga group and increased by 6.6% in the standard exercise control group. Improvements in heart rate variability were also found in the yoga group versus controls. The results of this study suggest that regular yoga practice both prevented and reduced perceived stress in pregnant women while simultaneously improving autonomic nervous system responses as indicated by changes in heart rate variability (Satyapriya et al., 2009). Limitations of this study include the use of self-report and practice diaries to indicate compliance with at-home yoga and standard prenatal exercise practice. Due to the bias toward over-reporting in self-reports of exercise practice, it is possible that one or both groups may have over-reported compliance with the study protocol. Additionally, as this study was investigating the effects of prenatal yoga classes on stress in pregnant women, limitations are posed to the generalizability of the study's results as hormonal changes in pregnant women differ substantially from the general population. Due to the interaction between ovarian hormones and cortisol response to stress, it is likely that the women in this study experienced physiological and/or subjective stress in a way that differs greatly from the general population.

In a study investigating the physical and perceptual benefits of yoga, Cowen & Adams (2005) compared the effects of two different styles of yoga, Hatha yoga and Ashtanga yoga, on measures of perceived stress and physical fitness. While Hatha yoga focuses on slow movement and mindfulness through correct alignment of deeply held postures sustained for longer periods of time, Ashtanga yoga focuses on mastery of repetitive asana sequences with rapid, face-paced movement coordinated with the breath. Results of the study showed significant improvements in both yoga groups on measures of physical fitness. Significant improvements were found in both groups on measures of perceived stress (PSS) and overall health perception; however, when comparing each group individually to their own baseline scores, improvements in perceived stress and health perception were only significant in the Ashtanga yoga group (Cowen & Adams, 2005). It is possible that the physically rigorous and repetitive nature of Ashtanga yoga resulted in additional physical benefits, allowing for the perception of improved stress and health perception in the Ashtanga yoga group. Limitations to this study include the use of a self-selected sample, lack of randomization and the absence of a control group.

As participants were self-selected to participate in either Hatha or Ashtanga yoga, differences in the overall personalities of the participants may have influenced differences in outcome measures between the two groups. This particular study also had a high dropout rate of approximately 35%. Additionally, the use of a participant group of all college students poses limitations to generalizability, as the age, education level, and perceived stress of college students may vary greatly from the general population. The post-yoga assessment also coincided with midterm examinations for many of the students participating in the study, which may have influenced the study's outcome. Future research should aim to investigate the stress-reducing benefits of yoga using a randomized & controlled study design in a more diverse sample population.

In order to examine the effects of an intensive Iyengar yoga course on perceived stress and psychological well-being in distressed women, Michalsen et al. (2005) conducted a study in which 24 self-selected female volunteers were recruited to complete twelve weeks of regular yoga training. Yoga classes lasting 1.5 hours were attended twice per week throughout the twelve-week course. Volunteers were given their preference to begin their practice immediately or serve as waitlist controls. The results of the study indicated that participants in the yoga group showed significant improvements in perceived stress compared to both the waitlist control group following 12 weeks of non-intervention and baseline scores as measured by the Cohen Perceived Stress Scale (CPSS). Additionally, participants completing the twelve-week yoga course showed marked improvement in self-report measures of State and Trait Anxiety, emotional well-being, as well as vigor, fatigue, and depression as assessed by the Profile of Mood States (POMS). Some common physical complaints associated with significant self-reported emotional stress include lower back pain, headache, and insomnia. For the purpose of this study, self-reported pain and insomnia were recorded using Likert scales. At baseline, all but one of the 16 participants in the yoga group, as well as 6 out of 8 controls, reported suffering from lower back pain. Participants in the yoga group suffering from low back pain and/or headache reported marked pain relief following intervention. While 6 out of 8 participants in the control group reported frequent lower back pain with 4 participants reporting frequent headaches, none of the participants in the waitlist control group reported improvement in back pain or headache. Three participants in the yoga group also reported a decrease in sleep disturbances following intervention, compared to only one participant in the control group (Michalsen et al, 2005). The results of this study indicate a wide array of potential benefits associated with regular yoga practice, including the reduction of perceived stress. Limitations to the design of this non-randomized study are posed by the small sample-size and self-selection bias. Further limitations to the generalizability of the results are posed by the inclusion of an all-female participant sample. Due to biology, upbringing, and societal conditioning, the perceived and physiological response to stress in women may differ greatly from men.

While long-term benefits may result from long-term regular yoga practice, evidence shows that even a single yoga class may significantly influence both physiological and perceived stress. In order to supplement the results obtained in the previous study, Michalsen et al. (2005) measured salivary cortisol concentration before and after a single Iyengar yoga class in another study sample consisting of 11 female participants who had been practicing yoga regularly for more than three months. Analysis of the samples showed a significant decrease in cortisol levels compared to baseline in 9 out of the 11 participants (Michalsen et al, 2005). The results of this analysis indicate the possibility of a short-term benefit of yoga practice on physiological stress response; however, are these results are limited due to the small sample size and lack of control group. The use of an all-female participant sample also poses limitations to the generalizability of the results of this study as the effects of yoga on stress response in females is likely to differ from that of males due to differences in biology.

An additional study compared the effects of a single Hatha yoga class versus an African dance class on perceived stress, positive affect, and salivary cortisol. Participants completed either one 90 minute Hatha yoga or African dance class, with a third group of students participating in a college level biology course serving as controls. The results of this study supported the researchers' hypotheses that a single 90-minute Hatha yoga class would decrease perceived stress and salivary cortisol. To control for circadian fluctuations in cortisol levels, salivary cortisol samples were collected at the same time of day, between 4:00pm and 6:00pm, across both groups. As anticipated, the African dance class also reported decreased perceived stress as indicated by scores on the Perceived Stress Scale (PSS); however, salivary cortisol increased compared to baseline levels, as anticipated, based on the more intense physical nature of African Dance. In the control group, no significant change was found in perceived stress or salivary cortisol after the 90-minute biology lecture (West et al., 2004). While the results of this study indicate a potentially beneficial effect of Hatha yoga on both psychological and biological indicators of stress, the results of this study are limited in generalizability by the use of a sample of all college students. Additionally, participants in this study were self-selected, posing additional limitations due to lack of randomization as individuals interested in taking yoga or African dance classes may vary greatly in personality and physical fitness levels from the general population.

Overall, seven studies were reviewed investigating the effects of regular yoga practice on perceived stress. The results of all seven studies showed improvements in perceived stress following long-term yoga intervention (Yoshihara et al., 2011; Granath et al., 2006; Satyapriya et al., 2009; Cowen & Adams, 2005; Smith et al., 2007; Bowden et al., 2012; Michaelsen et al., 2005). One study indicated that regular yoga practice may be equally effective as progressive muscle relaxation training in reducing perceived stress and anxiety, as well as improving overall quality of life (Smith et al., 2007). Another study indicated that sustained Kundalini yoga practice may be as beneficial as cognitive behavioral therapy (CBT) in reducing perceived stress as well as reducing stress-related behavior and exhaustion (Granath et al., 2006). Two studies indicated potential improvements in cardiovascular health and autonomic nervous system response, with one study finding significant improvements in heart-rate variability in pregnant women following a prenatal yoga program (Granath et al., 2006; Satyapriya et al., 2009). Two of the long-term yoga studies reviewed investigated the effects of yoga on mood. Both of these studies indicated significant improvements on measures of mood and emotional well-being, with one study indicating that yoga may be more beneficial than mindfulness in improving self-reported mood and vitality (Bowden et al., 2012; Michaelsen et al., 2005). Two studies looked at the effects of regular yoga practice on physiological stress response as indicated by salivary cortisol levels, both of which found no significant differences in salivary cortisol in response to stress following yoga intervention (Bowden et al., 2012; Granath et al., 2006). Interpretation of cortisol results found in both of these studies is limited due to limitations in the design of these studies and the lack of control for menstrual cycle status of female participants. Additional limitations preventing stronger interpretation of findings in the long-term yoga studies reviewed include non-randomized study design and self-selection bias, small sample sizes, and lack of long-term follow up. Limits to the generalizability of findings were also posed by the use of all-female participant samples in three of the studies reviewed. Upon reviewing the research, the results of these studies indicate a beneficial effect of sustained yoga practice on perceived stress with high participant compliance and without any reported negative effects. Future research should aim to further investigate the effects of long-term yoga practice on both subjective and physiological stress response using a randomized study design as well as larger sample sizes including both men and women over longer durations of time. Future research investigating the effects of yoga on cortisol stress response should also control for menstrual cycle status in female participant samples.

Two short-term studies were included in this review, both of which investigated the effects of a single yoga class on physiological response to stress as indicated by levels of salivary cortisol. The results of both of these studies indicated significant decreases in salivary cortisol in participants after a single yoga class compared to baseline (Michaelsen et al., 2005; West et al., 2004). One of these studies also investigated the effects of yoga on perceived stress, and found a significant decrease in perceived stress (PSS) compared to baseline following a single Hatha yoga class (West et al., 2004). Limitations to these studies were similar to limitations posed by methodology in the long-term studies and included non-randomized study design and self-selection bias, small sample sizes, and the use of an all-female participant sample in one of the studies. Upon reviewing these two short-term yoga studies, it appears that substantial physiological and subjective stress-reduction benefits may be possible following a single yoga class. Further investigation is needed to replicate these results, and future studies should aim to look at the short-term stress-reducing effects of yoga using a randomized and controlled study design including larger sample sizes with both male and female participants.

Yoga and Memory

Findings from animal research have suggested a relationship between physiological stress response and hippocampal volume loss (McEwen, 1998, 2000, 2001; Margarinos & McEwen, 1995; Gould et al., 1997). Human research suggests that hippocampal-dependent memory impairment may accompany stress-induced hippocampal volume reduction, and that the negative effects of stress on the structure and function of the hippocampus may increase with age (Van Petten, 2004; Kuhlmann et al., 2005; Almela et al., 2011; McEwen, 2002; Oitzl et al., 2010; Lupien et al., 2005). Studies have indicated that yoga may be effective in protecting against the negative impacts of stress on cognitive function (Rocha et al., 2012; Manjunath & Telles, 2004; Hariprasad et al., 2013; Froeliger, Garland & McClemon, 2012; Gothe et al., 2013). Further investigation is required to evaluate the potential neuro-protective effects of yoga practice on areas of the brain most susceptible to damage due to stress.

Yoga practice has shown promise in its ability to improve mood and decrease levels of stress and anxiety and to enhance hippocampal-dependent verbal memory function in healthy men. Rocha et al. (2012) compared levels of stress, anxiety, and depression as well as salivary-cortisol levels and verbal memory function in a randomized study comparing healthy young men before and after 6-months of yoga practice versus conventional physical exercise. Following just 6 months of yoga practice, participants showed a significant decrease in self-reported symptoms of depression (BDI), anxiety (BAI), and stress on the Lipp's Stress Symptoms Inventory (LSSI). Additionally, scores for depression, anxiety, and stress were reduced in comparison to a control group engaging in conventional physical activity classes after the 6-month period. The yoga group also showed a significant decrease in levels of salivary cortisol compared to controls with the yoga group decreasing in cortisol levels and the control group showing increased cortisol after 6-months. This elevation of cortisol in the control group may suggest the possibility of an additional external variable influencing group differences other than yoga practice. Because the participants in this study were all men in the Brazilian army, it is possible that the chronic stress inherent in a military lifestyle may have caused the increase in salivary cortisol levels found in the control group, while therapeutic intervention may have prevented a similar cortisol increase in the yoga group. Yoga practice was also found to have a beneficial effect on both short and long-term memory with the yoga group showing a significant improvement in performance on verbal-recall tasks after six months compared to controls. Memory was assessed using a protocol consisting of two lists containing 15 common nouns (target words). Each word was displayed individually on a computer screen. The word recognition test combined target words with distractor words. To evaluate short-term memory, the target word list and word recognition test were repeated for three trials. To increase interference in short-term memory recollection, the Forward Span Digit and Backward Span Digit tests were applied between trails. During the three word recognition trials, participants were instructed to learn the lists for future long-term retrieval. Participants were tested for long-term word retrieval one week later. The entire procedure was repeated twice, once at the beginning of the study and again following six months of intervention. The yoga group performed significantly better on measures of both short and long-term verbal memory recollection. (Rocha et al., 2012). While the results of this study are promising, the generalizability of the research is limited by the sample population of young male enlistees in the Brazilian army. The personalities and daily wellness habits of these participants may not be an accurate reflection of the general population, as well as specialty populations of individuals suffering from mental and physical health concerns who may benefit from yoga therapy intervention.

Yoga has also shown promise in its ability to improve spatial and verbal memory performance in healthy children. Manjunath & Telles (2004) investigated the effects of long-term yoga practice compared to fine arts education on hippocampal-dependent memory performance in middle-school aged children. Ninety children were recruited for participation in this study, with a third of the participants attending a ten day yoga camp (n=30), another third attending a ten day fine arts camp (n=30), and the final third recruited as controls (n=30). Both camps lasted approximately eight hours per day. The fine arts camp included 240 minutes daily of drama training along with recreational sports activities for approximately 60 minutes per day. The training in the fine arts camp also included 120 minutes of specialized training in creative activities such as dance, singing, pottery, painting, sketching, and paper crafts. The yoga camp included 90 minutes of daily asana practice, 60 minutes of daily pranayama (breathing exercise) practice, 30 minutes of "internal cleansing" practices, known as *kriyas*, 90 minutes meditation and devotional practice, and 30 minutes of guided relaxation. The yoga training also included 120 minutes of recreational games, as well as 60 minutes of philosophical story-telling. Results of this study showed significant improvement on measures of spatial memory compared to baseline for the yoga group only. No significant differences were found on measures of verbal memory across all three groups (Manjunath & Telles, 2004). The results of this study indicate that intensive yoga practice may improve spatial learning and memory recall in children. Limitations to the generalizability of this study include the utilization of a sample of middle-school aged children. Middle-school aged children are typically in a stage of brain development that differs greatly from that of adulthood. Children may have more neural plasticity than adults; thus plasticity of hippocampal memory function to treatment effects may differ from adults. Additional limitations include the non-randomized study design as the children participating in this study were voluntarily enrolled in yoga and fine arts camps by their parents. This may reflect specific parenting practices and household demographics that may differ significantly from the general population. Children selected by their parents to voluntarily enroll in fine arts and yoga camps are likely to come from higher socioeconomic backgrounds than children of the same age-group within the general population. Future research should look at the effects of yoga practice on spatial memory across different age groups using a randomized and controlled study design.

Two studies were reviewed investigating the effects of yoga on memory function in healthy populations of both middle-school aged children as well as young adults. While there currently remains a lack of relevant research in this area, the studies reviewed show promising results in support of the hippocampal-dependent memory enhancing effects of long-term yoga practice. One study investigating the effects of long-term yoga practice on stress response and memory in adult men found decreased perceived and physiological stress along with improvements in both immediate and delayed verbal recall, suggesting that the stress reducing-effects associated with yoga may have a positive effect on verbal memory function. Long-term yoga practice has been shown to decrease self-reported symptoms of depression, anxiety, and stress as well as salivary cortisol in response to stress in a population of young adult males in the Brazilian army (Rocha et al., 2012). Given the risky, high-stress environment inherent to a military lifestyle, along with the results showing an increase in salivary cortisol response in controls engaged in regular physical activity, these results indicate the possibility that yoga may not only decrease salivary cortisol, it may also prevent an increase in cortisol response induced by a high-stress lifestyle. Yoga practice was also found to have a beneficial effect on both short and long-term memory with the yoga group showing a significant improvement in performance on verbal-recall tasks after six months compared to controls. While, on its own, the use of an all-male sample population poses limitations to the generalizability of the study's results, overall this study helps provide us with a better understanding of how results of the other studies reviewed, which have mainly included female sample populations, may generalize to the population as a whole, regardless of gender. The second study reviewed investigated the effects of a 10-day yoga camp versus a 10-day fine arts camp on hippocampal-dependent spatial and verbal memory in middle-school aged children. The results of this study indicated that intensive yoga practice may improve spatial, but not verbal, memory performance in middle-school aged children (Manjunath & Telles, 2004). The results of this study are limited in generalizability due to the sample population of middle-school aged children who were self-selected by their parents to attend the two camps. The socioeconomic status, parental involvement, and overall upbringing of these children are likely to differ from the general population. While the results of these two studies show the potential for a positive influence of yoga on memory performance, further investigation is needed, utilizing a randomized and controlled study design, in order to replicate these results. In addition to further investigation into the effects of yoga on memory in healthy, younger individuals, it is also important to investigate the effects of yoga on memory in senior populations who are more at risk for hippocampal volume loss and memory impairment.

Yoga and memory in the elderly. Research has indicated that physical activity paired with cognitive stimulation work together to prevent age-related cognitive decline and dementia in the elderly. Regular physical activity alone has shown a moderate-to-strong positive effect on cognition across several studies (Hariprasad & Koparde et al., 2013; Lam et al., 2012; Maki et al., 2012, Lautenschlager et al., 2008; Baker et al., 2010). Studies have shown yoga to be effective against the negative impacts of stress on memory function. In a randomized clinical trial, Hariprasad & Koparde et al. (2013) investigated the benefits of yoga therapy intervention on cognitive function in 87 mentally healthy residents of elderly-care facilities, comparing performance on a variety of tasks after one month of daily and six additional months of weekly yoga practice between elderly adults in a yoga and waitlist control group. Participants with dementia, neurodegenerative disorders, stroke, major depressive disorder, psychosis, anxiety disorder, severe hearing and visual impairment, and inability to physically perform yogic practices were not included in this study. Results of this study showed significant improvement in immediate and delayed verbal recall (Rey's Auditory Verbal Learning Test, *RAVLT*), visual memory (Rey's Complex Figure Test, *CFT*), attention and working memory (Wechsler Memory Scale [WMS]- digit and spatial span), verbal fluency (Controlled Oral Word Association, *COWA*), executive function (Stroop color word interference test), and processing speed (Trail Making Test A and B) compared to baseline and controls following six-months of regular yoga practice. Moreover, the waitlist control group showed a decline in performance compared to baseline scores in executive function following the six-month waiting period, indicating that regular yoga practice may slow the progression of cognitive decline while improving overall cognitive performance in elderly populations (Hariprasad & Koparde et al., 2013). The results of this study are limited by its moderate sample size along with the high drop-out rate of approximately 25%. The high drop-out rate may indicate problems with patient compliance, posing a potential problem when considering yoga as a therapeutic intervention for use with elderly populations.

In a follow-up to their previous study, Hariprasad & Varambally et al. (2013) looked at the neurobiological effect of yoga on the hippocampus in a small number of elderly participants recruited for six months of yoga intervention. In this study, seven healthy elderly subjects engaged in six months of yoga intervention and received MRI scans prior to intervention and at a six-month follow-up. Volume measurements for both the hippocampus and superior occipital gyrus were generated from the entire image dataset using an automated algorithm called Diffeomorphic Anatomical Registration Using Exponential Lie Algebra (DARTEL) technique, thus eliminating the potential for experimenter bias. The results of the study indicated a significant increase in volume in the bilateral hippocampus with no change in volume observed in the superior occipital gyrus, a brain region observed as a control. A behavioral and functional correlate to the observed neuroplastic effect on the hippocampus was not attempted due to the small sample size of only seven participants (Hariprasad & Varambally et al., 2013). The results of this study were limited by its small sample size and the absence of a control group. Given the potential importance of these results, showing increases in hippocampal volume in an age group that, on average, typically experiences rapid decreases in hippocampal volume, it would be beneficial to attempt to confirm the results in a controlled study using a larger sample size.

Two studies were reviewed investigating the effects of long-term yoga practice on memory function and hippocampal volume. The first study showed that yoga may hold promise in its ability to slow the progression of age-related memory loss and cognitive decline while improving overall cognitive performance in elderly populations (Hariprasad & Koparde et al., 2013). The study was limited by it's moderate sample size and high drop-out rate, indicating potential problems with patient compliance should yoga be utilized as a therapeutic intervention for improving cognitive performance in elderly populations. The second study used MRI to look at looked at the neurobiological effect of yoga on the hippocampus in a smaller subpopulation of seven participants from the previous study. Results of this study showed an increase in hippocampal volume compared to baseline following six months of yoga intervention, suggesting that yoga may hold value in increasing hippocampal volume in the elderly during a stage of life when hippocampal volume is typically known to decline. The results of this study are limited by its small sample size and lack of control group. Additionally, researchers involved in the study opted to forgo analyses to determine a correlation between hippocampal plasticity and cognitive function due to the small sample size (Hariprasad & Varambally et al., 2013). Future research should aim to replicate these results using larger participant samples in order to determine a behavioral and functional correlate to any observed neuroplastic effect of yoga practice on the hippocampus.

Discussion

Studies investigating the effects of yoga on both perceived and physiological stress response have indicated that long-term yoga practice may hold therapeutic value in reducing perceived stress, while a single yoga class may reduce both perceived stress and the cortisol stress response in healthy populations. Based on the studies reviewed investigating the effects of yoga practice on cortisol stress response, there appears to be a reduction in salivary cortisol following short-term, but not long-term, yoga intervention. While this difference between short and long-term cortisol results may be due to methodological limitations posed by the long-term studies, it is also possible that yoga has an immediate, short-term cortisol-reducing effect that is not sustained over time. In addition to reductions in perceived and physiological stress, the results indicated that yoga improved overall quality of life, cardiovascular health, mood, emotional well-being, and vitality (Yoshihara et al., 2011; Smith et al., 2007; Granath et al., 2006; Satyapriya et al., 2009; Cowen & Adams, 2005; Michaelsen et al., 2005).

While studies included in this review indicate yoga to be a potentially beneficial therapeutic intervention for improving memory performance, there are few studies to date in this area. Specifically, further research is needed to investigate the effects of yoga intervention on hippocampal volume and related memory function, as the hippocampus is a brain area of particular interest in investigating the effects of chronic stress on the brain. Taken together, the results of the studies reviewed which investigated the effects of yoga on hippocampal-dependent memory function indicate that yoga may improve both short and long-term verbal recall in both young adults and seniors, but less is known about the effects in children. Improvements in spatial memory performance were shown in middle-school children following yoga intervention; however, spatial memory was not investigated in the adult yoga trials. Results indicating yoga may increase spatial memory in children warrant further investigation into yoga's effects on spatial memory in adults. Long-term yoga intervention has also been shown to increase bilateral hippocampal volume, along with hippocampal-dependent memory function in seniors. Replication of these results is very important, because an increase was found in bilateral hippocampal volume during a life stage in which we should expect to see hippocampal volume loss. Seniors are particularly at-risk for normal hippocampal volume loss with aging along with declined in episodic memory function. Moreover, accelerated hippocampal volume loss with aging has been associated with increased risk for Alzheimer's disease (Convit et al., 1996; Kaye et al., 1997; Schuff et al., 2009). It is crucial that future studies aim to replicate these results, as yoga intervention may have implications for the prevention and treatment of both age-related memory impairment and Alzheimer's disease.

Upon reviewing the research, it's apparent that there are many potential benefits to utilizing yoga as a therapeutic mind-body intervention to aid in alleviating chronic stress and improving memory function in both young and elderly populations. There are many reported benefits of regular yoga practice with very little risk involved, potentially making it an ideal supplemental or alternative intervention for individuals experiencing chronic stress as well as those at risk for age related memory dysfunction, which may be exacerbated by chronic over-activation of the body's stress response system. When practiced in a safe atmosphere under appropriate guidance from an experienced, well-trained yoga instructor or yoga therapist, the risk for injury is minimal. Moreover, the intensity of asana practice may be tailored to the needs of the individual, further decreasing risk for injury, particularly in individuals recovering from injury or illness, or those with mobility issues. Another important component of yoga is mindfulness, which an abundance of research has supported as beneficial to psychological well-being (Brown & Ryan, 2003; Grossman et al., 2004; Davis & Hayes, 2011; Zelazo & Lyons, 2012). Becoming involved with yoga also helps build a sense of community, which may be especially beneficial to elderly populations who all-too-often live in isolation from friends and family in nursing homes and other elderly care facilities. The physical risks involved with yoga practice are minimal, and there are few potential barriers to the accessibility of yoga. While the cost of yoga classes and supplies, such as yoga mats and other props, is often quite high, many yoga studios offer weekly classes for free or by donation, offering free use of the studio's yoga mats and other pricey yoga equipment. Additionally, many community-based nonprofit organizations, centered around bringing yoga to underserved populations, are continuing to make yoga more accessible to people of all backgrounds and socioeconomic status. Moreover, the cost of maintaining a regular yoga practice may prove to be far less than the cost of traditional psychotherapy and, as indicated by a review of the research, the stress-reducing effects of yoga are comparable to both cognitive behavioral therapy (CBT) and progressive muscle relaxation training. Although yoga classes may be less accessible in certain communities and geographic locations, the extensive availability of yoga DVDs along with free tutorials via online media outlets make a home-based practice accessible to almost anyone. Regular yoga practice does require considerable time and dedication, creating potential issues with patient compliance; however, internet-based yoga classes are becoming increasingly common, many of which are provided for free or at low cost, making the maintenance of a consistent yoga practice more convenient and affordable.

Stress is a major contributing factor to the onset and maintenance of most forms of chronic illness prevalent today. In 1998, a study following 46,026 employees working in corporate environments found that individuals who perceived themselves as "high stress" had a 46% higher risk for poorer health outcomes (Goetzel, 1998). The prevalence of chronic disease has reached epidemic proportions in the United States. In 2005, approximately 133 million Americans suffered from at least one chronic condition, and by 2020 experts estimate that number will grow to include a staggering 157 million. Chronic illness accounts for 75 percent of U.S. health care spending, with the seven most common chronic illnesses (cancer, diabetes, hypertension, stroke, heart disease, respiratory conditions, and mental disorders) costing nearly $1.3 trillion annually (National Conference of State Legislators, 2013). Given these alarming statistics, it remains crucial that we continue to investigate the efficacy of stress-reduction techniques, including mind-body therapies such as yoga.

While additional evidence continues to accumulate suggesting the beneficial effects of yoga for decreasing both perceived and physiological stress-response, improving memory, and preventing stress and age-related hippocampal volume loss, more investigation is still needed to fully determine the efficacy of yoga as a beneficial mind-body therapy. In order to adequately determine the effectiveness of yoga for reducing stress response and improving memory function, making it a good option for minimizing healthcare costs, future studies should give special consideration to the following points. No one study is expected to address all of these points; studies that begin to address these topics will start to accumulate the evidence needed to propel the field of yoga therapy forward. Future research should aim to investigate the stress-reducing effects of both short and long-term yoga practice in large samples of both young adult and senior populations using a randomized and controlled study design. Researchers should also aim for a participant sample with an equal number of male and female participants. Future investigation should aim to compare the effects of yoga versus other types of physical exercise and should include a waitlist control group. To reflect a typical Western yoga practice, yoga intervention should contain three components: *asana*, *pranayama*, and meditation. To determine the effects of yoga on stress response, a long-term investigation should aim for intervention lasting at minimum forty days, ideally lasting six months or longer. Measures of perceived stress, using a valid and reliable measure such as the Perceived Stress Scale (PSS), along with salivary cortisol in response to stress should be taken at baseline, following the first yoga class, and again following the conclusion of long-term yoga intervention. In order to accurately measure salivary cortisol in response to stress, the Trier Social Stress Test (TSST) should be utilized to elicit a physiological stress response. Salivary cortisol should be measured at before and after completion of the TSST in order to accurately determine if a cortisol stress response is present. Menstrual cycle phase should be controlled for in samples including young, pre-menopausal women in order to account for naturally occurring fluctuations in salivary cortisol across the menstrual cycle. Other physiological markers of sympathetic nervous system activation, such as heart rate, blood pressure, and heart rate variability may also be included in future research. To determine the effects of both short and long-term yoga practice on hippocampal dependent memory, measures of both long and short-term verbal recall should be taken at baseline, following the first yoga class, and following the completion of long-term intervention. Measures of spatial memory should also be included to determine if the spatial memory enhancing effects of yoga seen in children in prior research are also applicable to adults. To determine structural changes in the hippocampus, MRI should be used to investigate changes in hippocampal volume comparing volume measures at baseline to measures following completion of yoga intervention. Changes in hippocampal volume should be compared against measures of hippocampal-dependent memory to determine a correlation. Measures of hippocampal volume, along with verbal and spatial memory, should also be compared against measures of perceived stress and cortisol stress response to determine whether a relationship exists between changes in stress and memory function following yoga intervention. Special attention should be paid toward utilizing yoga as an intervention to both prevent hippocampal volume loss and memory decline and improve hippocampal function and related memory performance in elderly populations who are more at risk for cognitive dysfunction and memory loss.

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