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THE EFFECTS OF AN 8-WEEK YOGA INTERVENTION ON COGNITION AND
FUNCTIONAL FITNESS IN OLDER ADULTS

BY

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DISSERTATION

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ABSTRACT

Yoga practice is becoming increasingly popular in the West and there is growing interest in the mental benefits, including cognitive benefits that this mind-body exercise may offer. In spite of being a topical area of enquiry, few randomized control trials have been conducted to explore the cognitive benefits of yoga practice. The purpose of this study was to examine the efficacy of yoga in improving cognitive performance and functional fitness in middle aged and older adults. Participants (N=118) were randomly assigned to a yoga group (n=61) or a stretching control group (n=57). Both interventions lasted 8 weeks with structured hour long exercise classes conducted 3x/week. Participants in the yoga group engaged in Hatha yoga postures, breathing and meditative exercises whereas the control participants engaged in stretching exercises. Data were collected at baseline and following the 8 week intervention. Results showed that the yoga group performance was significantly better than the control group on cognitive measures assessing executive function, attention and processing speed. Changes in salivary cortisol and self-report anxiety measures partially explained the variance in the cognitive improvements as a result of yoga practice. The functional results showed that yoga was as good as the stretching group in improving strength, balance, flexibility and mobility in this population. To our knowledge this is the first randomized control trial to systematically examine the cognitive benefits of yoga in a sedentary older adult population. Overall the results of this study provide strong evidence for the effects of regular yoga practice on cognition and future research needs to examine the mechanisms underlying the yoga-cognition relationship.

Keywords: yoga intervention, executive function, functional fitness, older adults, salivary cortisol

To Aajoba

The most loving grandfather and a wonderful human being.

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CHAPTER 1

INTRODUCTION

Older adults are the fastest growing segment of the population in the U.S. as well as in other industrialized countries. The twenty-first century will witness even more rapid aging than did the century just past (United Nations, 2002). Aging is associated with not only the risk of rapid declines in cognitive function (Salthouse, 2009), but also increased functional limitation [Center for Disease Control (CDC), 2004a], loss of independence and reduced quality of life (Guralnik & Ferrucci, 2003). The incidence of functional limitations and disability increases with age and chronic disease (CDC, 2004a). These declines have major medical, social and economic implications and incur large public health care costs as these individuals have compromised physical as well as psychological function. For many decades, researchers have been testing the efficacy of physical activity based interventions for enhancing these functions in older adults. Given the increasing popularity of complementary and alternative medicine (CAM) and its suitability to older adult population exploring its physiological and psychological benefits is fundamental. However, little is known about the efficacy and mechanisms through which mind-body therapies like yoga affect physical and mental health.

Yoga is a commonly practiced, mind-body activity that has components centering on meditation, breathing, and postures. In recent US surveys of adults, 7.5% reported having used yoga at least once in their lifetime and 3.8%–5.1% reported having used it in the previous 12 months (Barnes, Powell-Griner, McFann & Nahin, 2004; Saper et al., 2004). The use of yoga and other CAM therapies is becoming increasingly popular, especially among older adult populations who use these alternative therapies for aging-related chronic conditions such as back pain, arthritis, anxiety, depression, and cancer (Cherniack, Senzel & Pan, 2001; Astin, Pelletier, Marie & Haskell, 2000; Eisenberg et al., 1998; Flaherty et al., 2001). The increasing proportion

of the older population with comorbidity is likely to amplify the number of individuals seeking CAM to manage their chronic health problems and to improve their quality of life (Williamson, Fletcher & Dawson, 2003). Yoga practice involves physical postures that mimic stretching, balance and strength exercises, and breathing and meditation that involve an active attentional component. Given the age related declines in cognitive function and functional limitations, yoga appears to be a form of exercise that targets these two domains of functioning. However, little is known about the effectiveness of yoga in maintaining or enhancing cognitive function and functional fitness in older adults.

Cognitive functioning is one aspect of human functioning that has received a great deal of attention due to both its intrinsic age-related changes, as well as the vital role that cognition plays in our lives. Cognitive functioning refers to the efficiency and accuracy of various mental processes. Salthouse (Salthouse & Ferrer-Caja 2003; Salthouse, 2009) has demonstrated that several aspects of cognitive function including reasoning, spatial visualization, processing speed and memory steadily decline with age and such declines have been shown to directly influence every day function and activity for older adults (Moody-Ayers, Mehta, Lindquist, Sands & Covinsky, 2005; Tucker-Drob, 2011). Cognitive processes such as executive control, working memory, episodic and semantic memory, verbal fluency, and reasoning, have all been shown to decline as a function of age (Bäckman, Small, Wahlin, & Larsson, 2000; Nilsson, 2003; Nilsson et al., 2004; Prull, Gabrieli, & Bunge, 2000; Wegesin et al., 2000). Since Spirduso's (1975) pioneering study, numerous studies have been conducted to examine the relationship between physical activity and cognitive performance. Both narrative and meta-analytic reviews have concluded that a positive relationship exists between physical activity and cognitive performance (Sofi et al., 2010; Angevaren et al., 2008; Colcombe & Kramer, 2003; Etnier, Nowell, Landers,

& Sibley, 2006; Etnier et al., 1997; Heyn, Abreu, & Ottenbacher, 2004; Hillman, Erickson, & Kramer, 2008; Kramer & Erickson, 2007; Sibley & Etnier, 2003). Many randomized controlled trials have been conducted to determine the effects of physical activity on cognitive function, however, due to the inconsistency of exercise intervention modes, methods and measures, coming to a consensus on this relationship is difficult (Chang, Nien, Tsai & Etnier, 2010; van Uffelen et al., 2008). Additionally, there is no consensus on whether aerobic, non-aerobic or a combination of these activities is more effective in producing such changes in cognitive function. Findings do suggest, however, that participation in physical activity interventions does not have a detrimental effect on cognitive function and may result in some positive and beneficial effect on at least one aspect of cognitive function. Moreover, most studies examining the chronic exercise effects on cognition in older adults have focused on aerobic (primarily walking) exercise and little is known about the physical activity based CAM therapies such as yoga and its effectiveness in promoting cognition in older adults.

Preliminary evidence suggests that yoga has a down regulating effect on both the sympathetic nervous system and the hypothalamic-pituitary adrenal (HPA) axis in response to stress (Ross & Thomas, 2010). Stress, in general, may lead to anxiety and depression, involving chronic sympathetic activation and activation of HPA (Esch, Stefano, Fricchione & Benson, 2002). Cortisol, a stress hormone and an end-product of the HPA axis has been assessed in some yoga studies and lower cortisol levels have been associated with improved affect (West et al., 2004; Kamei et al., 2000; Schell, Allolio & Schonecke, 1993). It is plausible that this may be one mechanism that leads to improved cognitive performance with yoga practice; however, this relationship has yet to be systematically examined.

The physical movement and postures of yoga may serve as a suitable approach to improve functional fitness, another critical domain of functioning that declines with aging. Functional performance is the extent to which one is capable of performing everyday activities such as walking, using stairs, lifting heavy objects. Over 34% of adults aged 65 or older report limitations with even the most basic activities of daily living (ADLs), such as bathing and dressing (US Census Bureau, 2006). Fortunately, there is good evidence that functional declines are attenuated by engaging in protective behaviors such as physical activity (Keysor & Jette, 2001; Paterson & Warbuton, 2010). Several descriptive and prospective studies, clinical trials and contemporary reviews of literature have examined the relationship between physical activity and physical function (Miller et al., 2000; Simons, McCallum, Friedlander, & Simons, 2000; Fried & Guralnik, 1997; Keysor, 2003; Keysor & Jette, 2001). Similar findings have been reported in the literature, identifying a sedentary lifestyle as an important risk factor for subsequent functional declines (McGuire et al., 2007; Seeman & Chen, 2002). Muscular strength, aerobic endurance, flexibility, agility/dynamic balance, and body mass index have been identified as distinct components of functional fitness (Rikli & Jones, 1997, 2001). Yoga involves standing, seated and supine postures that target all major muscle groups and can enhance these functional fitness components, thereby improving ADLs such as walking speed, rising and transferring from a chair, and climbing stairs that are critical determinants of quality of life.

Although the National Institutes of Health endorse the study of CAM, physical activity based therapies such as yoga have not been comprehensively studied to assess their physical and psychological benefits. Only one randomized controlled trial exists that has examined the effects of yoga on cognition and quality of life in healthy older adults (Oken et al., 2006). Healthy men

and women (n=135) aged 65-85 years were randomized to 6-months of Hatha yoga, aerobic walking or a waitlist control group to determine effects on cognitive function, fatigue, mood, and quality of life. While the yoga group showed significant improvement in quality-of-life and physical measures compared to exercise and wait-list control groups, no relative improvements in cognitive function were seen in the exercise intervention groups compared to the wait-list control group. The authors acknowledged two major reasons that explain these null findings. Firstly, the seniors recruited in the study were physically active at baseline engaging up to 3.5 hours per week (30 minutes per day) of physical activity. This may have resulted in a ceiling effect as the literature suggests a positive relationship between physical activity and cognitive function. Secondly, the exercise intervention groups met only once a week as compared to more frequent sessions in other successful randomized controlled trials (Colcombe & Kramer, 2003). It remains to be determined whether a yoga exercise program would show cognitive and functional benefits in a sedentary healthy older adult population.

Primary Aims and Hypotheses

In the light of this literature, the proposed randomized controlled trial investigated the effects of an 8-week yoga intervention on cognition and functional fitness in older adults. The primary outcome of interest in this study was the cognitive performance on the attention network test, n-back, task switching, trails making and pattern recognition tasks. The secondary outcome variable was functional fitness as measured by the tests of balance, flexibility, muscular strength and mobility. Specifically, it was hypothesized that:

- 1) Following the 8-week yoga intervention, participants in the yoga intervention group would show improved performance on measures of executive function when compared to the stretching control group.

2) The 8-week yoga intervention would show similar improvements in participants' functional fitness scores on the battery of tests measuring balance, strength, flexibility and mobility as compared to the stretching control group.

3) Changes in salivary cortisol levels, anxiety and stress scores from pre to post intervention would be associated with cognitive performance within the yoga group.

CHAPTER 2

LITERATURE REVIEW

The proposed randomized controlled trial will evaluate the effectiveness of yoga as a form of physical activity in improving physical function and cognition in sedentary older adults. The subsequent sections will briefly review the following: cognition and functional fitness declines associated with aging, current physical activity prevalence and recommendations for older adults, the functional and cognitive benefits of physical activity for older adults, yoga as a form of physical activity, the trends in yoga participation and popularity in the US and a review of yoga intervention studies with older adults that have provided preliminary evidence for cognitive, functional and psychological benefits. The proposed mechanisms and models by which yoga leads to improved physical and mental health are also discussed.

Aging and Cognitive Changes

There is little question that aging is a prevalent and enduring problem in the United States and elsewhere. As we age, our physical and mental abilities change considerably. It has been well-documented that increased age is associated with lower performance on various measures of cognitive functions, such as memory, attention and reaction time (Salthouse, 1993; Schaie, 1996). Cross-sectional comparisons have consistently revealed that increased age is associated with lower levels of cognitive performance, even in the range from 18 to 60 years of age (Salthouse, 2009). The body and brain mature rapidly during the early years of life, enabling us to gain mastery of our surroundings. As we mature into the second decade, most physical and central nervous systems are matured, and maintained for a short time (Roberts, 1972). Starting in the 40's, and continuing during the remainder of life, a gradual deterioration of behavioral and biological functioning occurs within the brain and body. Although there is evidence for average declines in cognition with aging, there is wide variability in the nature and extent of these

changes (Hofer & Alwin, 2008). As individuals age, many aspects of information processing become less efficient, including speed of processing, working memory capacity, inhibitory function, and long-term memory (Park & Reuter-Lorenz, 2009). Park and colleagues (2002) conducted a cross-sectional study with 345 adults aged 20-92 years and found that there are gradual age-related declines in the cognitive mechanisms of speed, working memory, and long-term memory, beginning in young adulthood. In the Victoria Longitudinal Study (Hultsch, Hertzog, Dixon & Small, 1998) the authors tested 250 middle-aged and older adults three times over 6 years. Data from this study also show strikingly similar findings for speed of processing, working memory, list recall, and vocabulary. Despite the age related declines in cognitive functioning, the consensus is that cognitive performance can be optimized and maintained by modifiable lifestyle factors and engagement in health-promoting or protective behaviors (Yaffe et al., 2009). With the rapid ageing of the world's population, investigating protective factors that may prevent or delay age-related disorders has become a new public health priority. Physical and psychological benefits of increased physical activity have been widely documented in healthy and chronically ill older adults (Warburton, Nicol & Bredin, 2006; Peterson & Pedersen, 2005; Geffken et al., 2001; Mazzeo et al., 1998).

Physical Activity Recommendations for Older Adults

Although regular physical activity has been demonstrated to be critical for the promotion of health and function as people age, persons over 50 years of age represent the most sedentary segment of the adult population. The Centers for Disease Control and Prevention (CDC) Physical Activity Guidelines for Americans were released in 2008 and state that all adults should avoid inactivity and that some physical activity is better than none. This is particularly the case for persons aged 75 and above, as only 12% of adults aged 75 and older engage in 30 minutes of

moderate physical activity on 5 or more days per week, and 65% report no leisure physical activity (USDHHS, 2000).

The most recent recommendations from the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) (Haskell et al., 2007) suggest that to promote and maintain health all healthy adults need moderate-intensity aerobic (endurance) activity for a minimum of 30 minutes on five days each week or vigorous-intensity activity for a minimum of 20 minutes on three days each week. These recommendations further suggest that combinations of moderate and vigorous exercise can be used to meet the requirements and that bouts of moderate-intensity exercise lasting a minimum of 10 minutes can be accumulated to achieve the 30 minute minimum. In addition to the aerobic exercise guidelines, the CDC recommends that adults should perform strength training at least three times per week on non-consecutive days, involving moderate or high intensity muscle-strengthening and balance activities targeting all major muscle groups. Although the importance of a physically active lifestyle for physical and psychological health is well-established (Penedo & Dahn, 2005), only 45% of the adult population in the US meets the public health recommendation of accumulating 30 minutes or more of moderate activity on five or more days of the week (CDC, 2008). These alarming statistics have contributed to Healthy People objectives focused on increasing physical activity in vulnerable groups such as aging adults.

The research studies over the past four decades have suggested that physical activity may benefit not only our physical bodies, but our mental functioning as well. The following sections review the physical activity, cognition and functional fitness literature.

Physical Activity and Cognition

Since Spirduso's (1975) pioneering study and findings that active older adults had significantly better cognitive performance than inactive older adults, several studies have been conducted to examine the relationship between physical activity and cognitive performance. This relationship has been examined for various cognitive functions using cross sectional, longitudinal and interventional methodologies. The association has been examined for chronic and acute exercise using specific as well as general measures of cognition, behavioral and neuroimaging techniques, in both animals and humans. Although the results of empirical studies have not been consistent, authors using meta-analytic techniques and narrative reviews have concluded that a positive relationship exists between physical activity and cognitive performance (Angevaren et al., 2008; Colcombe & Kramer, 2003; Etnier, Nowell, Landers, & Sibley, 2006; Etnier et al., 1997; Heyn, Abreu, & Ottenbacher, 2004; Hillman, Erickson, & Kramer, 2008; Kramer & Erickson, 2007; Sibley & Etnier, 2003, McAuley, Kramer & Colcombe, 2004).

A number of interventional studies have been conducted over the past decades; however, their outcomes have been mixed. Netz (2009) conducted a review to examine the relationship between physical activity and cognition for interventional studies. Out of the 16 studies reviewed, 13 studies applied aerobic exercise as an intervention program. Eight of these studies reported improvements (Dustman et al., 1984; Fabre, Chamari, Mucci, Masse-Biron, & Prefaut, 2002; Hassmen & Koivula, 1997; Hawkins, Kramer, & Capaldi, 1992; Kara, Pinar, Ugur, & Oguz, 2005; Kramer et al., 1999; Moul, Goldman, & Warren, 1995; Rikli & Edwards, 1991), while the other five (Blumenthal et al., 1989; Blumenthal et al., 1991; Emery & Gatz, 1990; Panton, Graves, Pollock, Hagberg, & Chen, 1990; Hill, Storandt, & Malley, 1993) did not find that aerobic exercise training had a beneficial effect on cognitive functioning. Two studies

applied resistance training as an intervention, but their results on cognitive functioning were ambiguous: one found improvement in some memory tasks (Perrig-Chiello et al., 1998), while the other did not find any improvement (Tsutsumi, Don, Zaichkowsky, & Delizonn, 1997). Another study applying general physical activity including strength, aerobic, balance and stretching (Williams & Lord, 1997) did report improvement in memory. It is difficult to determine why some studies find improvements in performance with enhanced fitness while others fail to observe such a relationship. Clearly, there are possible methodological reasons for the mixed pattern of results. For example, the length and intensity of fitness interventions have varied quite widely across studies. Also, the use and nature of control groups have varied, from failure to include any control groups (Kara et al., 2005) to failure to include non-aerobic exercise groups (Fabre et al., 2002). Finally, the types of perceptual and cognitive tasks that have been employed to assess mental function have also been quite varied.

Colcombe and Kramer (2003) in their meta-analysis reviewed RCTs conducted with sedentary healthy older adults and classified the varied cognitive tasks used in this literature into four categories: i) speed tasks - tasks such as simple reaction time or finger tapping, which presumably tap low-level central nervous system function uncontaminated by subject strategies or high-level cognition, ii) visuospatial tasks – tasks involving spatial and visual information, iii) controlled processing - tasks that require controlled, effortful processing, and iv) executive function tasks – tasks that involve coordination, inhibition, scheduling, planning, and working memory. They found that more complex tasks benefit more from physical activity participation than simple tasks ($g=0.68$, $p<.05$ for executive function tasks; $g=0.461$, $p<.05$ for control tasks; $g=0.426$, $p<.05$ for spatial tasks; and $g=0.274$, $p<.05$ for speed tasks). While executive-control processes showed the largest benefit from aerobic fitness training, controlled processes, which at

least partially overlap with executive processes and visuospatial processes, also showed reliable benefits from aerobic training. In addition, participation in relatively brief training programs provided at least as much benefit as moderate training, but not quite as much as long-term training programs, while short bouts of exercise (less than 30 min.) had very little impact on cognitive function. Overall, they found that fitness training increased performance by 0.5 SD on average, regardless of the type of cognitive task, the training method, or participants' characteristics. More recently, Smith and colleagues (2010) conducted a meta-analysis to examine this relationship and reported that individuals randomly assigned to receive aerobic exercise training demonstrated only modest improvements in attention and processing speed ($g=0.158$, $p<.003$), executive function ($g=0.123$, $p<.018$) and memory ($g=0.128$, $p<.026$). The significant variation reported in these two meta-analytic reviews is possibly due to the differences in the study characteristics of the reviewed RCTs. While the Colcombe & Kramer (2003) review included only RCTs conducted with sedentary healthy older adults, Smith and colleagues (2010) reviewed all interventional studies which reported mean sample age as > 18 years. Regardless of the methodological differences, both these meta-analyses suggest that participation in aerobic physical activity can help improve cognitive function particularly in the domain of processing speed and executive function.

Executive function in the physical activity literature has included the behaviors of planning, task coordination, initiation and stopping of behaviors, and processing of semantic information. These cognitive control processes regulate thought and action. Over time, the specific descriptors used to describe the subcomponents of executive function have been modified slightly so that executive function in the physical activity literature is now typically described as planning, scheduling, inhibition, and working memory (Colcombe & Kramer, 2003;

Hillman et al., 2006; Kramer et al., 1999). Recent psychological and neuropsychological research suggests that executive functions are multifaceted and that different types of executive functions are correlated but separable (Miyake et al., 2000). They identified mental set shifting, inhibition of pre-potent responses and information updating and monitoring as the three key functions of executive control processes. Shifting is an executive function that concerns going back and forth between multiple tasks, operations, or mental sets (Monsell, 1996). It is also referred to as “attention switching” or “task switching,” in the cognition literature. Inhibition concerns one’s ability to deliberately inhibit dominant, automatic, or pre-potent responses when necessary. Information updating and monitoring are functions of the working memory which refer to one’s ability to hold and remember information for a short period of time. These executive functions involve encoding incoming information for relevance to the task at hand and then appropriately revising the items held in working memory by replacing old, no longer relevant information with newer, more relevant information (Morris & Jones, 1990). Working memory appears to be the most important type of memory for everyday life and is the most often studied (Balota, Dolan & Duckeck, 2000; Luo & Craik, 2008; Zacks, Hasher & Li, 2000). Salthouse (Salthouse & Ferrer-Caja, 2003; Salthouse, 2009) has demonstrated that several cognitive functions including reasoning, spatial visualization, processing speed and memory steadily decline with age and such declines in neurocognitive function have been shown to directly influence every day function and activity for older adults (Moody-Ayers et al., 2005; Tucker-Drob, 2011).

Although a generally positive effect of physical activity on cognitive performance has been demonstrated for older adults, one limitation of this literature is that it has largely focused on aerobic exercise (Brisswalter, Collardeau & Renae, 2002; Colcombe & Kramer, 2003;

Erickson & Kramer, 2009; Tomporowski, 2003). The focus on aerobic forms of exercise was largely based on the presumed role of cardiovascular fitness as a potential mechanism of the relationship (Chodzko-Zajko, 1991; Colcombe et al., 2004). However, findings from meta-analytic reviews suggest that cardiovascular fitness is not the most likely mechanism of the effect (Angevaren et al., 2008; Etnier et al., 2006). This then suggests that increases in cardiovascular fitness are not necessary for cognitive benefits, and, thus, other forms of physical activity that do not particularly emphasize improvements in cardiovascular fitness should be explored.

Furthermore, given that the ACSM guidelines promote cardiorespiratory, resistance, and flexibility exercises for older adults (Thompson, Gordon & Pescatello, 2009), examination of the potential benefits of other forms of exercise for cognitive performance is warranted.

Recently, a few researchers have shown that resistance exercise also has positive effects on cognition (Cassilhas et al., 2007; Chang & Etnier, 2009a, Chang, Etnier & Barella, 2009b; Perrig-Chiello et al., 1998; Pontifex et al., 2009). However, to date, other types of exercise modalities such as flexibility or mind-body exercises have been largely ignored in the physical activity and cognition literature. Researchers have suggested that our understanding of the effect of different exercise modalities on cognition is still in its infancy; thus, it is important to further examine other modes of exercise as potentially benefiting cognitive performance (Erickson & Kramer, 2009; Kramer et al., 2005). The following sections reviews yoga, a mind-body based non-aerobic form of physical activity and it's potential to benefit cognitive function.

Yoga as Physical Activity

According to the National Center for Complementary and Alternative Medicine, CAM is defined as a group of diverse medical and health care systems, practices, and products that are not presently considered to be part of conventional medicine. CAMs encompass a range of mind-

body methodologies, such as yoga, tai-chi, and meditation that may be beneficial to the health of their practitioners. Yoga is an ancient Indian science and way of life that includes the practice of specific postures, regulated breathing and meditation (Taimini, 1961). It is designed to bring balance and health to the physical, mental, emotional, and spiritual dimensions of the individual. Yoga is often depicted metaphorically as a tree and comprises eight aspects: *yama* (universal ethics), *niyama* (individual ethics), *asana* (physical postures), *pranayama* (breath control), *pratyahara* (control of the senses), *dharana* (concentration), *dyana* (meditation), and *samadhi* (bliss) (Iyengar, 1979).

A popular practice in India, yoga has become increasingly more popular in Western societies (Garfinkel & Schumacher, 2000; Chandler, 2001; Raub, 2002) with a report suggesting that 15 million Americans have practiced yoga at least once in their lifetime (Saper, Emsberg, Davis, Culpepper, Phillips, 2004). Currently Yoga is among the 10 most widely practiced forms of complementary healthcare in the U.S. (Barnes et al., 2004). A recent survey of 5,050 people estimated that 7% of US adults, i.e. 15.6 million people practice yoga and Americans spend \$5.7 billion a year on yoga classes and products, including equipment, clothing, vacations and media, DVDs, videos, books and magazines (Macy, 2008). Wolsko and colleagues (2004) in their national survey found that 1 in 5 Americans had used a mind-body technique and 22% of the users were aged 50 years or older. Yoga classes are now offered at 75% of all U.S. health clubs (Corliss, 2001), as well as at yoga studios and in private homes. Yoga may be attractive as an alternative to traditional aerobic and strength training programs because it requires little space, virtually no equipment, has limited side effects (Garfinkel & Schumacher, 2000; Raub, 2002, Labarthe & Ayala, 2002) and, with its focus on relaxation, body awareness, and meditation provides a qualitatively different exercise experience which may be perceived as less strenuous

and more pleasurable. Given these characteristics, yoga satisfies many of the conditions which have been shown to be strongly related to participation in physical activity, such as few barriers to participation, being enjoyable (Sallis et al., 1989), and having a low-to-moderate intensity (Pollock, 1988). Yoga is an alternative form of physical activity which may assist in achieving recommended levels of physical activity for some individuals. Research that has evaluated the energy expenditure of yoga indicates that yoga is essentially equivalent to moderate forms of exercise (Hagins, Moore & Rudle, 2007; DiCarlo et al., 1995).

Hatha yoga is the most common form of yoga practiced in North America and involves the practice of physical postures in conjunction with awareness of the breath to help develop mental focus and to connect the mind, body, and spirit (Roland, Jakobi & Jones, 2011). Hatha yoga requires participants to hold and move between a series of stationary positions that use isometric contraction and relaxation of different muscle groups to create specific body alignments. Major classifications of poses are standing, forward and backward bending, twists, hand balancing, inversions, and restoratives (Friend, 2006). Yoga requires focused effort in completing the pose, controlling the body, and breathing at a steady rate. In addition, breathing (pranayama) and meditation exercises are practiced to calm and focus the mind and develop greater self-awareness (Morone & Greco, 2007). There are many different styles of hatha yoga characterized by the rate at which postures are performed, environmental temperature, physical intensity, level of difficulty, and emphasis on body alignment and relaxation. In addition, the use of aids (e.g., blocks and straps) enables those of most functional abilities to participate in yoga (Groessl et al., 2008). Iyengar yoga, one of the Hatha yoga techniques, is a system for developing physical and mental well-being through stretching of all muscle groups for strength, flexibility, and physical balance, that is particularly suitable to older adults. Iyengar yoga is

amenable to easy adaptation for older adults through modifications of the poses and the use of props, such as yoga blocks, bands and chairs.

Ross and Thomas (2010) reviewed studies comparing the effects of yoga and aerobic exercise and concluded that, in both healthy and diseased populations; yoga may be as effective as or better than aerobic exercise at improving a variety of health-related outcome measures. Several literature reviews have been conducted that examine the impact of yoga on specific health conditions including cardiovascular disease (Raub, 2002), metabolic syndrome (Innes, Bourguignon, Taylor, 2005), diabetes (Upadhyay, Balkrishna, Upadhyay, 2008), cancer (Bower, Woolery, Sternlieb, Garet, 2005), low back pain (Posadzki & Ernst, 2011) and anxiety (Kirkwood, Rampes & Tuffrey, 2005). Although these reviews acknowledge the lack of rigorous methodology and RCTs, each of them report positive results. Raub (2002) concluded that the yoga practices of controlling body, mind, and spirit combine to provide useful psychophysiological effects for healthy people and for people compromised by musculoskeletal and cardiopulmonary disease. Innes and colleagues (2005) reviewed studies evaluating the effects of yoga on cardiovascular disease (CVD) and indices of CVD risk associated with the insulin resistance syndrome and concluded that yoga may reduce many IRS-related risk factors for CVD, may improve clinical outcomes, and may aid in the management of CVD and other IRS-related conditions. Upadhyay and colleagues (2008) concluded that short-term benefits for patients with diabetes may be achieved from practicing yoga. Bower and colleagues (2005) noted positive effects for cancer patients and survivors on a variety of outcomes, including sleep quality, mood, stress, cancer related distress, cancer related symptoms, overall quality of life, as well as functional and physiological measures. Kirkwood and colleagues (2005) did not make a definitive claim about the efficacy of yoga in reducing anxiety and anxiety disorders due to

inadequacies in study quality, however, they concluded that the results were encouraging, particularly with obsessive compulsive disorder. Posadzki and Ernst (2011) conducted a systematic review to assess the effectiveness of yoga as a treatment option for low back pain. The authors concluded that yoga does lead to a significantly greater reduction in low back pain than usual care, education or conventional therapeutic exercises.

Although these reviews contribute to the large body of research evidence attesting to the positive health benefits of yoga, very little is known about the benefits of yoga for sedentary healthy older adults, in improving functional performance and cognition. Yoga is often considered an adjunct therapy and its effectiveness has been tested in combination with conventional medical treatments and usual care in clinical populations. This has limited its research and examination as an independent therapy in both clinical as well as healthy populations. Given the nature of yoga and the inherent and active attentional component involved in its practice, its psychological and cognitive benefits need to be thoroughly explored. The following section reviews the studies that have explored the yoga-cognition relationship.

Yoga and Cognition

Mind-body interventions are alternative therapies that cover a variety of techniques designed to enhance the mind's capacity to affect bodily function and symptoms. Yoga is one such approach that has components focusing on meditation, breathing, and postures. Yoga therapy enables the practitioner to move slowly and safely into the modified postures concentrating initially on relaxing their body, breathing fully, and developing awareness of the sensations in their body and thoughts in their mind. The technique of yoga involves focusing one's attention on breathing or specific muscles or parts of body and it is unknown whether the attentional practice in yoga would generalize to conventionally assessed attentional function.

There has been growing interest in exploring the cognitive benefits of yoga but very few cross-sectional, longitudinal and experimental studies have investigated its immediate and long term effects across life-span.

Chronic Effects of Yoga on Cognition

In one of the earliest studies investigating yoga effects on cognition, Naveen and colleagues (1997) assessed whether performing three pranayama practices, i.e., left, right, or alternate nostril breathing or breath awareness four times a day for ten days would alter the performance of school children on verbal and spatial memory tests, compared to those of a control group who did no specific practice. Results showed that after ten days of yoga breathing practices (*pranayamas*) all four trained groups showed a significant increase in spatial memory scores compared to the control group.

In a blinded, randomized controlled trial involving 120 menopausal women, Chattha and colleagues (2008) compared the effects of an 8-week regimen of daily asana and pranayama with an intervention that mirrored the activities of yoga by utilizing non strenuous walking and stretching exercises. They assessed attention and concentration using the six-letter cancellation test (SLCT) and Punit Govil Intelligence Memory Scale (PGIMS) subscales. They found that the yoga group performed significantly better ($p < 0.001$) compared with the control group, with higher effect sizes on the SLCT and seven tests of PGIMS including remote memory, mental balance, attention and concentration, immediate and delayed recall, visual retention and recognition. There was significant improvement within both groups with significant difference between groups; however, the effect sizes were greater in the yoga group than in the control group.

While most of the yoga studies have been conducted in India, only one group of researchers has compared the efficacy of yoga in a sample of healthy older adults and in a multiple sclerosis population in the US (Oken et al., 2004; Oken et al., 2006). Oken and colleagues in 2004 compared the effects of their 6-month Iyengar yoga and stationary cycling intervention on attention and alertness in patients with multiple sclerosis (MS). No significant improvements were noted in attention and alertness or quality of life for either exercise condition. The non-significant findings in this study may have been a result of the sample characteristics. Given that the participants were MS patients who suffer from the progressive degenerative neural disease, no improvement or change in cognitive performance may actually be indicative of maintenance of cognitive function which by itself maybe a critical finding. In 2006, they conducted another exercise trial with 135 healthy seniors (Oken et al., 2006) to study and compare the effects of Iyengar yoga and walking cognition using the Stroop color-word task, Cambridge Neuropsychological Battery and Wechsler Memory Scales. Again similar negative results were found indicating no changes in the cognitive outcomes for either group.

No changes on cognitive functioning, in both of the above studies may also be indicative of a ceiling effect since the older adult sample was healthy and active (30mins/day of exercise) before beginning the intervention. Sedentary older adults may experience differential benefits from a similar intervention. It is also possible that sub-groups of the sample may have evidenced differential benefits which are lost when the data are averaged. Li and colleagues (2002) found such sub groups when they re-analyzed participants' perceived physical function after a tai-chi intervention. The non-significant findings for cognitive outcomes in Oken's studies may also have to do with the duration and frequency of the yoga sessions as acknowledged by the authors. The exercise classes in both the studies met only once a week for a period of 90 minutes, as

compared to other exercise interventions with seniors which are designed to meet three times per week (Colcombe and Kramer, 2003) with the total exercise time summing to 180 minutes, which is twice as much. It is possible that the frequency and duration may have been insufficient to show a significant difference on the cognitive measurements in Oken's studies.

Kyizom and colleagues (2010) provide some electrophysiological evidence in their study with 60 patients with type 2 diabetes. The patients were divided into two groups; a control group that received only conventional medical therapy and a yoga-group that received conventional medical therapy along with a pranayama and yoga-asana intervention. The yoga group was taught pranayama and yoga-asana by a certified yoga instructor daily for initial 5 days and then they were called regularly at an interval of 7 days for supervision and compliance.

Electrophysiological recordings of event related potential - P300 were taken twice in both the groups - baseline recording at the time of recruitment and the subsequent recording after 45 days in response to a standard auditory odd-ball paradigm. Significant decrease in the latency and improvement in the amplitude of P300 was observed in the yoga group while the control group did not show any significant changes. These observed changes in the P300 latency and amplitude reflect the allocation of attentional resources indicating faster cognitive information processing.

Acute Effects of Yoga on Cognition

Few studies have investigated the acute effects of a yoga session on aspects of cognition. Sarang and Telles (2007) evaluated the performance on a six letter cancellation task in males (age 18 – 48 years) immediately before and after two yoga based relaxation techniques and a control session of equal duration. They used cyclic meditation and supine rest and found that the net scores were significantly higher after both practices as compared to the control session. The magnitude of change was higher after cyclic meditation than supine rest suggesting that cyclic meditation brings about a greater improvement in performance on a six letter cancellation task

which requires selective attention, concentration, visual scanning abilities and a repetitive motor response. Researchers speculated that the improvements in cognition may have been due to reduced physiological arousal, resulting in reduced anxiety and improved performance.

In another study using the six letter cancellation task, Telles and colleagues (2008) found that all three age groups (medical students, middle-aged adults and older persons), the changes in cancellation scores (either total errors or net scores) after *Kapalabhati* (a yoga breathing technique characterized by forceful exhalation and high-frequency breathing) suggested improvement. The authors concluded that this improvement may be related to the fact that *Kapalabhati* is associated with increased sympathetic activity, and increased sympathetic tone is associated with better vigilance (Fredrikson & Engel, 1985).

In a following study, Joshi & Telles (2009) employed neuroimaging techniques and compared the P300 event related potentials on the odd-ball paradigm before and after *Kapalabhati* and compared it with breathing awareness. Results showed that the P300 peak latency decreased after *Kapalabhati* suggesting a decrease in time needed to perform task, which requires selective attention. On the other hand, the P300 peak amplitude increased after breath awareness suggesting an increase in the neural resources available for the task.

Gothe and colleagues (2013, in press) examined the effects of an acute yoga session on cognitive performance in 30 female college-aged participants ($M_{\text{age}} = 20.07$). They completed three counterbalanced testing sessions: a yoga session, an aerobic exercise session, and a baseline assessment and the flanker and n-back tasks were used to measure inhibitory control and working memory – two domains of executive function. They found that cognitive performance after a 20 minute yoga session was significantly superior (shorter reaction times, increased

accuracy) when compared to the aerobic and baseline conditions for both the flanker and n-back tasks.

Given the paucity of literature on yoga and cognition in older adults, it is prudent to review the tai-chi, meditation and mindfulness studies on healthy older adults, which are mind-body therapies similar to yoga. There appears to be more evidence and studies conducted with other mind-body CAM therapies in comparison to yoga, however we restrict our appraisal to studies conducted with healthy older adults and discuss the classic reviews conducted to investigate these diverse therapies. An exploratory study examined the effects of a 10-week tai-chi intervention on cognitive function in 20 older adults ($M_{\text{age}} = 76.5$). Improvement post intervention was seen in two cognitive measures of executive function namely the trail making test and the digit symbol substitution test (Matthews & Williams, 2008). In a cross-sectional study examining tai-chi practitioners, healthy exercisers and non-exercising older adults ($M_{\text{age}} = 68.4$), the tai-chi practitioners performed better on the attention (sustained and divided attention) and memory tests (everyday memory function and encoding, recall/organization of verbal information) when compared to both the other groups of older adults (Man, Tsang, Hui-Chan, 2010). Recently, Chang and colleagues (2010) conducted a review of six studies to assess the potential of tai-chi chuan as a mode of physical activity that could have cognitive benefits for older adults. Three studies examined the effects of long-term tai-chi chuan practice on cognition using the Mini Mental State Examination (MMSE), and the findings of these studies were not consistent (Burgener, Yang, Gilbert, & Marsh-Yant, 2008; Deschamps, Onifade, Decamps & Bourdel-Marchasson, 2009; Nowalk et al., 2001). Although the MMSE is useful for assessing cognitive impairment, it might not be particularly sensitive to change as a result of an intervention (Salthouse, 2007) and might be influenced by personality factors (e.g., education;

Roselli et al., 2009). However, there is some evidence that tai-chi chuan can benefit particular measures of cognition. In particular, significant effects were found when measures of executive function (Burgener et al., 2008; Matthews & Williams, 2008) were used, suggesting that the effects of tai-chi chuan on cognition might be task specific. Thus, the results from studies testing the effects of tai-chi chuan are consistent with the results of recent meta-analyses in showing that the effect of chronic exercise on cognition is task-specific (Angevaren et al., 2008; Colcombe & Kramer, 2003).

Several researchers have investigated the effects of meditation on cognition. Yoga practice involves a meditation component and it is possible that the cognitive benefits of these two mind-body mechanisms may be similar. Canter and Ernst (2003) conducted a systematic review of RCTs to evaluate the effect of transcendental meditation on cognitive function. TM is a standardized form of meditation in which the practitioner sits with eyes closed for 15–20 min twice daily and repeats a mantra in a prescribed manner. Overall, they found four trials with large positive effects on cognitive function; four provided only weak evidence for a positive effect and two showed no effect. However, only one RCT in this review was conducted with a sample of healthy older adults. Alexander and colleagues (1989) randomly allocated 73 elderly volunteers from residential homes, a nursing home and a housing complex for the elderly to four treatment groups using stratification by Dementia Screening Test (DST) scores. For 3 months volunteers practiced TM, mindfulness training (MF) comprising structured and creative mental activities, mental relaxation (MR) involving sitting with eyes closed and repeating a self-chosen syllable, or were no treatment waiting-list controls. There was no significant difference between groups in changes in DST scores pre and post-treatment. Post-treatment, the TM, group performed significantly better than no-treatment controls on the associate learning subtest of the

DST but pairwise comparisons between TM and MR or MF were not statistically significant. The MF group performed better than the TM and other groups on the word fluency subtest of the DST, but again there were no statistically significant pairwise differences between groups. The TM group had the lowest scores post-test on the Stroop Color Word Interference Test, a measure of the degree to which incongruent stimuli (e.g. the word blue in red) delays reading responses, but there were no significant differences between treatments.

Analogous to the aerobic exercise literature, there clearly is mixed evidence for the relationship between yoga and other forms of mind-body based exercises, and cognition. Besides, several forms of yoga exist, ranging from gentle modifiable poses like Iyengar yoga, to most commonly practiced postures like Hatha yoga, to more vigorous movements and dynamic postures like Bikram yoga. The yoga protocols for previous studies have varied and given the diverse forms and postures of yoga, it is not surprising that the results from acute and chronic yoga exercise across samples and age groups are equivocal. However, other aspects of mental and physical health that have been consistently studied in yoga research in both clinical and non-clinical populations include positive and negative affect, perceived health, physical function and quality of life. We review the literature linking physical activity and function in the following sections and the studies that have examined the effects of yoga on functional fitness and affect in older adults.

Physical Activity, Functional Fitness and Psychological Well being

As we age, susceptibility to chronic conditions, functional limitations and disability, and comorbidity increase, often resulting in compromised physical, emotional, and psychological well-being and reduced quality of life (QOL). It is clear, however, that the variability of age-related functional losses increases with age. Some individuals maintain a relatively high level of

mental and physical functioning in old age while others experience a dramatic decline (Morse, 1993).

Poor physical function, functional limitations and disability are adverse health outcomes associated with aging, afflicting over 66% of older adults (CDC, 2004a). Activities of daily living such as walking across a room, climbing a flight of stairs, and performing personal and social role activities are often painful and difficult for older adults. Fortunately, there is good evidence that functional declines are attenuated by engaging in protective behaviors such as physical activity. Physical activity has been identified as having a protective effect on physical function and limitations (Keysor, 2003) and physical activity interventions may represent an effective behavioral strategy for attenuating functional decline and reducing risk of disability (Miller et al., 2000; Singh, 2002; Keysor, 2003). Recently, Paterson and Warbuton (2010) conducted a systematic review of the physical activity-function relationship reporting evidence to support a dose-response relationship between aerobic physical activity and improved functional performance and reduced functional limitations. Similarly, an earlier review by Keysor and Jette (2001) suggested that the majority of exercise training studies resulted in improvements in important physical function performance behaviors, such as walking speed, rising and transferring from a chair, and climbing stairs. Individuals who engage in more intense exercise tend to exhibit more favorable physiological changes (Paterson & Warbuton, 2010); however, even short durations of physical activity are associated with a decelerated trajectory of functional limitations (Miller et al., 2000). Yet, there are very little data regarding the extent to which strength and/or balance training may independently improve functional fitness. As an adjunct to aerobic training, however, there is some evidence to suggest that these training modalities may counter the age-related loss in muscle size, coordination, and power necessary

for daily living (Keysor, 2003). Thus as our population becomes increasingly older, it will be important to discourage sedentary behavior and encourage physical activity to improve functional fitness and minimize functional limitations (Rejeski, Brawley, & Haskell, 2003).

Apart from attenuating functional declines and reducing the risk of disability (Keysor, 2003; Miller et al., 2000; Singh 2002) physical activity interventions also enhance psychological well-being and quality of life in older adults (McAuley et al., 2006; Rejeski et al., 2002). While several factors such as health, physical function and independence constitute quality of life in old age, psychological well-being is of particular significance to quality of life as it reflects the desire to maintain productivity, independence, and an active interaction with the environment (Spiriduso, Francis, & MacRae, 2004). In addition to the direct physical-health benefits of physical activity, several studies suggest that engaging in physical activity or exercise programs can also benefit emotional well-being. Most qualitative reviews studying the aging population (Brown, 1992; McAuley & Rudolph, 1995; O'Connor, Aenchenbacher, & Dishman, 1993; Spiriduso & Cronin, 2001) have concluded that habitual exercise may improve psychological well-being. Antidepressant (Motl et al., 2005; Blumenthal et al., 1999; Mather et al., 2002) and anxiolytic effects (Landers & Petruzzello, 1994; Petruzzello et al., 1991; McDonald and Hodgdon, 1991) of physical activity have been demonstrated in the literature suggesting that physical activity improves mood (Arent, Landers, & Etnier, 2000) and reduces symptoms of depression and anxiety.

The physical activity, anxiety and stress literature has advanced to the point where there are reviews of reviews (Landers & Petruzzello, 1994; Gauvin & Spence, 1998). Petruzzello and colleagues (1991) provided the most comprehensive meta-analysis with over 100 studies examining the effects of both acute and chronic exercise on psychological self-report and

psychophysiological indices of stress. The overall effect size ranged from low ($d=.24$) to moderate/high ($d=.65$) with greater effects on self-report measures from chronic exercise and greater effects on psychophysiological effects from acute exercise. Additional evidence for the antidepressant effect of physical activity among older adults has been provided from a number of experimental studies (Blumenthal et al., 1999; Mather et al., 2002; McNeil, LeBlanc & Joyner, 1992; Penninx et al., 2002; Singh et al., 1997, 2001). According to North, McCullagh, and Tran (1990), the effect of physical activity on depression is reportedly moderate ($d=.53$), but clinically depressed participants showed large decreases in depression as a result of physical activity, whereas persons from the general population showed small or no decreases due to lower floor and higher ceiling effects for the clinical sample. Meta-analysis of the effects of exercise on mood in older adults (Arent, Landers, & Etnier, 2000) indicated an overall effect size of 0.24 for treatment versus comparison effects, and a mean change effect size of 0.38 standard deviations for single-group pretest–posttest studies. Among healthy older adults, resistance training has been associated with improved mood states. McLafferty and colleagues (McLafferty, Wetzstein & Hunter, 2004) conducted a study examining the effects of a 24-week resistance training program with three weekly meetings. Following the program, participants reported significant improvements in total mood scores, as well as reductions in confusion, anger and tension. Similarly, physical activity has been reported as a correlate of positive mood among women. In a study evaluating predictors of mood among women who had recently started a walking program, in addition to social support, physical activity was significantly associated with greater positive mood (Janisse, Nedd, Escamilla & Nies, 2004).

Clearly, contemporary reviews suggest a positive association between physical activity and indices of quality of life such as mood and affect (McAuley & Morris, 2007; McAuley &

Elavsky 2006; Netz, Wu, Becker & Tenenbaum, 2005; King et al., 2000). These reviews have concluded that the relationship is positive and remarkably consistent across sub-groups, activity settings and activity mode. While these generalizations are being made, very little is known about alternative non-traditional forms of exercise and their role in attenuating functional declines, and improving psychological well-being. A vast majority of the existing studies have assessed the role of aerobic exercise such as walking or anaerobic forms such as strength training, and the effectiveness of other modes like yoga, tai-chi and forms of martial arts remains to be examined. Such research is necessary because it has obvious implications for older adults who may be unable to engage in more intense types of activity due to limited mobility or chronic illness.

Yoga, Functional Fitness and Psychological Well being

Studies have shown that yoga practice can lead to improvements in hand-grip strength (Madanmohan, Thombre & Balakumar, 1992), muscular endurance (Ray, Hegde & Selvamurthy, 1986), flexibility (Gharote & Ganguly, 1979) and decreases in percent body fat (Bera & Rajapukar, 1993; Madhavi et al., 1985). Oken and colleagues (2006) in their trial conducted several physical assessments including the forward-bend flexibility, the chair sit and reach, one leg stands and chair stands at baseline and at the end of their 6 month intervention with older adults. Results showed that only the yoga group exhibited significant improvements in flexibility and balance.

These results are expected as yoga practice involves performing postures that are similar to many of the functional fitness assessments such as one leg stands. Cowen and Adams (2005) conducted a pilot study investigating the effects of a six week Astanga and Hatha yoga on functional and psychological outcomes. They randomized healthy adults ($n=26$, $M_{\text{age}} = 31.8$) into

one of the two yoga groups. At the end of six weeks, the improvements differed for each group when compared to baseline assessments. The Astanga yoga group had decreased diastolic blood pressure and perceived stress, and increased upper body and trunk dynamic muscular strength and endurance, flexibility, and health perception. Improvements for the Hatha yoga group were significant only for trunk dynamic muscular strength and endurance, and flexibility. These findings not only underscore the functional benefits of yoga practice but also confirm that these benefits differ by the form of yoga practiced.

In another randomized controlled trial (Williams et al., 2005), subjects ($M_{age} = 48.3$) with non-specific chronic low back pain were randomized to either an Iyengar yoga therapy or an educational control group. After the 16-week program, analyses of medical and functional outcomes revealed significant reductions in pain intensity (64%), functional disability (77%) and pain medication usage (88%) in the yoga group at the post and 3-month follow-up assessments. The authors concluded that Iyengar yoga therapy did confer greater benefits to chronic lower body pain patients than an educational program.

In a cross sectional study conducted in Poland, researchers found that elderly women ($M_{age} = 63.5$) who participated in 120 minutes/week of yoga practice performed better on the Senior Fitness Tests – including the 30-second chair stand, arm curl and back scratch test than women who regularly participated in swimming exercises (Sierpowska, Ciechanowicz & Cywinska-Wasilewska, 2006). In a repeated measures study, Schmid, Puymbroeck & Kocaja (2010) conducted a 12-week single armed yoga intervention to determine whether fear of falling and functional fitness improved among 14 older adults ($M_{age} = 78.36$). There was a 34% increase in lower body flexibility and positive changes were seen in fear of falling and static balance as measured by the Senior Fitness Test.

One legged balance may have health implications such as reducing risk of falls, and has been shown previously to be improved in healthy older people practicing tai-chi, another mind-body technique which includes balance exercises (Tse & Bailey, 1992; Li et al., 2004). Some studies have investigated the functional benefits of tai-chi and have found promising results. Much like yoga, tai-chi, a traditional form of low-to-moderate intensity exercise, is purported to promote health and fitness, delay disability, and maintain physical performance in later life. Tai-chi has gained popularity in Western society due to its health-related benefits for older adults including improved balance control (Tse & Bailey, 1992; Wolfson et al., 1996), reduction in the incidence of falling (Wolf, Barnhart & Kutner, 1996) and functional limitations, enhanced psychological well-being, and increased perceptions of movement efficacy (Li et al., 2001a). Li and colleagues (2001b) conducted a 6 month randomized controlled trial to examine the benefits of tai-chi in physically inactive older adults. They concluded that tai-chi practice leads to a significant improvement in self-efficacy and increased levels of perceived physical function. These data were later re-analyzed (Li et al., 2002) to determine whether subgroups of the study sample, if any, evidenced differential benefits from the intervention. A latent curve analyses indicated that tai-chi participants with lower levels of physical function at baseline benefited more from the tai-chi training program than those with higher physical function scores. A shortcoming of these findings is that, these changes were seen on self-report measures of physical function. The authors themselves acknowledged that objective physical health measures such as functional tests would not only help confirm these findings but also provide a more rigorous examination of the effects of other tai-chi like mind-body therapies on physical function.

In addition to improving physical functioning, yoga has a number of positive effects on psychosocial functioning which have been reported in healthy as well as clinical populations spanning a wide age-range. Psychological effects include increased self-efficacy, coping, social support and positive mood. Hatha yoga has been reported to produce improvements in mood comparable to aerobic exercise (Berger & Owen, 1992; 1988). Oken and colleagues (2004), in their study with MS patients also compared the effects of their intervention on psycho-social variables including mood, anxiety, fatigue, and quality of life. They found that both exercise conditions produced significant improvement in fatigue compared with wait-list controls. The yoga group also performed significantly better than the exercise group on levels of fatigue and on several measures of health status including pain and social functioning. In a later study with healthy seniors (Oken et al., 2006), similar results were observed with the yoga intervention group improving on quality of life measures related to sense of well-being and energy and fatigue compared to controls.

In 2006, a team of researchers in Taiwan developed a Silver Yoga Program for older adults (Chen, Tseng, Ting & Huang, 2007). In a RCT lasting six months (Chen et al., 2009), researchers tested the efficacy of this program for community dwelling older adults ($n=139$, $M_{age} = 69.2$). The subjective sleep quality, physical health perception, and mental health perception of the participants in the yoga group were significantly better than those in the control group, and the daytime dysfunction and depression state of the participants in the yoga group were significantly less than the control group. These benefits were seen after 3 months of the program and the improvements were maintained after the six months of the study. Similar improvements in sleep quality were found in a sample of patients with lymphoma ($n=39$, $M_{age} = 51$) who participated in 7 weekly yoga sessions (Cohen et al., 2004). Patients who were randomized to the

Tibetan yoga group reported significantly lower sleep disturbance scores during the 3 month follow-up compared with patients in the wait-list control group. This included better subjective sleep quality, faster sleep latency, longer sleep duration, and less use of sleep medications. Manjunath & Telles (2005) also found similar results in a sample of older adults ($n=69$, $M_{age}=70.1$) living in a residential home for the aged. The older adults were randomly allocated to one of three groups: yoga, Ayurveda or a waitlist control. After six months, the yoga groups reported feeling more rested in the mornings with longer sleep duration than the other two groups. In an acute yoga study, Wood (1993) reported that a 30 minute yoga breathing and stretching program had a positive effect on perceptions of both, mental and physical energy and increased high positive mood in a sample of healthy adults ($n=71$, age range 21-76). In another pilot study conducted with older female dementia patient family caregivers ($n=12$, $M_{age}=56$), six sessions of a yoga-meditation program revealed statistically significant reductions in depression and anxiety and improvements in perceived self-efficacy (Waelde, Thompson & Gallagher-Thompson, 2004).

Apart from older adult populations, positive psychosocial effects have been observed in young adults as well as clinical populations. In a healthy group of 194 participants enrolled in a 3 month community-based yoga program, significant pre-post improvements on depression, anxiety and self-efficacy scales were reported (Lee et al., 2004). In a RCT, healthy college students showed a reduction in perceived stress and improved affect in response to a 90 minute African dance and yoga session when compared to a control. Another RCT including adolescents with irritable bowel syndrome was found to reduce anxiety and adaptive coping following four weeks of yoga home-practice compared to waitlist controls (Kuttner et al., 2006). A 4-month

treatment of yoga for headaches was found to be effective in improving coping and headache symptoms compared to standard treatment controls (Latha & Kaliappan, 1992).

Two reviews examining yoga for depression and anxiety have underscored the promise of yoga for improving affect. In one review of five RCTs examining yoga for depression, beneficial effects were reported in four of five RCTs (Kirkwood et al., 2005). In another review, all eight randomized studies of yoga for clinical anxiety disorders reported a reduction in symptoms following yoga (Pilkington, Kirkwood, Rampes & Richardson, 2005). Findings did not appear to vary as a function of symptom severity, suggesting that benefits may be available to individuals with mild depressive symptoms and anxiety through to clinical level symptomology. It has been argued that increased mastery of poses, emotional release, tolerance of vulnerability related to opening of the body posture, and a sense of relaxation in restorative poses all contribute to the positive effects of yoga on mood (Woolery, Myers, Stemlieb & Zeltzer, 2004). Yoga has also been linked to social benefits, consistent with the notion that exercise performed in a group can promote social well-being, which in turn is important for functional status in chronic disease (Weinberger, Tierney, Booher & Hiner, 1990). Yoga classes have been associated with social benefits in a range of populations, including a RCT of yoga for a multi-ethnic group of breast cancer survivors (Moadel et al., 2007), cancer patients (DiStasio, 2008), and a pilot study treating osteoarthritis of the knees (Kolasinski et al., 2005).

Given that the eight limbs of yoga are so multidimensional and include aspects of exercise (asana), breathing (pranayama), concentration (dharana), and meditation (dyana), it is not surprising that researchers have found positive effects of yoga on a variety of outcome measures. While the previously discussed studies involving yoga's effects on cognitive function in older adults led to non-significant results (Oken et al., 2006) yoga clearly appears to have

some effect on the physiology of the practitioner as is evident from the reviewed studies and the preliminary pilot results and this warrants further enquiry. The investigated and proposed mechanisms and models are discussed in the following section.

Mechanisms of Health Related Yoga Effects

Various underlying mechanisms for the effect of yoga on physical and mental health have been proposed. Although interrelated, these can be broadly classified into physiological and psychological mechanisms. One of the proposed and partially tested hypotheses is that yoga practice decreases anxiety and stress reactivity thereby regulating the hypothalamic-pituitary-adrenal axis. More recently, Brown and Gerbarg (2005) have proposed a neurophysiological model suggesting potential effects of yoga practice on the brain structure.

A growing body of research evidence supports the belief that certain yoga techniques may improve physical and mental health through down-regulation of the hypothalamic–pituitary–adrenal (HPA) axis and the sympathetic nervous system (SNS) (Ross & Thomas, 2010). The HPA axis is a major coordinator of the biological response to stress. This system is activated in response to stress and mobilizes resources needed to cope with the stressor. Prolonged activation of this system is thought to have deleterious effects on brain function. In a recent nature review, Lupien and colleagues (2009) concluded that chronic exposure to stress hormones, whether it occurs during the prenatal period, infancy, childhood, adolescence, adulthood or aging, has an impact on brain structures involved in cognition and mental health. Yoga has been shown to have immediate psychological effects including decreased anxiety (Kirkwood et al., 2005), depression (Uebelacker, 2010), stress (Chong, 2011), and improved QOL and well-being (Oken et al., 2006). These studies suggest that yoga has an immediate quieting effect on the SNS/HPA axis response to stress. La Forge (1997) suggested that at least

part of the power of yoga's effects is its ability to help participants cultivate better stress management skills. While the precise mechanism of action has not been determined, it has been hypothesized that some yoga exercises cause a shift toward parasympathetic nervous system dominance (Innes, Bourguignon & Taylor, 2005). An RCT comparing African dance and Hatha yoga showed that cortisol levels decreased after the Hatha yoga session in healthy college students and the changes in positive affect and change in cortisol were negatively correlated (West et al., 2004). Kamei and colleagues (2000) also report similar reductions in serum cortisol levels after a 50 minute yoga session in a sample of 8 yoga instructors. A 3-month Iyengar yoga program for women ($M_{age} = 37.9$) also showed decreased salivary cortisol levels and improvements in stress, anxiety and well-being (Michalsen et al., 2005). Similar results were observed in a 6-week RCT with breast cancer outpatients (Raghavendra et al., 2009). Decreased anxiety, stress, depression and salivary cortisol were reported by the yoga group patients as compared to the usual care controls. Other analogous techniques, including mindfulness based stress reduction (Marcus et al., 2003), transcendental meditation (MacLean et al., 1997), tai-chi (Esch et al., 2007) have been shown to elicit a similar relaxation response along the SNS/HPA axis by reducing salivary cortisol levels and anxiety, and improving mood.

Eysenck (1979, 1983) has suggested that anxiety interferes with the normal functioning of working memory, a system that combines processing and storage functions. Anxiety is of importance within the field of cognition because it is often associated with adverse effects on the performance of cognitive tasks (see Eysenck, 1992, for a review). Adverse effects of anxiety on processing efficiency depend on two central executive functions involving attentional control: inhibition and shifting (Eysenck, Derakshan, Santos & Calvo, 2007). The position that reduced anxiety leading to improved cognitive performance within the mind-body literature ties back to

the studies conducted by Yesavage and colleagues (1982, 1984) who investigated the effects of relaxation training on memory and attention in healthy older adults. In one of the early studies, 26 healthy older adults participated in a weekly session of progressive muscle relaxation for four weeks (Yesavage et al., 1982). The participants' anxiety was assessed using the Symptom Checklist 90 and Self-Assessment Scale Geriatric – anxiety subscale. The results showed that subjects with a relatively high level of anxiety improved on the word-list learning measure after the relaxation sessions. In another follow up study (Yesavage & Jacob, 1984), the authors assessed attentional capacity as 25 healthy older adults were trained in techniques to improve face-name recall. Techniques consisted of relaxation training and a mnemonic device. Anxiety was measured simultaneously with attentional measures. Results indicated that subjects showing the greatest reduction in self-reported anxiety and cognitive interference, and the greatest increase in attention (measured using a divided attention task), showed the most face-name recall following training. The authors concluded that older adult's anxiety level has a cognitive component that interferes with performance on attentional and memory tasks, but it can be reduced through relaxation training. The relaxation and mnemonic techniques therefore increased the available memory processing capacity by improving attention and reducing anxious rumination. A similar mechanism might underlie the yoga-cognition relationship; however it remains to be systematically explored.

Although the precise role of neurotransmitters is unknown, there is recent evidence of change in neurotransmitter function with yoga practice. Streeter and colleagues (2010) compared the beneficial effects of yoga and exercise on mood and anxiety, including changes in γ -aminobutyric acid (GABA) activity. They randomized healthy subjects (18-45 years) to either a 12-week yoga or a metabolically matched aerobic walking intervention. The yoga group reported

greater improvement in mood and greater decreases in anxiety than the walking group and there were positive correlations between improved mood and decreased anxiety and thalamic GABA levels. This is the first time that a behavioral intervention (i.e., yoga postures) has been associated with a positive correlation between acute increases in thalamic GABA levels and improvements in mood and anxiety scales. Changes in functioning of key neurotransmitters have also been reported with similar interventions. For example, practitioners of Yoga Nidra (a type of meditation) were found to have increased dopamine activity in the ventral striatum during meditation when compared to a control activity of listening to a speech (Kjaer et al., 2002). These findings demonstrate that increased thalamic GABA levels are associated with improved mood and decreased anxiety and it may be one of the several mechanisms by which yoga leads to improved psychological health.

Other physiological explanations have also been identified over past decades. It may be that yoga improves psychological well-being by altering blood chemistry (Kolsawalla, 1978). Yellin (1983) reported that yoga practice increases healthy circulation of blood and air through the body, and facilitates a relaxed state of mind, which can lead to improved cognitive performance. Heilbronn (1992) proposed that there are three dominant mechanisms, which are responsible for yoga's benefits. First, holding a posture controls the blood flow, and in the subsequent relaxation of the pose, enhanced blood flow flushes the surrounding organs and removes toxins. Second, regular practice of yoga postures stretches the muscles, clearing the tension and imbalances, thus permitting the free flow of energy around the body. Finally, vigorous yoga practice allows for the sublimation of the adrenaline, which is produced in response to stressors. It has also been argued that the extension and flexion of muscles during yoga poses is associated with activation of antagonistic neuromuscular systems as well as

tendon-organ feedback resulting in increased range of motion and relaxation (Riley, 2004). Yoga interventions for individuals with arthritis and other musculoskeletal conditions have found improvement in a range of physical outcomes, including pain, strength, joint tenderness, range of motion and disability (Evans et al., 2009).

Brown and Gerbarg (2005) have proposed a neurophysiological model of yoga and argued its mechanisms may include brain areas and actions on the limbic system, thalamus, and cortex. They suggest that the mechanisms contributing to a state of calm alertness include increased parasympathetic drive, calming of stress response systems, neuroendocrine release of hormones, and thalamic generators. There is some neuroimaging evidence from the meditation and mindfulness literature suggesting that meditation may even alter the structure of the brain, with experienced meditators having thicker layers in their cerebral cortexes (Kaufman, 2005). Tang and Posner (2010) reviewed studies that have employed attention training methods arising from Asian traditions (e.g. integrative body-mind training and mindfulness) and methods developed in Europe and the USA (practice). They reported increased anterior cingulate cortex involvement during rest among mind-body practitioners that could account for improved executive attention. A functional magnetic resonance imaging study of the attention network task (ANT; Posner, Sheesea, Odludasa & Tang, 2006) showed that the task produced increases in connectivity between the dorsal anterior cingulate cortex and lateral prefrontal cortex during performance. This suggests that the ANT that taps executive function aspects of attention and inhibitory control might involve both midline and lateral areas during task performance.

Central to the practice of yoga are pranayama and asanas, or physical exercises. In asanas, the body is held in stillness in a physical posture for a specific length of time (at least for five full breaths, as long as 5 minutes in some yoga classes, and sometimes even for one hour in

certain yoga traditions). The physical holding of the body is meant to teach muscular control, but even more importantly mental control, because yoga theory proposes that pain and discomfort are due more to perceptions than to physical realities. As originally outlined by Pantanjali, yoga is a practice of discipline, which ultimately leads to a steady control of the sense and mind (Iyengar, 1979). Yoga, therefore, is an intervention whose primary purpose and effect is the cultivation of self-control, and it is proposed that this may be the mechanism through which yoga improves psychological health and well-being. Yoga breathing may be useful for restoring a sense of control when an individual is confronted by an anxiety-inducing trigger (Brown and Gerbarg, 2005). Yoga's effectiveness in reducing anxiety may be due to its capacity for lowering excitability and increasing concentration and self-control (Sharma, Yadava, & Hooda, 2005).

Traditional yoga theory indicates that the effects of yoga are due to its combined impact on the mind and body. Yoga practice teaches an individual new behaviors – physical activities (exercises and breathing practices), which can be implemented in order to manage responses and reactions. These altered responses and reactions facilitate improved outcomes. The alteration of thoughts and actions helps the yoga practitioner to achieve psychological balance in the present moment, which leads to health and well-being. Cognitive behavioral therapies hold that psychological distress is caused by disturbances in the cognitive processes, and that a psycho-educational approach designed to teach new cognitions and more productive behaviors can eliminate psychological distress (Corey, 2005). Yoga may, therefore, be viewed as an ancient form of cognitive behavioral therapy that leads to better psychosocial health for the practitioner.

While these mechanisms are not necessarily mutually exclusive, future research on yoga should examine these potential mediators and elucidate the connections between these processes. Evans and colleagues (2009) propose employing a biopsychosocial model to

systematically examine the benefits of yoga. The biopsychosocial model of health addresses a person's physiology, psychology, environment and behavior to understand how social and psychological factors interact with biology to influence illness and health (Gatchel et al., 2007). Although the studies reviewed have examined the separate effects on physiological, psychosocial and spiritual systems, in reality, yoga is a holistic form of mind-body exercise which is likely to affect multiple systems of the individual's functioning and physiology simultaneously. Clearly, evidence indicates that yoga holds promise in acting favorably upon multiple and widespread aspects of an individual's health. Future empirical studies of yoga should incorporate the same stringent research standards as those used in the physical activity and exercise literature. Well-designed RCTs need to be conducted that systematically examine: i) the physical, cognitive and psychosocial benefits of yoga, and ii) investigate the underlying mechanisms in an effort to establish yoga as a viable form of therapy for the aging as well as other populations.

The Present Study

Despite yoga's wide popularity, there are a limited numbers of randomized controlled yoga studies using objective quantitative outcome measures to evaluate the efficacy of this mode of exercise. In the light of this literature and building on a recent pilot study (Gothe, Pontifex, Hillman & McAuley, 2013 in press) the SAY Exercise trial, a two-arm, randomized controlled trial examined the effects of an 8-week yoga intervention that incorporated *Hatha* yoga, on cognition and functional fitness in older adults. Primary outcomes were cognitive performance assessed using a battery of neuropsychological tests targeting various executive function domains. Functional fitness tests assessing balance, strength, mobility and flexibility were secondary outcome measures. Anxiety, stress, depression and salivary cortisol levels were assessed to examine possible mediators underlying the yoga-cognition relationship. Participants

(N= 118) were randomized to either a yoga group or a stretching control group. Both groups met three times a week for the 8 week period to participate in structured group exercise classes. A complete description of the measures and the randomized groups is detailed in the following chapter. Data were collected at baseline and following the 8-week intervention to investigate the cognitive, functional and affective benefits of yoga practice.

CHAPTER 3

METHODS

Participant Recruitment

Participants were recruited through University of Illinois list serv – E-week, fliers, community groups and postings. Individuals who responded to the advertisements were contacted via telephone or email and were provided a description of the study, to determine eligibility, and extend an offer to participate in the study. The complete list of inclusion and exclusion criteria are presented in Table 1. Participants were also screened for cognitive impairment using the Telephone Interview for Cognitive Screening (TICS-M; de Jager, Budge, & Clark, 2003), and for depressive symptomology using the shortened version of the Geriatric Depression Scale (GDS-15; Yesavage, et al., 1982b). Participants who met all the inclusion criteria and agreed to participate were mailed a copy of the University of Illinois Institutional Review Board approved informed consent and documents for physician’s release. Participants were requested to bring the completed and signed copies of these documents to a group orientation session where the details of the study and the study protocols were explained to the participants. Towards the end of the orientation, each participant was given a questionnaire packet and scheduled for their baseline assessments. Both, the assessors and the participants were blinded at the time of pre-testing.

Randomization and group assignment

After completion of all baseline assessments, participants were randomized by age and sex into one of two groups: yoga practice or stretching exercise. Spouses and friends who had signed up for the study were randomized together into the same group. A letter was mailed to the participants with their group placement and instructions for the first day of exercise class.

Yoga Group: The yoga intervention was designed as a beginner but progressive 8-week program involving supervised group sessions. The supervised group sessions were held three times a week for the 8-week duration at the Exercise Psychology Lab's exercise studio. Each class was structured as follows:

Postures (Aasana)	30 min
Relaxation (Shavaasana)	5 min
Breathing (Pranayama)	10 min
Teach meditation technique	5 min
Practice meditation technique	15-20 min
Discussion and Q&A	5 min
Total class time	75 min

These sessions were led by certified yoga instructors (Caucasians, male 43 years and female 42 years old) incorporating *Hatha* yoga poses. Within the 3 sessions each week, new postures, breathing and meditative exercises were introduced on Mondays, Wednesday's class helped to further develop concepts while reviewing and adding some new postures. Friday's class was dedicated to reviewing the week's material to ensure the yoga practice was smooth and progression was gradual and steady through the 8-week intervention. Yoga practice was done barefoot and participants used chairs (as necessary) yoga mats, yoga blocks and belts during the sessions.

Stretching Control Group: The stretching group served as a control to the yoga intervention for the period of 8-weeks. Participants in this group also met on the same days and times at the Exercise Psychology Lab, in a separate exercise studio, to engage in stretching exercises that met the CDC anaerobic recommendation (Haskell et al., 2007). Each class consisted of a warm up and a cool down and the participants completed 10-12 repetitions of 8-10 different exercises led by a certified personal trainer. Resistance bands, blocks and chairs were

used to perform these exercises (example: bicep curls, tricep extensions, flutter kicks seated in the chair etc.).

Participants in both groups completed exercise logs where they rated their enjoyment, rating of perceived exertion and performance at the end of each class. The instructors in both groups monitored participants' attendance over the course of the 8-week program.

Measures

Demographic and participant information

Basic demographic information was collected including age, sex, marital status, date of birth, occupation, income, education and past experience with yoga.

Cognitive Assessments

A combination of cognitive tasks was employed to measure a variety of executive functions like attention, inhibition, shifting and working memory. Both, computer based and paper pencil cognitive tests were completed by all study participants during the baseline and follow-up cognitive assessment appointment. Given the large number, tests were not counterbalanced across participants. All participants completed the assessments in the same order as presented below.

Attention Network Task. The ANT (Fan et al., 2002) is an attentional test that uses the Eriksen flanker task (Eriksen & Eriksen, 1974) as a target. The stimuli consisted of a row of five visually presented white lines, with arrowheads pointing leftward or rightward, against a black background. Similar to the flanker task, the ANT requires participants to determine whether the central arrow points left or right. This target was flanked on either side by two arrows in the same direction (congruent condition), or in the opposite direction (incongruent condition) or lines (neutral condition). The participant's task was to indicate the direction of the central target by pressing either the right mouse button or the left mouse button as quickly as possible. Prior to

a target, cues were used to provide information about when and where the target will be presented. Each trial began with a cue followed by a target 500 ms later (for no-cue trials the cue event is invisible). Cue and target remained on display until response, or for a maximum of 5 seconds. Trials in which subjects were slower than 2000 ms were followed by visual feedback that read “too slow,” for the first 1000 ms of the inter-trial interval. Inter-trial interval was randomized between 1200 and 3000 ms. Besides the congruency factor and the cue factor, we counterbalanced whether the target points left or right, and whether the arrows are displayed in the top or the bottom box. All possible combinations of this $2 \times 4 \times 2 \times 2$ design were represented in each block of 48 trials. There were five blocks, for a total of 240 trials. Each of the five blocks of 48 trials lasted approximately 4 minutes, and subjects were encouraged to take short breaks between blocks. Reaction time and accuracy on the neutral, congruent and incongruent trials was examined.

Task Switching. There are multiple versions of the task switching paradigm, however, for this study we employed the version used by Kramer and colleagues (1999) and Pashler (2000). In this task participants were asked to switch between judging whether a number (1, 2, 3, 4, 6, 7, 8, or 9) is odd or even and judging whether it is low or high (i.e., smaller or larger than 5). Numbers were presented individually for 1500 ms against a pink or blue background at the center of the screen, with the constraint that the same number did not appear twice in succession. If the background was blue, participants reported as quickly as possible whether the letter was high (“X” key) or low (“Z” key) using their left hand. If the background was pink, participants used their right hand to report as quickly as possible whether the number was odd (“N” key) or even (“M” key). Participants completed four single task blocks (2 blocks of odd/even and 2 blocks of high/low) of 24 trials each. Due to the difficulty of this task, participants were provided with a

practice block in which they switched from one task to the other for 20 trials. This practice block allowed the participants to become acquainted with the switching block and ensured compliance with task instructions. Finally, they completed a ‘mixed’ block of 120 trials during which the task for each trial was randomly chosen. Local switch cost was calculated which refers to the difference in performance for trials when the preceding trial involved the same task (non-switch trial) and those when the preceding trial was of the other task (switch trial). Global switch cost was also calculated which was the difference in the average reaction time on the single blocks and the mixed block. Accuracy and reaction time on single and switch blocks was also examined.

Running Memory Span. The letter version of the running memory span test was used (Broadway & Engle, 2010). Participants were instructed to report the last n letters ($n = 3, 4, 5$ or 6) from a string of $m+n$ letters presented on the screen. The letters were presented sequentially in the center of the screen in black 18-pt font against a gray background. There were three trials for each target length in each running memory span task. Three trials for each target length presented lists in which $m = 0$ distractors preceded the targets (whole recall trials). One trial for each target length presented lists in which $m = 1$ and 2 distractors preceded the targets (partial recall trials). The target lengths were blocked (randomly ordered), and the number of distractors preceding the targets was randomized within blocks. The participants were informed at the start of a block how many letters to report from each list in that block. The input rate was 2000 ms and the stimulus duration was 300 ms with the inter-stimulus interval of 1700 ms. After the inputs terminated for a trial, the participants made their responses by clicking the cells of a 3x4 grid displaying all letters from the set of possible letters. The response screen reminded the participants how many letters to report. The responses in the span tasks were constrained to

forward order. To maintain the correct serial position of recalled items with respect to their position in the exposed list, the participants were instructed to click on a blank option for each item that could not be recalled (i.e., strict serial position scoring was applied to the response sequences). One point was assigned for each item correctly chosen in the correct serial position. For example, if four items—J, K, L, and T—were to be reported, responding “J blank L T” would receive 3 points, but responding “J L T” would receive 1 point. Partial recall score was calculated for trials when $m > 0$ and total recall score presented performance on trials where $m = 0$.

N-Back Task. Working memory was assessed with a modified serial n-back task (Kirchner, 1958; Nystrom et al., 2000) that involved two consecutive phases: 1-back, and the 2-back. Each phase required the participants to discriminate between a sequence of letters that served as stimuli. In the 1-back condition, the participant was instructed to respond as quickly and accurately as possible if the current letter was the same as the previous trial for the 1-back condition, and two trials previous for the 2-back condition. A practice block of 13 stimuli and five experimental blocks of 20 stimuli each were presented for each of the two conditions. Accuracy (percentage correct) and reaction times are recorded for each item. All stimuli letters were in white, small caps, Arial size 72, approximately 3 cm tall, presented one at a time on a computer screen with a black background for a duration of 2000 ms with a fixed 1500 ms inter-trial interval. Reaction time and accuracy on the 1 and 2 back conditions was examined.

In addition to the computer based tasks, two paper-and-pencil tests from the Salthouse (1993) battery were administered: trail making and pattern-comparison. Each of these tasks contains an instruction page with several examples, followed by two pages of test items.

Trail Making. The Trail Making Test is composed of two parts, A and B. Part A consisted of 25 circles printed on a sheet of paper. Each circle contained a number from 1 to 25.

The subject's task was to connect the circles with a pencil line as quickly as possible, beginning with the number 1 and proceeding in numerical sequence. Part B consisted of 25 circles numbered from 1 to 13 and lettered from A to L. The task in part B was to connect the circles, in sequence, alternating between numbers and letters. The assessors immediately drew attention to any errors, which the participant corrected before proceeding with the test. The scores represent the time taken in seconds taken to complete each part of the test and the difference between part A and B.

Pattern Comparison. Two separately timed pages of the letter-comparison items were administered. Items in the pattern-comparison task were 30 pairs of line segments composed of three, six, or nine segments. The participant wrote an S (for same) between the two patterns if they were identical or a D (for different) if they were not. One half of the pairs differed because of a shift in the position of one line segment in a pair member. Two separately timed pages, each with 30 pairs of the patterns to compare were administered. The score was the total number of patterns correctly completed on both pages minus the number incorrectly completed.

Functional Fitness Tests

As functional fitness and physical performance were secondary outcomes of the study, a battery of dynamic balance, mobility, gait speed, flexibility and muscle strength tests were administered at baseline and the end of the intervention.

Participants completed the Senior Fitness Test (Rikli & Jones, 2001). The tests included 8-Foot Up-and-Go, a test of physical agility and dynamic balance (best of two timed trials); the Arm Curl test, which assesses arm muscle strength endurance, specifically of the biceps (# of reps in 30 seconds); Chair Stand test, which assesses lower body strength (# of reps in 30 seconds), the Back Scratch and Chair Sit-and-Reach, tests of upper body and lower body flexibility (distance in inches between finger tips, and fingertips and toes respectively). To assess

balance we used the Four Square Step Test (FSST; Dite & Temple, 2002), a test of dynamic standing balance where the subject steps into 4 squares and is required to step forward, backward, and sideway to the right and left, and the One-leg Stand Test consisting of balancing on one leg (left and right), unsupported for up to 30 seconds. We also assessed gait speed, which was the better of two recorded times over a 4-meter course (Short Physical Performance Battery, Guralnik et al., 1994; Hoenig et al., 2006).

Perceived Stress Scale. Perceived Stress was measured using the 14-item Perceived Stress Scale (PSS; Cohen, Kamarck & Mermelstein, 1983). Each item is rated on a 5 point scale from never (0) to very often (4). The scale has showed adequate reliability and is designed to measure the degree to which situations in one's life are appraised as stressful. The scale score is computed by aggregating the item scores with higher scores indicating greater stress.

State Trait Anxiety Inventory. The STAI (Spielberger, Gorsuch & Lushene, 1970) is a 40 item instrument divided into two sections. The first subscale measures state anxiety, i.e. anxiety about an event, the second measures trait anxiety, i.e. a stable tendency to respond with anxiety. Items are scored on a four point likert scale (1=not at all to 4=very much so) resulting in a range of scores from 20-80 for each subscale. Higher scores are indicative of greater anxiety. The STAI has demonstrated high internal reliability in community dwelling older adults (Kabacoff, Segal, Hersen & Van Hasselt, 1997). Participants completed the state subscale during the cognitive testing sessions following the saliva sample collection at both time-points.

Salivary Cortisol. Salivary cortisol is an excellent indicator of plasma-free cortisol, increasingly used to assess hypothalamic–pituitary–adrenal axis secretory activity and rhythm (Arafah, Nishiyama, Tlaygeh & Hejal, 2007; Dorn, Lucke, Loucks & Berga, 2007). An extensive meta-analysis (Dickerson & Kemeny, 2004) suggests that significant cortisol responses were

elicited by cognitive tasks ($d=.20$), effects were significantly greater for assessments obtained in the afternoon ($d=.46$) and 21-40 minutes after the onset of the stressor ($d=.38-.41$). Capitalizing on these results, in the present study, two saliva samples were collected at each time-point during the cognitive testing appointments that were held in the afternoon. The cognitive assessments acted as a ‘psychological stressor’ to induce a stress response and saliva samples before beginning the session (baseline level) and 40 minutes into the session (response to stressor) were collected from the participants. The passive drool procedure was employed which involved allowing the subject to pool saliva in his/her mouth (~1.5ml) and then send it through a short straw into a vial. Because cortisol production has a circadian rhythm (Dickmeis, 2009; Dorn, Lucke, Loucks, & Berga, 2007) the pre and post cognitive assessments and saliva sample collection were conducted at the same time of the day (2:00 pm pre-stressor and 2:40 pm post-stressor) for all participants. Samples were stored at -20 C upon collection. A high sensitivity cortisol enzyme immunoassay kit (Salimetrics Inc., State College, PA) was used to assess cortisol levels in the saliva samples. All saliva samples for a participant were assayed together in duplicates by a blinded chemical engineer in the Institute for Genomic Biology lab space. The detection range for the assay was 0.012-3.000 $\mu\text{g/dL}$. Samples exceeding 3.0 $\mu\text{g/dL}$ (very high cortisol concentrations), were re-analyzed in duplicates after dilution (10x). A 4-parameter sigmoid minus curve fit was examined for each plate based on the standards and controls (R^2 range: .999 to 1). The intra- and inter-assay coefficients of variation (CVs) were < 15% as recommended by the manufacturer.

Post Intervention Data Collection

After the last exercise class, participants were scheduled for their post intervention assessments, which mirrored their baseline testing appointments. The packet of questionnaires was given to all participants on the last day of class to collect the psychosocial data.

Power Analysis

Chronic physical activity and executive function literature has statistically summarized the results to report a moderate effect size of .68 for executive function tasks (Colcombe & Kramer, 2003). Findings from the Gothe et al. (2013, in press) study showed an effect size of .54 on the flanker task and .66 averaged across the three n-back conditions. However, given that the executive function tasks in the present study have not been employed in the yoga-cognition literature, a moderate effect size ($d=.40$ or $f=.30$) was considered for power calculations.

Using this moderate effect size of $f=.30$ (Cohen, 1988), a power analysis was conducted using G*Power version 3.1.2 (Faul et al., 2009). For a power of 80% (for one tailed $\alpha = .05$), often recommended as appropriate power in behavioral research (Green, 1991) and assuming a moderately strong correlation among the repeated measures ($r=.50$), the analysis yielded a sample size of 68 participants. Allowing for 15% attrition and to accommodate the wide range of outcomes in the study, we planned to recruit 40 participants per treatment condition to maximize power, bringing the total sample size to 80.

Data Checking and Analysis

Questionnaire and functional fitness data were entered and checked by trained graduate students and undergraduate research assistants, and quality of data was checked for missing data and erroneous data by examining descriptive statistics and score ranges of all variables. A data file with participant IDs and their performance on the computer based cognitive tests was

generated using the E-prime software. Paper pencil cognitive tests were scored by trained research assistants and the scores were entered into an SPSS data file. Subsequently, all data were examined for violation of basic statistical assumptions (i.e., normality, multicollinearity, and homoscedascity).

Prior to all hypothesis testing, independent sample *t*-tests were conducted to examine whether significant mean differences existed in demographic, health and physical activity variables among the two groups at baseline. For all hypotheses, analyses first examined whether outcomes changed differentially from baseline to post-intervention using repeated measures analysis of covariance with baseline means and age as covariates.

The primary aim of this study was evaluate whether participation in the 8-week yoga intervention improved cognitive performance on the executive function tasks. A series of repeated measures analyses of covariance (ANCOVAs) controlling for age, education and baseline performance were employed to explore group effects for all the cognitive outcomes. The secondary outcome of the study was functional fitness and a repeated measures multivariate analyses of covariance (MANCOVAs) controlling for age were conducted to assess differences between the groups, time and group*time interaction effects on the balance, flexibility, strength and mobility tests.

In an attempt to explore the predictors of the yoga-cognition relationship, multiple linear regression analyses were conducted to determine whether change in the post-stressor salivary cortisol level, anxiety and stress scores predicted the improvements in cognitive performance (for each of the executive function measures) for the yoga group.

CHAPTER 4

RESULTS

Participant Characteristics

Figure 1 shows the flow of participants through the trial. Advertisement and recruitment efforts were successful in generating a total of 265 contacts of which 118 participants completed all baseline assessments and were randomized (by age and sex) to participate in the SAY Exercise Trial. Time commitment and travel plans during the study duration were the most common exclusionary reasons. The final sample size for the study was 118 ($M_{age}=62.5, \pm 5.59$) with $n=61$ in the yoga group and $n=57$ in the stretching control. Approximately 20% of the study participants represented minority groups as seen in Table 2. The mean TICS-M score for the sample was 30.65 (range= 24 to 38; ± 3.27) which was well above the cut off of 21 which is indicative of cognitive deficiency. Again, all individuals scored below the cut-off point of ≥ 5 with a mean of 1.05 (range=0 to 4, ± 1.22) on the GDS-15. No participant failed screening based on their TICS-M or GDS-15 score.

Table 3 shows the participant characteristics by group. Within both groups, majority of the participants were female, married, working full time, well-educated and relatively affluent. An independent samples t-test showed no significant differences between conditions on any of these characteristics (all p 's $\geq .20$). Approximately one third of the participants in both groups had tried yoga previously (range: 6 years to 40 years ago) but were no longer practicing at the time of the SAY Exercise Trial. The average attendance at the yoga classes was 80.82% (19.2 ± 3.8 sessions) and was not significantly different from the stretching exercise classes at 81.29% (19.4 ± 3.8 sessions).

Retention at Follow-up

One hundred and eight participants successfully participated in the intervention and

completed all follow up assessments resulting in an overall attrition rate of only 8.47%. As seen in the CONSORT, the dropouts at follow up were due to family emergency=3; no longer interested=3; time commitment=2; sickness=1, traveling=1. A series of t-tests were conducted to determine whether the completers differed from the dropouts on any demographic or baseline measures. Analysis revealed that there were no significant differences on any of the demographic (all p 's > .05) or baseline cognitive and functional outcomes (all p 's > .05).

Cognitive Outcomes

The mean reaction time (RT), accuracy (AC) and test scores for the cognitive measures are presented in Table 4. Post adjusted scores from the ANCOVAs are also presented in Table 4. No significant baseline differences were found between the two groups (all p 's > .05). Age, education and baseline performance were included as covariates in all analyses.

Attention Network Task

Analyses revealed a significant group effect for reaction time on the congruent trials [$F(1,103)=10.71$, $p<.001$, partial $\eta^2=.09$], incongruent trials [$F(1,103)=6.05$, $p=.02$, partial $\eta^2=.06$], and neutral trials [$F(1,103)=5.94$, $p=.02$, partial $\eta^2=.05$]. Each of these group effects favored the intervention group with participants in the yoga group showing faster reaction times at follow up as compared to their stretching counterparts.

Analyses on task accuracy showed no significant group differences at follow up on the congruent [$F(1,103)=1.654$, $p=.20$, partial $\eta^2=.02$], incongruent [$F(1,103)=1.25$, $p=.27$, partial $\eta^2=.01$] or neutral trials [$F(1,103)=.34$, $p=.56$, partial $\eta^2=.003$]. As seen in Table 4, both groups showing a ceiling effect for the congruent and neutral trials and a similar improvement on the

incongruent trials at follow up. Thus, no speed-accuracy trade off was observed within the yoga group as they displayed improved reaction times.

There were no significant group differences for the attention networks: alerting [$F(1,103)=.23$, $p=.63$, partial $\eta^2=.00$], orienting [$F(1,103)=.08$, $p=.79$, partial $\eta^2=.00$] and conflict [$F(1,103)=.34$, $p=.56$, partial $\eta^2=.00$].

N-Back Task

For reaction times on the n-back task, no significant group effects were observed for 1-back [$F(1,104)=.01$, $p=.91$, partial $\eta^2=.00$] or the 2-back conditions [$F(1,104)=1.40$, $p=.24$, partial $\eta^2=.01$]. Overall, longer reaction times were observed on the 2-back condition as compared to the 1-back condition.

No significant mean differences were observed on 1-back accuracy [$F(1,104)=1.62$, $p=.21$, partial $\eta^2=.02$]. However, a significant group difference was seen on 2-back accuracy [$F(1,104)=11.87$, $p<.001$, partial $\eta^2=.10$], with the participants in the yoga group exhibiting higher accuracy on the 2-back condition at follow up compared to the stretching controls.

Although the yoga group showed improved accuracy, no speed-accuracy trade-off was observed as seen in the reaction time ANCOVAs.

Running Memory Span

The repeated measures ANCOVA showed a significant group effect for the partial recall score [$F(1,103)=7.28$, $p=.008$, partial $\eta^2=.07$] with the yoga group showing higher recall scores as compared to the stretching controls. The total recall score on the running span approached significance [$F(1,103)=2.82$, $p<.09$, partial $\eta^2=.03$] indicating a similar trend favoring the yoga group.

Task Switching

Of the four reaction time measures, the ANCOVA showed a significant group effect on mixed and repeat reaction times. A significant mean difference favoring the yoga group was observed on the mixed block [$F(1,103)=4.08$, $p=.04$, partial $\eta^2=.04$]. The yoga participants were more efficient in switching between the odd-even and low-high tasks as compared to the stretching controls. Within the mixed block of trials, the yoga group also showed significantly faster reaction times on the repeat [$F(1,103)=4.5$, $p=.03$, partial $\eta^2=.04$] but no significant differences were observed on the switch trials [$F(1,103)=1.72$, $p=.19$, partial $\eta^2=.01$]. The reaction time on the single block approached significance [$F(1,103)=3.18$, $p=.07$, partial $\eta^2=.03$], again favoring the yoga group that displayed faster times.

Significant group difference was also observed on single block accuracy [$F(1,103)=5.35$, $p=.02$, partial $\eta^2=.05$] while mixed block accuracy approached significance [$F(1,103)=2.96$, $p=.09$, partial $\eta^2=.02$]. The yoga group showed better accuracy on the single block and a similar trend was observed on the mixed block of trials. Within the mixed block, no group differences were seen on switch accuracy [$F(1,103)=2.56$, $p=.11$, partial $\eta^2=.02$] whereas repeat accuracy approached significance [$F(1,103)=3.2$, $p=.08$, partial $\eta^2=.03$] favoring the yoga group.

There were no significant group differences at follow up on the local cost [$F(1,103)=.06$, $p=.81$, partial $\eta^2=.001$] and global cost [$F(1,103)=.56$, $p=.46$, partial $\eta^2=.01$] variables.

Trail Making

No significant group difference was observed for Trail A time at follow up [$F(1,103)=.187$, $p=.67$, partial $\eta^2=.002$]. However, the ANCOVA showed a significant group effect for trail B time at follow up [$F(1,103)=10.12$, $p=.002$, partial $\eta^2=.089$]. This significant group difference on trails B also translated into a significant group difference on trail cost (time

B- time A), [F(1,103)=10.53, $p=.002$, partial $\eta^2=.093$] with the yoga group showing less interference than the control condition.

Pattern Comparison

A significant group effect for the pattern recognition test scores was observed at follow up [F(1,103)=34.51, $p<.001$, partial $\eta^2=.251$] with the yoga group recognizing significantly more patterns compared to the stretching controls. The superior performance of the yoga group was not a result of the speed-accuracy trade-off, since no significant group effects were observed for the number of errors on this task [F(1,103)=.306, $p=.58$, partial $\eta^2=.003$]. The yoga intervention was effective in improving attention and speed of processing as reflected by performance on the pattern comparison task.

Functional Fitness Outcomes

The secondary hypothesis stated that the 8-week yoga intervention would show similar improvements in participants' functional fitness scores on the battery of tests measuring balance, strength, flexibility and mobility as compared to the stretching control group. This hypothesis was completely supported by the data with both groups showing similar time effects and improvements on the functional fitness measures.

Table 5 shows the intervention effects on the functional fitness outcomes for the yoga intervention and stretching control groups at baseline and follow up. There were no significant group differences between the two groups on any of the outcome variables at baseline (all p values $\geq .14$). Age was used as a covariate in all analyses.

Balance

A repeated measures MANCOVA showed a significant time effect for balance measures [F(3,103)=16.26, $p<.001$, partial $\eta^2=.32$]. Upon closer examination, the significant time effects were observed for the four square step test [F(1,105)=39.75, $p<.001$, partial $\eta^2=.27$] and right leg balance [F(1,105)=5.49, $p=.02$, partial $\eta^2=.05$]. Interestingly, a significant group*time interaction was observed for left leg balance, favoring the yoga group [F(1,105)=4.25, $p=.04$, partial $\eta^2=.04$].

Strength

A repeated measures MANCOVA showed a significant time effect for strength measures [F(2,103)=61.50, $p<.001$, partial $\eta^2=.54$]. The significant effects were observed for both, the chair stand test [F(1,104)=92.97, $p<.001$, partial $\eta^2=.47$] and the arm curl test [F(1,104)=93.52, $p<.001$, partial $\eta^2=.47$]. No group*time interactions were observed for the two strength tests however, a significant between-subjects main effect was observed for sex [F(2,101)=8.374, $p<.001$, partial $\eta^2=.14$] with males completing more chair stands and arm curls than women.

Flexibility

A repeated measures MANCOVA showed a significant time effect for flexibility measures [F(4,101)=2.54, $p=.04$, partial $\eta^2=.09$]. Upon closer examination, the time effect was observed for back scratch (right side) [F(1,104)=3.65, $p=.05$, partial $\eta^2=.03$] and sit and reach (right side) [F(1,104)=6.27, $p=.01$, partial $\eta^2=.06$]. Similar results were observed for back scratch and sit and reach for left side [F(1,104)=13.47, $p<.001$, partial $\eta^2=.11$] and [F(1,104)=59.56, $p<.001$, partial $\eta^2=.36$]. Additionally, there was a main effect for sex [F(4,101)=4.76, $p=.001$, partial $\eta^2=.16$] with females showing greater flexibility than males.

Mobility

A repeated measures MANCOVA showed a significant time effect for mobility measures [$F(4,100)=12.42$, $p<.001$, partial $\eta^2=.33$]. Additionally a between subjects main effect was observed for age on the 8-ft up and go [$F(1,103)=22.16$, $p<.001$, partial $\eta^2=.18$], the gait speed test [$F(1,103)=4.12$, $p=.04$, partial $\eta^2=.04$] and the stairs up time [$F(1,103)=4.79$, $p=.03$, partial $\eta^2=.04$].

In summary, we observed significant time effects for each of the balance, flexibility, strength and mobility measures, indicating that both groups improved on these outcomes across the 8-week intervention. In addition, a group*time interaction was observed for left leg balance, where the yoga participants showed larger improvements than the stretching controls.

Predictors of the Yoga-Cognition Relationship

The means and standard deviations of the variables measuring affect, including anxiety, stress and salivary cortisol are presented in Table 6. Again, no baseline differences were observed between the two groups (all p 's $\geq .15$). A distribution of cortisol data showed 8 outliers ($n=5$ for yoga, $n=3$ for control) that were more than 3 standard deviations away from the mean levels at least one time-point including follow-up. Two of the 8 participants had reported life events (death in the family, laid off at work) to the research staff during the course of the trial, however no record was documented for the remaining 6 participants who exhibited extremely high cortisol levels. These data points were dropped from further analyses to avoid situational bias, resulting in a sample size of 100 at follow up for cortisol analyses.

Group differences at follow-up

At follow-up, a significant group difference for post stressor cortisol levels was observed [$F(1,97)=4.55$, $p=.04$, partial $\eta^2=.045$] where the yoga group showed lower values than the

stretching control (.16 µg/dL Vs. .19 µg/dL respectively). No significant group differences were observed on the self-report stress and anxiety scales at follow up (all p 's $\geq .21$). However, significant time effects were observed for perceived stress [$F(1,106)=11.58$, $p=.001$, partial $\eta^2=.10$], trait anxiety [$F(1,106)=21.52$, $p<.001$, partial $\eta^2=.17$] and state anxiety scores [$F(1,106)=9.05$, $p=.003$, partial $\eta^2=.08$]. The time effects were in the expected direction with both groups reporting lowered stress and anxiety after 8-weeks of exercise. Change scores (baseline-follow up) were calculated for each of the predictor variables and cognitive variables, and were used in the regression analysis to examine predictors of cognitive improvements within the yoga and stretching control groups (see Table 6 for change scores).

Predictors of cognitive performance

The third hypothesis about changes in salivary cortisol levels, anxiety and stress scores from pre to post intervention predicting cognitive performance was only partially supported. No consistent predictors were observed, however salivary cortisol levels predicted performance on the running span task and trait anxiety predicted performance on trail making part B. Results from the multiple regression analyses conducted for each of the cognitive measures are presented in Tables 7-9.

Multiple regression analysis on the running span scores indicated that post stressor change in salivary cortisol predicted change in the total recall scores on the running span task ($\beta=.332$, $p=.02$) but not on the partial recall score ($\beta=.124$, $p=.40$). The result was in the expected direction such that positive change in the cortisol level (i.e. larger difference in baseline and follow up indicative of lowered stress level) predicted improved total recall scores on the running span task. The only other predictor was the trait anxiety score that predicted performance on the trail making part B ($\beta=-.35$, $p=.02$). The result was in the expected direction such that an increase

in trait anxiety score resulted in poor performance on trails part B. The self-report measures of perceived stress and state anxiety did not predict performance any of the cognitive performance measures within the yoga group. However, perceived stress predicted reaction time on the incongruent flanker condition ($\beta=-.43$, $p=.01$) for the stretching group, such that increased stress scores predicted longer reaction times on the incongruent condition of the ANT.

CHAPTER 5

DISCUSSION

Overview of Results

The purpose of this study was to investigate the efficacy of an 8-week yoga intervention in improving cognitive and functional outcomes in a healthy but sedentary community dwelling adult population. Participants in the yoga intervention showed significantly improved performance on all cognitive measures. The 8-week yoga intervention improved executive functions including attention and information processing speed, working memory capacity, efficiency of mental set shifting and perceptual comparison speed. In conjunction with the cognitive outcomes, the functional fitness measures showed a significant time effect that was comparable to the stretching group that participated in CDC recommended stretching and strengthening exercises. The predictor hypothesis was only partially supported and changes in cortisol only predicted scores on the running span task. Analyses of the functional fitness measures showed that yoga was as good as the CDC recommended anaerobic guidelines in improving balance, strength, flexibility and mobility outcomes in this sample of sedentary older adults. In summary, 8 weeks of regular yoga practice had cognitive and physical health benefits that demand rigorous replication and systematic examination in future studies.

Cognitive Outcomes

Executive functions are multifaceted and in an effort to mirror the physical activity and cognition findings, a variety of standardized cognitive tasks representing various domains of executive function were employed in this study. Running span and n-back represented working memory related functions, task switching and trails part B represented mental set shifting, attention network task examined sustained attention and inhibitory control whereas trails part A and the pattern comparison assessed speed of processing and motor control. Following 8-weeks

of yoga practice, participants showed significant improvements on each of these executive function measures. On some tasks assessing attention and processing speed, participants showed improved reaction times whereas higher accuracy was recorded on executive functions involving working memory capacity. Overall, these results are promising and demand rigorous RCTs to replicate these findings and examine cognitive benefits of yoga across other standardized cognitive measures used in the physical activity literature.

Yoga participants showed significant improvements on both the working memory tasks: n-back and running span at follow up. Working memory is an executive function that involves cognitive processes such as maintaining and updating information, and manipulation and reorganization of data (Miyake et al., 2000). Maintenance has been defined as transferring, maintaining (including rehearsal), and matching of information in working memory (Fletcher & Henson, 2001) whereas manipulation refers to the additional reorganization or updating of each memory set. These tasks tap sustained attention and analytical processing without requiring the formation of novel strategies or solutions (Bless, 2003). The yoga group showed higher accuracy on the 2-back condition as well as better partial and total recall on the running span. The yoga participants exhibited a significantly greater number of processing runs involving accurate and sustained working memory discriminations. They were also able to maintain focus and accurately retrieve information from working memory under conditions that require more cognitive resources and continual updating and manipulation of information.

The yoga participants also showed improved visuo-spatial and perceptual processing on the trail making and pattern comparison tests indicating greater efficiency in sustaining attention and speed of processing. The pattern-comparison test is thought to represent a perceptual-comparison speed construct (Salthouse, 1993) because the task not only requires perception of

the stimuli and a simple motor response but also an additional judgment of physical identity. The trail making test on the other hand requires immediate recognition of the symbolic significance of numbers and letters, ability to scan the page continuously to identify the next number or letter in sequence, flexibility in integrating the numerical and alphabetical series, and completion of these requirements under the pressure of time. The yoga intervention seemed to have affected these cognitive processes that resulted in faster reaction times on Trails B and reduced interference compared to the stretching control condition. It has been argued that the trail making test, is one of the best measures of general brain functions (Reitan & Wolfson, 2004), as the ability to deal with the numerical and language symbols (numbers and letters) is sustained by the left cerebral hemisphere; the visual scanning task necessary to perceive the spatial distribution of the stimulus material is represented by the right cerebral hemisphere; and speed and efficiency of performance may reflect the overall adequacy of brain functions.

The yoga group showed significantly faster reaction times on the attentional network task including the neutral, congruent and incongruent flanker conditions. The ANT has not been used in the yoga-cognition literature but similar results have been reported in response to Eriksen's flanker in an acute yoga study (Gothe, Pontifex, Hillman & McAuley, 2013). We also explored flanker cost (incongruent-congruent), an outcome that has been a frequently examined in the physical activity and cognition literature (Voss et al., 2010; McAuley et al., 2011). No significant group differences were observed on this variable in the current study. As one would expect, reaction times for the incongruent trials were longer than congruent and neutral trials. The dominant explanation for this finding is that the presentation of flankers results in automatic activation of the response channel associated with the flanker stimuli (Gratton, Coles, & Donchin, 1992; Gratton, Coles, Sirevaag, Eriksen, & Donchin, 1988), leading to fast correct

responses in the congruent condition (i.e., the flankers are identical to the target and facilitate a correct and fast response). In the incongruent condition, the automatic activation leads to fast incorrect responses, necessitating attentional control processes to overrule the incorrect automatic activation, resulting in slow correct responses. Overall, the faster reaction times represented effective information processing and inhibitory control following the 8-week yoga intervention. It is important to note that no trade off was observed for the yoga group and the faster reaction times did not compromise the accuracy of their responses. As seen in Table 4, there appeared to be a ceiling effect for accuracy on the neutral and congruent conditions with participants scoring 99% on an average at baseline as well as follow up, and both groups showing a similar improvement on incongruent condition.

Task switching provides a measure of executive function by testing participants' abilities to switch between mental sets and flexibility in performing simultaneous functions. Again, the yoga group showed faster reaction times on the mixed block and repeat trials that involved sustained information processing and set shifting. A similar trend was observed on the single reaction times that approached significance favoring the yoga group. We also examined local and global switch cost measures that have been reported in the physical activity and cognition literature. It is suggested that local switch cost represents a measure of attentional set re-configuration and inhibition, two sub-components of executive function (Miyake et al., 2000), whereas global cost reflects the efficiency of maintaining multiple task sets in working memory as well as the selection of the task to be performed next (Kray and Lindenberger, 2000). We examined both, global and local cost measures in the present study but found no significant differences, as a function of the interventions. Performance on the task switching task is a measure of attentional set re-configuration and inhibition, two sub-components of executive

function (Miyake et al., 2000). The faster reaction times on the ANT and task switch represent effective information processing, mental set flexibility, and inhibitory control.

Across all cognitive measures, no speed accuracy trade-off was observed indicating that the yoga group showed improved cognitive performance without compromising on the speed or accuracy for the different cognitive outcomes assessed in this study. Overall, the results also suggest that yoga practice showed significant cognitive benefits while performing more challenging tasks, such as the 2-back and mixed block performance as compared to the 1-back or single trials on the task switching paradigm. It also improved overall attentional, perceptual and mental set shifting abilities as suggested by the performance across ANT conditions, the pattern recognition and the trail making scores

Predictors of the Yoga-cognition Relationship

The exploratory hypothesis of changes in salivary cortisol, anxiety and stress predicting cognitive performance was only partially supported in this study. Although the yoga group showed an attenuated stress response to the cognitive tasks (stressor), these change scores predicted performance on the trail making part B and running span working memory tasks. The regression results indicated that a greater reduction in cortisol levels and lowered trait anxiety was predictive of improvements in working memory performance and mental flexibility. However, the perceived stress and state anxiety scores showed no associations with cognitive measures. These null findings can be explained by the short duration of the study and the fact that all participants were both physically and mentally healthy and high functioning. They indicated ‘feeling good’ and ‘more relaxed’ on the program evaluations, however, the self-report measures may not have captured these subjective perceptions effectively given the short duration of the intervention.

Although the predictors did not consistently predict variance in the cognitive performance measures, the changes in cortisol levels following yoga practice and improving executive functions are significant findings. Stress and anxiety may be particularly critical in affecting information processing. The ability to self-regulate emotions has been found to be a key component in enhancing cognition (Moore and Malinowski, 2009). It is possible that the calming effects of yoga combined with the increased capacity to focus on the present improved cognitive performance after 8-weeks of regular practice. Yoga enhances present moment awareness by teaching participants to notice subtle distractions (feelings; thoughts) while repeatedly bringing attention back to the meditation object such as one's breath or specific parts of the body. This process can promote attentional stability.

Mean level changes in cortisol following a yoga intervention have been previously reported (West et al., 2004; Kamei et al., 2000; Raghavendra et al., 2009; Granath et al., 2006; Michalsen et al., 2005) where yoga practice has shown improved stress levels by restoring the body's sympathetic-parasympathetic balance. Research has also shown that prolonged activation of the HPA system has deleterious effects on brain function (Sapolsky, Krey & McEwen, 2002; Sapolsky, 1992) and neuroendocrine studies suggest that brain exposure to higher cortisol concentrations contribute to cognitive deficits as we age (Li et al., 2006; Franz et al., 2011). Larger RCTs assessing a broader spectrum of cognitive functions and comprehensive cortisol assessment protocols will enable us to reliably determine if yoga interventions moderate the deficits and improve cognitive performance by acting upon the HPA system. Future research also needs to examine other physiological changes that may underlie the yoga-cognition relationship.

Other than the mechanisms explored in this study, there are a number of possible processes that may explain the relationship between yoga and cognitive improvement. Yoga

practice involves focusing on the sensations of the breath, body and thoughts while maintaining a relaxed state of mind. During formal meditation practice, distractions will arise and the meditator is taught to acknowledge discursive thoughts, and non-judgmentally return his/her attention back to their breathing. Regular meditation practice allows the meditator to cultivate moment-to-moment awareness of the self and environment. It is possible that, such practice can lead to meta-cognitive processing which is the conscious awareness of cognitive control processes (Fernandez-Duque, Baird, & Posner, 2000). It has been established that improvements in meta-cognition are related to the ability to restrict bottom-up processing of exogenously/endogenously driven, task-irrelevant information (Posner & Rothbart, 1998). Participants in the yoga intervention may have experienced heightened meta-awareness which enabled them to improve attention sustainability by releasing cognitive appraisals of irrelevant information. In addition, yoga practice is extremely guided and involves sustained attention to the instructor's cues to perform the body movements. From a cognitive perspective, the practice of yoga requires participants to not only mirror the instructor's movements but also to learn exercises while maintaining an inward focus and proprioception.

In the physical activity-cognition literature, experiencing novel activities (Lewis et al., 2009) and anaerobic interventions have been shown to have unique cognitive benefits on brain structure and function (Voss et al., 2010). From this neuroscientific perspective, tasks that involve mind wandering, memory consolidation, thought focused inwards to the self (self-referential thinking), and taking the perspective of others into one's own view of the world have been associated with the default mode network. This is a network of brain regions that are active when the individual is at rest but not focused on the outside world (Buckner et al., 2008; Schilbach et al., 2008). There is evidence that supports a relationship between the default mode

network and executive function, where increased default mode network function has been associated with better working memory performance in young adults (Hampson et al., 2006), and better performance on a range of executive function tasks in older adults (Andrews-Hanna et al., 2007; Damoiseaux et al., 2008; Persson et al., 2007; Voss et al., 2010). The postures, breathing as well as meditative practice of yoga in this study largely parallel the self-referential thoughts and mind-wandering functions of the DMN and the structural and functional brain changes may have resulted in the improved cognitive performance on the executive function measures for the yoga participants.

Functional Fitness Outcomes

In terms of functional measures, yoga was as effective as the CDC anaerobic guidelines in improving outcomes of balance, flexibility, strength and mobility in this older adult sample. Although yoga practice does not entail use of weights or resistance bands, the yoga postures, stretches and holds involve working with the practitioner's own body weight. For instance, the down dog posture (*adho mukha shvanasana*) involves sustaining one's body weight on upper and lower body muscles including the trapezius, triceps, glutes and hamstrings, forming an inverted V shape. It is expected that practice of these postures over the course of the 8-week intervention is likely to have resulted in these functional gains. Similarly, practice of the tree pose (*vrikshasana*) focuses on balance by working one side of the body at a time. Much like the CDC anaerobic recommendations, yoga practice involves seated, standing as well as supine postures that target all major muscle groups. With the increasing popularity of yoga and larger numbers of older adults adopting alternate modes of physical activity, these findings have critical implications. Poor function has been associated with disability, loss of independence and reduced quality of life (Guralnik & Ferrucci, 2003). Yoga may serve as an alternate form of

therapy to improve balance, mobility and strength among older adults and combat age related declines. Replication of these results in larger and more diverse samples may enable researchers and practitioners to establish regular practice of yoga as a proxy for meeting anaerobic CDC guidelines for some older adult populations.

Strengths and Limitations

The SAY Exercise trial is the first randomized control trial to have systematically examined the effect of yoga on cognition in sedentary, healthy, middle aged and older adults. Standardized neuropsychological tests were employed in the present study which has been a limitation of previous work in the yoga-cognition literature. Another strength of this work is the existence of an exercise control group. Although a majority of the sample comprised of well-educated, affluent Caucasian women, the study was successful in drawing approximately 20% of individuals from minority groups, which is proportional to the distribution of minorities in the Champaign-Urbana area. This study is also a first in contrasting the functional benefits of yoga with CDC recommended anaerobic guidelines for adults. Objective measures of functional fitness were employed to examine improvements in balance, mobility, flexibility and strength. Retention rates throughout the intervention were high and both groups showed good adherence to the exercise sessions. Although this study contributes greatly to the sparse yoga-cognition literature, it does have some limitations. The salivary cortisol assessment protocol used in this trial could be refined in future work. Taking into account the duration of the study and participant burden to complete assessments, saliva samples were collected only once at each time-point in the present study. Collecting multiple saliva samples at each timepoint and at various times of the day to account for the circadian rhythm of cortisol may serve as more reliable markers. The perceived stress scale did not accurately capture situational stressors such

as being laid off at work or death in the family. Such life events should be formally recorded in the future, to more accurately and reliably account for outliers in the data sets. Although salivary cortisol levels partially predicted cognitive performance, these data call for replication as well as exploring other physiological markers that may explain the underlying yoga-cognition mechanisms. While this trial was successful in examining short term effects of yoga, the absence of a longer follow up timepoint is a limitation which should be addressed in future trials. Such a design would allow for monitoring the improvements, maintenance or declines in cognitive functioning in comparison to age related changes. Most of the classic physical activity interventions that examine cognitive and functional outcomes are longer in duration lasting 6-12 months, for example the Healthy Active Lifestyle Trial (McAuley et al., 2011) that examined cognitive outcomes, and the FlexToBa Trial (McAuley et al., 2012) that examined functional outcomes in older adults. It remains to be determined if larger cognitive and functional gains would be observed with longer yoga interventions designed for more than 8-weeks of practice. It also remains to be seen whether a combination of site- and home-based yoga program will show similar results. It is also important to recognize the role of outcome expectations that may have affected study outcomes. Given that these participants did not perform yoga routinely, the novelty and instruction during the yoga session and the mind-body nature of this exercise may have resulted in motivational and attentional enhancements during the cognitive tasks resulting in improved performance. Participants are likely to have outcome expectations for any form of physical activity, however it remains to be determined if these expectations are particularly enhanced in the context of novel mind-body based interventions.

Conclusions and Future Directions

In conclusion, the 8-week yoga intervention was found to have positive effects on cognitive and functional well-being of the participants. While yoga was superior to stretching in improving cognitive performance on a variety of executive function and processing speed measures, yoga was just as effective as anaerobic CDC guidelines in improving functional fitness outcomes. A closer examination of possible predictors indicated that the HPA axis might play a role in inducing cognitive changes, however the exact neurobiological changes within the brain remain unknown. The physical activity and cognition literature has adopted advanced neuroimaging techniques to examine structural and functional changes that occur as a result of exercise and it remains to be seen how yoga compares to those findings. Future studies should replicate these outcomes across different age groups, among clinical populations and examine the dose-response relationship of varied durations and frequencies of yoga practice. While this study examines the short term effects of yoga, it remains to be determined whether these health benefits are sustained over time and offset the course of normal age related declines. A longer follow-up period will enable researchers to thoroughly examine trajectories of change. The functional outcomes also indicated that yoga was as effective as CDC guidelines in improving functional fitness in older adults. These findings have important clinical implications as yoga may serve as an alternate form of physical activity for individuals who maybe unable to meet CDC guidelines, including populations such as the frail elderly or individuals with disabilities. The gentle and modifiable nature of practically all yoga postures promises to be a well received, enjoyable and an exercise form that is easy to adopt and maintain for older adults. Together, these functional and cognitive benefits can lead to improved health related quality of life as the population continues to age. Clearly, yoga research is still in its nascent stages and with its

increasing popularity across the globe, researchers need to adopt rigorous systematic approaches to examine its bio-psycho-social benefits across the lifespan.

REFERENCES

- Alexander, C. N., Chandler, H. M., Langer, E. J., Newman, R. I., & Davies, J. L. (1989). Transcendental Meditation, Mindfulness, and Longevity: An Experimental Study With the Elderly. *Journal of Personality and Social Psychology*, 57(6), 950-964.
- Andrews-Hanna, J. R., Snyder, A. Z., Vincent, J. L., Lustig, C., Head, D., Raichle, M. E., & Buckner, R. L. (2007). Disruption of Large-scale Brain Systems in Advanced Aging. *Neuron*, 56(5), 924.
- Angevaren, M., Aufdemkampe, G., Verhaar, H. J. J., Aleman, A., & Vanhees, L. (2008). Physical Activity and Enhanced Fitness to Improve Cognitive Function in Older People without known Cognitive Impairment. *Cochrane Database of Systematic Reviews*, (16)3, CD005381.
- Arafah, B. M., Nishiyama, F. J., Tlaygeh, H., & Hejal, R. (2007). Measurement of Salivary Cortisol Concentration in the Assessment of Adrenal Function in Critically Ill Subjects: A Surrogate Marker of the Circulating Free Cortisol. *Journal of Clinical Endocrinology & Metabolism*, 92(8), 2965-2971.
- Arent, S. M., Landers, D. M., & Etnier, J. L. (2000). The Effects of Exercise on Mood in Older Adults: A meta-analytic review. *Journal of Aging and Physical Activity*, 8(4), 407-430.
- Astin, J., Pelletier, K., Marie, A., & Haskell, W. (2000). Complementary and Alternative Medicine Use Among Elderly Persons: One-year Analysis of a Blue Shield Medicare Supplement. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 55(1), M4-M9.
- Bäckman, L., Small, B. J., Wahlin, A., & Larsson, M. (2000). Cognitive Functioning in Very Old Age. In *The handbook of aging and cognition (2nd ed.)*. (pp. 499-558): Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.
- Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory Changes in Healthy Older Adults.

- In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory*. (pp. 395-409). New York: US: Oxford University Press.
- Barnes, P. M., Powell-Griner, E., McFann, K., & Nahin, R. L. (2004). Complementary and Alternative Medicine Use Among Adults: United States, 2002. *Seminars in Integrative Medicine*, 2(2), 54-71.
- Bera, T. K., & Rajapurkar, M. V. (1993). Body Composition, Cardiovascular Endurance and Anaerobic Power of Yogic Practitioner. *Indian Journal of Physiology and Pharmacology*, 37, 225-228.
- Berger, B. G., & Owen, D. R. (1988). Stress Reduction and Mood Enhancement in Four Exercise Modes: Swimming, Body Conditioning, Hatha Yoga, and Fencing. *Research Quarterly for Exercise and Sport*, 59(2), 148.
- Berger, B. G., & Owen, D. R. (1992). Mood Alteration with Yoga and Swimming – Aerobic Exercise May Not be Necessary. *Perceptual and Motor Skills*, 75(8), 1331-1343.
- Bjelland, I., Dahl, A. A., Haug, T. T., & Neckelmann, D. (2002). The Validity of the Hospital Anxiety and Depression Scale: An Updated Literature Review. *Journal of Psychosomatic Research*, 52(2), 69-77.
- Bless, H. (2003). The Consequences of Mood on the Processing of Social Information. In A. Tesser & N. Schwarz (Eds.), *The Blackwell Handbook of Social Psychology: Intraindividual Processes*. (pp. 391-411). Malden, MA: Blackwell Publishers.
- Blumenthal, J. A., Emery, C. F., Madden, D. J., George, L. K., Coleman, R. E., Riddle, M. W., et al. (1989). Cardiovascular and Behavioral Effects of Aerobic Exercise Training in Healthy Older Men and Women. *Journal of Gerontology*, 44, 147-157.
- Blumenthal, J. A., Emery, C. F., Madden, D. J., Schneibolk, S., Walsh-Riddle, M., George, L.K., et al. (1991). Long-term Effects of Exercise on Psychological Functioning in Older Men and Women. *Journal of Gerontology*, 46, P352-361.

- Blumenthal, J. A., Babyak, M. A., Moore, K. A., Craighead, W. E., Herman, S., Khatri, P., et al. (1999). Effects of Exercise Training on Older Patients with Major Depression. *Archives of Internal Medicine*, 159, 2349-2356.
- Bower, J. E., Woolery, A., Sternlieb, B., & Garet, D. (2005). Yoga for Cancer Patients and Survivors. *Cancer Control: Journal of the Moffitt Cancer Center*, 12(3), 165-171.
- Brisswalter, J., Collardeau, M., & Renae, A. (2002). Effects of Acute Physical Exercise Characteristics on Cognitive Performance. *Sports Medicine*, 32(9), 555-566.
- Brown, D. R. (1992). Physical Activity, Aging, and Psychological Well-being: An Overview of the Research. *Canadian Journal of Sport Sciences*, 17(3), 185-193.
- Brown, R. P., & Gerbarg, P. L. (2005). Sudarshan Kriya Yogic Breathing in the Treatment of Stress, Anxiety, and Depression: Part I-Neurophysiologic Model. *Journal of Alternative and Complementary Medicine*, 11(1), 189-201.
- Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The Brain's Default Network. *Annals of the New York Academy of Sciences*, 1124(1), 1-38.
- Burgener, S. C., Yang, Y., Gilbert, R., & Marsh-Yant, S. (2008). The Effects of a Multimodal Intervention on Outcomes of Persons With Early-Stage Dementia. *American Journal of Alzheimer's Disease and Other Dementias*, 23(4), 382-394.
- Canter, P., & Ernst, E. (2003). The Cumulative Effects of Transcendental Meditation on Cognitive Function — a systematic review of randomised controlled trials. *Wiener Klinische Wochenschrift*, 115(21), 758-766.
- Cassilhas, R. C., Viana, V. A. R., Grassmann, V., Santos, R. T., Santos, R. F., Tufik, S. R., et al. (2007). The Impact of Resistance Exercise on the Cognitive Function of the Elderly. *Medicine & Science in Sport & Exercise*, 39(8), 1401-1407.
- Centers for Disease Control (2004a). National Center for Health Statistics, The State of Aging and Health in America 2004.

- http://www.cdc.gov/aging/pdf/State_of_Aging_and_Health_in_America_2004.pdf. Accessed January 15, 2012.
- Centers for Disease Control. (2004b). National Nursing Home Survey. http://www.cdc.gov/nchs/data/nnhsd/Estimates/nnhs/Estimates_FunctionalStatus_Tables.pdf. Accessed January 15, 2012.
- Centers for Disease Control and Prevention. (2008). US Department of Health and Human Services Physical activity guidelines for Americans. Washington (DC). <http://www.health.gov/PAGuidelines/guidelines/default.aspx>. Accessed January 15, 2012.
- Chandler, K. (2001). The Emerging Field of Yoga Therapy. *Hawaii Medical Journal*, 60(11), 286-287.
- Chang, Y.-K., & Etnier, J. (2009a). Exploring the Dose-response Relationship Between Resistance Exercise Intensity and Cognitive Function. *Journal of Sport & Exercise Psychology*, 31(5), 640-656.
- Chang, Y.-K., Etnier, J., & Barella, L. (2009b). Exploring the Relationship Between Exercise Induced Arousal and Cognition Using Fractionated Response Time. *Research Quarterly for Exercise and Sport*, 80(1), 78-86.
- Chang, Y.-K., Nien, Y.-H., Tsai, C.-L., & Etnier, J. L. (2010). Physical Activity and Cognition in Older Adults: The Potential of Tai Chi Chuan. *Journal of Aging and Physical Activity*, 18(4), 451-472.
- Chattha, R., Nagarathna, R., Padmalatha, V., & Nagendra, H. R. (2008). Effect of Yoga on Cognitive Functions in Climacteric Syndrome: A Randomised Control Study. *BJOG: an International Journal of Obstetrics and Gynaecology*, 115(8), 991-1000.
- Chen, K.-M., Tseng, W.-S., Ting, L.-F., & Huang, G.-F. (2007). Development and Evaluation of a Yoga Exercise Programme for Older Adults. *Journal of Advanced Nursing*, 57(4), 432-

441.

- Chen, K.-M., Chen, M.-H., Chao, H.-C., Hung, H.-M., Lin, H.-S., & Li, C.-H. (2009). Sleep Quality, Depression State, and Health Status of Older Adults After Silver Yoga Exercises: Cluster Randomized Trial. *International Journal of Nursing Studies*, 46(2), 154-163.
- Cherniack, E., Senzel, R., & Pan, C. (2001). Correlates of Use of Alternative Medicine by the Elderly in an Urban Population. *Journal of Alternative and Complementary Medicine*, 7, 277-280.
- Chodzko-Zajko, W. J. (1991). Physical Fitness, Cognitive Performance, and Aging. *Medicine & Science in Sports & Exercise*, 23(7), 868-872.
- Chong, C., Tsunaka, M., Tsang, H., Chan, E., & Cheung, W. (2011). Effects of Yoga on Stress Management in Healthy Adults: A Systematic Review. *Alternative Therapies*, 17(1), 32-38.
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale: NJ: Lawrence Erlbaum Associates.
- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A Global Measure of Perceived Stress. *Journal of Health and Social Behavior*, 24(4), 385-396.
- Cohen, L., Warneke, C., Fouladi, R. T., Rodriguez, M. A., & Chaoul-Reich, A. (2004). Psychological Adjustment and Sleep Quality in a Randomized Trial of the Effects of a Tibetan Yoga Intervention in Patients with Lymphoma. *Cancer*, 100(10), 2253-2260.
- Colcombe, S., & Kramer, A. F. (2003). Fitness Effects on the Cognitive Function of Older Adults: A Meta-analytic Study. *Psychological Science*, 14(2), 125-130.
- Colcombe, S. J., Kramer, A. F., McAuley, E., Erickson, K. I., & Scalf, P. (2004). Neurocognitive Aging and Cardiovascular Fitness: Recent Findings and Future Directions. *Journal of Molecular Neuroscience*, 24(1), 9-14.

- Corey, G. (2005). *Theory and practice of counseling and psychotherapy*. California: Brooks/Cole publishers.
- Corliss, R. (2001). The Power of Yoga. *Time*, 157, 54-63.
- Cowen, V., & Adams, T. (2005). Physical and Perceptual Benefits of Yoga Asana Practice: Results of a Pilot Study. *Journal of Bodywork and Movement Therapies*, 9(3), 211-219.
- Damoiseaux, J. S., Beckmann, C. F., Arigita, E. S., Barkhof, F., Scheltens, P., Stam, C. J., ... & Rombouts, S. A. R. B. (2008). Reduced Resting-State Brain Activity in the “Default Network” in normal aging. *Cerebral Cortex*, 18(8), 1856-1864.
- D'Ath, P., Katona, P., Mullan, E., Evans, S., & Katona, C. (1994). Screening, Detection and Management of Depression in Elderly Primary Care Attenders. I: The Acceptability and Performance of the 15 item Geriatric Depression Scale (GDS15) and the Development of Short Versions. *Family practice*, 11(3), 260-266.
- de Jager, C. A., Budge, M. M., & Clarke, R. (2003). Utility of TICS-M for the Assessment of Cognitive Function in Older Adults. *International Journal of Geriatric Psychiatry*, 18(4), 318-324.
- Deschamps, A., Onifade, C., Decamps, A., & Bourdel-Marchasson, I. (2009). Health-related Quality of Life in Frail Institutionalized Elderly: Effects of a Cognition-action Intervention and Tai Chi. *Journal of Aging and Physical Activity*, 17(2), 236-248.
- DiCarlo, L., Sparling, P., Hinson, B., Snow, T., & Roskopf, L. (1995). Cardiovascular, Metabolic and Perceptual Responses to Hatha Yoga Standing Poses. *Medicine, Exercise, Nutrition & Health*, 4, 107–112.
- Dickerson, S. S., & Kemeny, M. E. (2004). Acute Stressors and Cortisol Responses: A Theoretical Integration and Synthesis of Laboratory Research. *Psychological Bulletin*, 130(3), 355-391.
- Dickmeis, T. (2009). Glucocorticoids and the Circadian Clock. *Journal of Endocrinology*,

200(1),3-22.

- DiStasio, S. A. (2008). Integrating Yoga into Cancer Care. *Clinical Journal of Oncology Nursing*, 12(1), 125-130.
- Dite, W., & Temple, V. (2002). A Clinical Test of Stepping and Change of Direction to Identify Multiple Falling Older Adults. *Archives of Physical Medicine and Rehabilitation*, 83(11), 1566-1571.
- Dorn, L. D., Lucke, J. F., Loucks, T. L., & Berga, S. L. (2007). Salivary Cortisol Reflects Serum Cortisol: Analysis of Circadian Profiles. *Annals of Clinical Biochemistry*, 44(3), 281-284.
- Dustman, R. E., Ruhling, R. O., Russell, E. M., Shearer, D. E., Bonekat, H. W., Shigeoka, J. W., et al. (1984). Aerobic Exercise Training and Improved Neuropsychological Function of Older Individuals. *Neurobiology of Aging*, 5, 35-42.
- Eisenberg, D. M., Davis, R. B., Ettner, S. L., Appel, S., Wilkey, S., Van Rompay, M., et al. (1998). Trends in Alternative Medicine Use in the United States, 1990-1997. *The Journal of the American Medical Association* 280(18), 1569-1575.
- Emery, C. F., & Gatz, M. (1990). Psychological and Cognitive Effects of an Exercise Program for Community-residing Older Adults. *The Gerontologist*, 30, 184-188.
- Eriksen, B., & Eriksen, C. (1974). Effects of Noise Letters upon the Identification of a Target Letter in a Nonsearch Task. *Attention, Perception, & Psychophysics*, 16(1), 143-149.
- Erickson, K. I., & Kramer, A. F. (2009). Aerobic Exercise Effects on Cognitive and Neural Plasticity in Older Adults. *British Journal of Sports Medicine*, 43(1), 22-24.
- Esch, T., Stefano, G. B., Fricchione, G. L., & Benson, H. (2002). The Role of Stress in Neurodegenerative Diseases and Mental Disorders. *Neuro-endocrinology letters*, 23(3), 199-208.
- Esch, T., Duckstein, J., Welke, J., & Braun, V. (2007). Mind/body Techniques for Physiological and Psychological Stress Reduction: Stress Management via Tai Chi Training - a Pilot

- Study. *Medical Science Monitor*, 13(11), CR488-CR497.
- Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The Influence of Physical Fitness and Exercise Upon Cognitive Functioning: A Meta-analysis. *Journal of Sport & Exercise Psychology*, 19(3), 249-277.
- Etnier, J. L., Nowell, P. M., Landers, D. M., & Sibley, B. A. (2006). A Meta-regression to Examine the Relationship Between Aerobic Fitness and Cognitive Performance. *Brain Research Reviews*, 52(1), 119-130.
- Evans, S., Tsao, J., Sternlieb, B., & Zeltzer, L. K. (2009). Using the Biopsychosocial Model to Understand the Health Benefits of Yoga. *Journal of Complementary and Integrative Medicine*, 6(1), Article 15.
- Eysenck, M. W. (1979). Anxiety, Learning, and Memory: A Reconceptualisation. *Journal of Research in Personality*, 13, 363-385.
- Eysenck, M. W. (1983). Anxiety and Individual Differences. In G. R. J. Hockey (Ed.), *Stress and Fatigue in Human Performance*. (pp 273-298). Sussex: Wiley, Chichester.
- Eysenck, M. W. (1992). *Anxiety: The Cognitive Perspective*. Hove, UK: Lawrence Erlbaum Associates Ltd.
- Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and Cognitive Performance: Attentional Control Theory. *Emotion (Washington, D.C.)*, 7(2), 336-353.
- Fabre, C., Chamari, K., Mucci, P., Masse-Biron, J., & Prefaut, C. (2002). Improvement of Cognitive Function by Mental and/or Individualized Aerobic Training in Healthy Elderly Subjects. *International Journal of Sports Medicine*, 23, 415-421.
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the Efficiency and Independence of Attentional Networks. *Journal of Cognitive Neuroscience*, 14(3), 340-347.

- Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical Power Analyses Using G*Power 3.1: Tests for Correlation and Regression Analyses. *Behavior Research Methods*, 41(4), 1149-1160.
- Fernandez-Duque, D., Baird, J. A., & Posner, M. I. (2000). Executive Attention and Meta-cognitive Regulation. *Consciousness and Cognition*, 9(2), 288-307.
- Flaherty, J. H., Takahashi, R., Teoh, Kim, J.-I., Habib, S., Ito, M., et al. (2001). Use of Alternative Therapies in Older Outpatients in the United States and Japan. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 56(10), M650-M655.
- Franz, C. E., O'Brien, R. C., Hauger, R. L., Mendoza, S. P., Panizzon, M. S., Prom-Wormley, E., ... & Kremen, W. S. (2011). Cross-sectional and 35-year Longitudinal Assessment of Salivary Cortisol and Cognitive Functioning: The Vietnam Era Twin Study of Aging. *Psychoneuroendocrinology*, 36(7), 1040-1052.
- Fredrikson, M., & Engel, B. T. (1985). Cardiovascular and Electrodermal Adjustments during a Vigilance Task in Patients with Borderline and Established Hypertension. *Journal of Psychosomatic Research*, 29(3), 235-246.
- Fried, L. P., & Guralnik, J. M. (1997). Disability in Older Adults: Evidence Regarding Significance, Etiology, and Risk. *Journal of the American Geriatrics Society*, 45(1), 92-100.
- Friend, J. (2006). *Anusara Yoga Teacher Training Manual* (9th ed.). The Woodlands, Texas: Anusara Press.
- Garfinkel, M., & Schumacher Jr, H. R. (2000). Yoga. *Rheumatic Disease Clinics of North America*, 26(1), 125-132.
- Gatchel, R. J., Peng, Y. B., Peters, M. L., Fuchs, P. N. & Turk, D. C. (2007). The Biopsychosocial Approach to Chronic Pain: Scientific Advances and Future Directions. *Psychological Bulletin*, 133(4), 581-624.

- Gauvin, L., & Spence, J. C. (1998). Measurement of Exercise-induced Changes in Feeling States, Affect, Mood, and Emotions. In J. Duda (Ed.), *Advances in Exercise and Sport Psychology Measurement* (pp. 311-324). Morgantown, WV: Fitness Information Technology.
- Geffken, D. F., Cushman, M., Burke, G. L., Polak, J. F., Sakkinen, P. A., & Tracy, R. P. (2001). Association between Physical Activity and Markers of Inflammation in a Healthy Elderly Population. *American Journal of Epidemiology* 153(3), 242-250.
- Gharote, M. L., & Ganguly, S. K. (1979). Effects of a Nine-week Yogic Training Programme on Some Aspects of Physical Fitness of Physically Conditioned Young Males. *Indian Journal of Medical Sciences*, 33(10), 258-263.
- Gothe, N.P., Hillman, C.H. & McAuley, E. (2013, in press). Acute Yoga versus Aerobic Exercise: Effects on Inhibition and Working Memory. *Journal of Physical Activity and Health*.
- Granath, J., Ingvarsson, S., von Thiele, U., & Lundberg, U. (2006). Stress Management: A Randomized Study of Cognitive Behavioral Therapy and Yoga. *Cognitive Behavior Therapy*, 35(1), 3-10.
- Green, S. B. (1991). How Many Subjects Does It Take To Do A Regression Analysis. *Multivariate Behavioral Research*, 26(3), 499-510.
- Groessler, E. J., Weingart, K.R., Aschbacher, K., Pada, L., & Baxi, S. (2008). Yoga for Veterans With Chronic Low-back Pain. *Journal of Alternative and Complementary Medicine*, 14, 1123-1129.
- Guralnik, J., & Ferrucci, L. (2003). Assessing the Building Blocks of Function: Utilizing Measures of Functional Limitation. *American Journal of Preventive Medicine*, 25(112-121).
- Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., et al.

- (1994). A Short Physical Performance Battery Assessing Lower Extremity Function: Association With Self-Reported Disability and Prediction of Mortality and Nursing Home Admission. *Journal of Gerontology*, 49(2), M85-M94.
- Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., et al. (2000). Lower Extremity Function and Subsequent Disability. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 55(4), M221-M231.
- Hagins, M., Moore, W., & Rundle, A. (2007). Does Practicing Hatha Yoga Satisfy Recommendations for Intensity of Physical Activity Which Improves and Maintains Health and Cardiovascular Fitness? *BMC Complementary and Alternative Medicine* 7, 40-40.
- Haley, S. M., Jette, A. M., Coster, W. J., Kooyoomjian, J. T., Levenson, S., Heeren, T., et al. (2002). Late Life Function and Disability Instrument. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 57(4), M217-M222.
- Hampson, M., Driesen, N. R., Skudlarski, P., Gore, J. C., & Constable, R. T. (2006). Brain Connectivity Related to Working Memory Performance. *The Journal of Neuroscience*, 26(51), 13338-13343.
- Haskell, W. L., Lee, I. M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., et al. (2007). Physical Activity and Public Health: Updated Recommendation for Adults From the American College of Sports Medicine and the American Heart Association. *Circulation*, 116(9), 1081-1093.
- Hassmen, P., & Koivula, N. (1997). Mood, Physical Working Capacity and Cognitive Performance in the Elderly as Related to Physical Activity. *Aging*, 9(1-2), 136-142.
- Hawkins, H. L., Kramer, A. F., & Capaldi, D. (1992). Aging, Exercise, and Attention. *Psychology and Aging*, 7, 643-653.
- Heilbronn, F. S. (1992). The Use of Hatha Yoga as a Strategy for Coping With Stress in

- Management Development. *Management Learning*, 23(2), 87-87.
- Heyn, P., Abreu, B. C., & Ottenbacher, K. J. (2004). The Effects of Exercise Training on Elderly Persons with Cognitive Impairment and Dementia: A Meta-analysis. *Archives of Physical Medicine and Rehabilitation*, 85(10), 1694-1704.
- Hill, R. D., Storandt, M., & Malley, M. (1993). The Impact of Long-term Exercise Training on Psychological Function in Older Adults. *Journal of Gerontology*, 48, P12-17.
- Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be Smart, Exercise Your Heart: Exercise Effects on Brain and Cognition. *Nature Reviews: Neuroscience*, 9(1), 58-65.
- Hillman, C. H., Motl, R. W., Pontifex, M. B., Posthuma, D., Stubbe, J. H., Boomsma, D. I., et al. (2006). Physical Activity and Cognitive Function in a Cross-section of Younger and Older Community-dwelling Individuals. *Health Psychology*, 25(6), 678-687.
- Hoenig, H., Ganesh, S. P., Taylor, D. H., Pieper, C., Guralnik, J., & Fried, L. P. (2006). Lower Extremity Physical Performance and Use of Compensatory Strategies for Mobility. *Journal of the American Geriatrics Society*, 54(2), 262-269.
- Hofer, S. M., & Alwin, D. F. (2008). *Handbook of Cognitive Aging: Interdisciplinary Perspectives*. Los Angeles: Sage Publications.
- Hultsch, D. F., Hertzog, C., Dixon, R. A., & Small, B. J. (1998). *Memory Changes in the Aged*. London: Cambridge Univ. Press.
- Innes, K. E., Bourguignon, C., & Taylor, A. G. (2005). Risk Indices Associated with the Insulin Resistance Syndrome, Cardiovascular Disease, and Possible Protection with Yoga: A Systematic Review. *The Journal of the American Board of Family Practice*, 18(6), 491-519.
- Iyengar, B. K. S. (1979). *Light on Yoga*. New York: Schoken Books.
- Jackson, R., & Baldwin, B. O. B. (1993). Detecting Depression in Elderly Medically III Patients: The Use of the Geriatric Depression Scale Compared with Medical and Nursing

- Observations. *Age and Ageing*, 22(5), 349-353.
- Janisse, H., Nedd, D., Escamilla, S., & Nies, M. (2004). Physical Activity, Social Support, and Family Structure as Determinants of Mood Among European-American and African-American Women. *Women Health*, 39(1), 101-116.
- Jette, A. M., Haley, S. M., Coster, W. J., Kooyoomjian, J. T., Levenson, S., Heeren, T., et al. (2002). Late Life Function and Disability Instrument. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 57(4), M209-M216.
- Joshi, M., & Telles, S. (2009). A Nonrandomized Non-naïve Comparative Study of the Effects of Kapalabhati and Breath Awareness on Event-related Potentials in Trained Yoga Practitioners. *Journal of Alternative and Complementary Medicine*, 15(3), 281-285.
- Kabacoff, R. I., Segal, D. L., Hersen, M., & Van Hasselt, V. B. (1997). Psychometric Properties and Diagnostic Utility of the Beck Anxiety Inventory and the State-Trait Anxiety Inventory with Older Adult Psychiatric Outpatients. *Journal of Anxiety Disorders*, 11(1), 33-47.
- Kamei, T., Toriumi, Y., Kimura, H., Ohno, S., Kumano, H., & Kimura, K. (2000). Decrease in Serum Cortisol During Yoga Exercise is Correlated with Alpha Wave Activation. *Perceptual and Motor Skills*, 90(3), 1027-1032.
- Kara, B., Pinar, L., Ugur, F., & Oguz, M. (2005). Correlations Between Aerobic Capacity, Pulmonary and Cognitive Functioning in the Older Women. *International Journal of Sports Medicine*, 26, 220-224.
- Kaufman, M. (2005, Jan 3). Meditation Gives Brain a Charge, Study Finds. *Washington Post*.
- Keysor, J. J., & Jette, A. M. (2001). Have We Oversold the Benefit of Late-Life Exercise? *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(7), M412-M423.
- Keysor, J. (2003). Does Late-life Physical Activity or Exercise Prevent or Minimize

- Disablement? A Critical Review of the Scientific Evidence. *American Journal of Preventive Medicine*, 25 (3, Supplement 2), 129-136.
- King, A. C., Pruitt, L. A., Phillips, W., Oka, R., Rodenburg, A., & Haskell, W. L. (2000). Comparative Effects of Two Physical Activity Programs on Measured and Perceived Physical Functioning and Other Health-related Quality of Life Outcomes in Older Adults. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 55(2), M74-M83.
- Kirchner, W. K. (1958). Age Differences in Short-term Retention of Rapidly Changing Information. *Journal of Experimental Psychology*, 55(4), 352-358.
- Kirkwood, G., Rampes, H., Tuffrey, V., Richardson, J., & Pilkington, K. (2005). Yoga for Anxiety: A Systematic Review of the Research Evidence. *British Journal of Sports Medicine*, 39(12), 884-891.
- Kjaer, T. W., Bertelsen, C., Piccini, P., Brooks, D., Alving, J. r., & Lou, H. C. (2002). Increased Dopamine Tone During Meditation-induced Change of Consciousness. *Cognitive Brain Research*, 13(2), 255-259.
- Kline, G. M., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., McCarron, R. F., et al. (1987). Estimation of VO₂max from a One-mile Track Walk, Gender, Age, and Body Weight. *Medicine and Science in Sports and Exercise*, 19(3), 253-259.
- Kolasinski, S. L., Garfinkel, M., Tsai, A. G., Matz, W., Van Dyke, A., Schumacher, H. R. (2005). Iyengar Yoga for Treating Symptoms of Osteoarthritis of the Knees: A Pilot Study. *Journal of Alternative and Complementary Medicine*, 11(4), 689-693.
- Kolsawalla, M. B. (1978). An Experimental Investigation into the Effectiveness of Some Yogic Variables as a Mechanism of Change in the Value-attitude System. *Journal of Indian Psychology*, 1(1), 59-68.
- Kramer, A. F., Hahn, S., Cohen, N. J., Banich, M. T., McAuley, E., Harrison, C.R., et al. (1999).

- Ageing, Fitness and Neurocognitive Function. *Nature*, 400, 417-418.
- Kramer, A. F., Colcombe, S. J., McAuley, E., Scalf, P. E., & Erickson, K. I. (2005). Fitness, Aging and Neurocognitive Function. *Neurobiology of Aging*, 26(1, Supplement), 124-127.
- Kramer, A. F., & Erickson, K. I. (2007). Effects of Physical Activity on Cognition, Well-being, and Brain: Human Interventions. *Alzheimer's and Dementia*, 3(2, Supplement), S45-S51.
- Kray, J., & Lindenberger, U. (2000). Adult Age Differences in Task Switching. *Psychology and Aging*, 15(1), 126-147.
- Kuttner, L., Chambers, C. T., Hardial, J., Israel, D. M., Jacobson, K., & Evans, K. (2006). A Randomized Trial of Yoga for Adolescents with Irritable Bowel Syndrome. *Pain Research and Management*, 11(4), 217-223.
- Kyizom, T., Singh, S., Singh, K. P., Tandon, O. P., & Kumar, R. (2010). Effect of Pranayama & Yoga-asana on Cognitive Brain Functions in Type 2 Diabetes-P3 Event Related Evoked Potential (ERP). *Indian Journal of Medical Research*, 131, 636-640.
- Labarthe, D., & Ayala, C. (2002). Nondrug Interventions in Hypertension Prevention and Control. *Cardiology Clinics*, 20, 249-263.
- La Forge, R. (1997). Mind-Body Fitness: Encouraging Prospects for Primary and Secondary Prevention. *Journal of Cardiovascular Nursing*, 11(3), 53-65.
- Lajoie, Y., & Gallagher, S. P. (2004). Predicting Falls Within the Elderly Community: Comparison of Postural Sway, Reaction Time, the Berg Balance Scale and the Activities-Specific Balance Confidence (ABC) scale for Comparing Fallers and Non-fallers. *Archives of Gerontology and Geriatrics*, 38(1), 11-26.
- Landers, D. M., & Petruzzello, S. J. (1994). Physical Activity, Fitness, and Anxiety. In *Physical Activity, Fitness, and Health: International Proceedings and Consensus Statement*. (pp. 868-882): Champaign, IL, England: Human Kinetics Publishers.

- Latha, D., & Kaliappan, K. V. (1992). Efficacy of Yoga Therapy in the Management of Headaches. *Journal of Indian Psychology*, 10(1-2), 41-47.
- Lee, S. W., Mancuso, C. A., & Charlson, M. E. (2004). Prospective Study of New Participants in a Community-based Mind-body Training Program. *Journal of General Internal Medicine*, 19(7), 760-S.
- Lewis, C. M., Baldassarre, A., Committeri, G., Romani, G. L., and Corbetta, M. (2009). Learning Sculpts the Spontaneous Activity of the Resting Human Brain. *Proceedings of the National Academy of Sciences*, 106(41), 17558–17563.
- Li, F., Harmer, P., McAuley, E., Fisher, K. J., Duncan, T. E., & Duncan, S. C. (2001a). Tai Chi, Self-efficacy, and Physical Function in the Elderly. *Prevention Science: The Official Journal of the Society for Prevention Research* 2(4), 229-239.
- Li, F., Harmer, P., McAuley, E., Duncan, T. E., Duncan, S. C., Chaumeton, N., et al. (2001b). An Evaluation of the Effects of Tai Chi Exercise on Physical Function Among Older Persons : A Randomized Controlled Trial. *Annals of Behavioral Medicine*, 23(2), 139-146.
- Li, F., Fisher, K. J., Harmer, P., & McAuley, E. (2002). Delineating the impact of Tai Chi Training on Physical Function among the Elderly. *American Journal of Preventive Medicine*, 23(2 Suppl), 92-97.
- Li, F., Fisher, K. J., Harmer, P., Irbe, D., Tearse, R. G., & Weimer, C. (2004). Tai Chi and Self-Rated Quality of Sleep and Daytime Sleepiness in Older Adults: A Randomized Controlled Trial. *Journal of the American Geriatrics Society*, 52(6), 892-900.
- Li, G., Cherrier, M. M., Tsuang, D. W., Petrie, E. C., Colasurdo, E. A., Craft, S., ... & Wilkinson, C. W. (2006). Salivary Cortisol and Memory Function in Human Aging. *Neurobiology of Aging*, 27(11), 1705-1714.
- Luo, L., & Craik, F. I. M. (2008). Aging and Memory: A Cognitive Approach. *The Canadian*

- Journal of Psychiatry / La Revue Canadienne de Psychiatrie*, 53(6), 346-353.
- Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of Stress Throughout the Lifespan on the Brain, Behavior and Cognition. *Nature reviews:Neuroscience*, 10(6), 434-445.
- MacLean, C. R. K., Walton, K. G., Wenneberg, S. R., Levitsky, D. K., Mandarino, J. P., Waziri, R., et al. (1997). Effects of the Transcendental Meditation Program on Adaptive Mechanisms: Changes in Hormone Levels and Responses to Stress After 4 Months of Practice. *Psychoneuroendocrinology*, 22(4), 277-295.
- Macy, D. (2008). Yoga Journal Releases 2008 'Yoga in America' Market Study Practitioner Spending Grows to Nearly \$6 Billion a Year. *Yoga Journal*.
- Madanmohan, Thombre, D. P., & Balakumar, B. (1992). Effect of Yoga Training on Reaction Time, Respiratory Endurance and Muscle Strength. *Indian Journal of Physiology and Pharmacology*, 36(4), 229-233.
- Madhavi, S., Raju, P. S., Reddy, M. V., Annapurna, N., Sahay, B. K., Kumari, D. G., et al. (1985). Effect of Yogic Exercises on Lean Body Mass. *The Journal of the Association of Physicians of India*, 33(7), 465-466.
- Man, D. W. K., Tsang, W. W. N., & Hui-Chan, C. W. Y. (2010). Do Older T'ai Chi Practitioners Have Better Attention and Memory Function? *Journal of Alternative and Complementary Medicine*, 16(12), 1259-1264.
- Manjunath, N. K., & Telles, S. (2005). Influence of Yoga and Ayurveda on Self-rated Sleep in a Geriatric Population. *The Indian Journal of Medical Research*, 121(5), 683-690.
- Marcus, M. T., Fine, P. M., Moeller, F. G., Khan, M. M., Pitts, K., Swank, P. R., et al. (2003). Change in Stress Levels Following Mindfulness-based Stress Reduction in a Therapeutic Community. *Addictive Disorders & Their Treatment*, 2(3), 63-68.
- Mather, A. S., Rodriguez, C., Guthrie, M. F., McHarg, A. M., Reid, I. C., & McMurdo, M. E.

- (2002). Effects of Exercise on Depressive Symptoms in Older Adults with Poorly Responsive Depressive Disorder: Randomised Controlled Trial. *British Journal of Psychiatry*, 180, 411-415.
- Matthews, M., & Williams, H. (2008). Can Tai chi Enhance Cognitive Vitality? A Preliminary Study of Cognitive Executive Control in Older Adults After a Tai Chi Intervention. *The Journal of the South Carolina Medical Association*, 104(8), 255-257.
- Mazzeo, R. S., Cavanagh, P., Evans, W. J., Fiatarone, M., Hagberg, J., McAuley, E., et al. (1998). ACSM Position Stand: Exercise and Physical Activity for Older Adults. *Medicine & Science in Sports & Exercise*, 30(6), 992-1008.
- McAuley, E., Wójcicki, T. R., White, S. M., Mailey, E. L., Szabo, A. N., Gothe, N., ... & Estabrooks, P. (2012). Physical Activity, Function, and Quality of life: Design and Methods of the *FlexToBa*™ Trial. *Contemporary Clinical Trials*, 33(1), 228-236.
- McAuley, E., Kramer, A. F., & Colcombe, S. J. (2004). Cardiovascular Fitness and Neurocognitive Function in Older Adults: A Brief Review. *Brain, Behavior, and Immunity*, 18(3), 214-220.
- McAuley, E., Konopack, J. F., Motl, R. W., Rosengren, K., & Morris, K. S. (2005). Measuring Disability and Function in Older Women: Psychometric Properties of the Late-Life Function and Disability Instrument. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 60(7), 901-909.
- McAuley, E., & Elavsky, S. (2006). Physical Activity, Aging, and Quality of Life: Implications for Measurement. In W. Zhu & W. Chodzko-Zajko (Eds.), *Measurement Issues in Aging and Physical Activity* (pp. 57-68). Champaign, IL: Human Kinetics.
- McAuley, E., Konopack, J., Motl, R., Morris, K., Doerksen, S., & Rosengren, K. (2006). Physical Activity and Quality of Life in Older Adults: Influence of Health Status and Self-efficacy. *Annals of Behavioral Medicine*, 31(1), 99-103.

- McAuley, E., & Morris, K. S. (2007). State of the Art Review: Advances in Physical Activity and Mental Health: Quality of Life. *American Journal of Lifestyle Medicine*, 1(5), 389-396.
- McAuley, E., & Rudolph, D. (1995). Physical Activity, Aging, and Psychological Well-being. *Journal of Aging and Physical Activity*, 3, 67-96.
- McDonald, D. G., & Hodgdon, J.A. (1991). *The Psychological Effects of Aerobic Fitness Training: Research and Theory*. New York: Springer-Verlag.
- McGuire, L., Strine, T., Okoro, C., Ahluwalia, I., & Ford, E. (2007). Healthy Lifestyle Behaviors Among Older U.S. Adults with and without Disabilities, Behavioral Risk Factor Surveillance System, 2003. *Preventing Chronic Disease*, 4(1), A09-A09.
- McLafferty, C., Wetzstein, C., & Hunter, G. (2004). Resistance Training is Associated with Improved Mood in Healthy Older Adults. *Perceptual and Motor Skills*, 93(3), 947-957.
- McNeil, J. K., LeBlanc, E.M., & Joyner, M. (1992). The Effect of Exercise on Depressive Symptoms in the Moderately Depressed Elderly. *Psychology and Aging*, 6, 487-488.
- Michalsen, A., Grossman, P., Acil, A., Langhorst, J., Ldtke, R., Esch, T., et al. (2005). Rapid Stress Reduction and Anxiolysis among Distressed Women as a Consequence of a Three-month Intensive Yoga Program. *Medical Science Monitor*, 11(12), CR555-CR561.
- Miller, M. E., Rejeski, W. J., Reboussin, B. A., Have, T. R., & Ettinger, W. H. (2000). Physical Activity, Functional Limitations, and Disability in Older Adults. *Journal of the American Geriatrics Society*, 48(10), 1264-1272.
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The Unity and Diversity of Executive Functions and Their Contributions to Complex “Frontal Lobe” Tasks: A Latent Variable Analysis. *Cognitive Psychology*, 41(1), 49-100.
- Moadel, A. B., Shah, C., Wylie-Rosett, J., Harris, M. S., Patel, S. R., Hall, C. B., Sparano, J. A.

- (2007). Randomized Controlled Trial of Yoga Among a Multi-ethnic Sample of Breast Cancer Patients: Effects on Quality of Life. *Journal of Clinical Oncology*, 25(28), 4387-4395.
- Monzell, S. (1996). Control of Mental Processes. In *Unsolved mysteries of the mind: Tutorial Essays in Cognition*. (pp. 93-148). Oxford, England: Erlbaum (Uk) Taylor & Francis Publications.
- Moody-Ayers, S. Y., Mehta, K. M., Lindquist, K., Sands, L., & Covinsky, K. E. (2005). Black-White Disparities in Functional Decline in Older Persons: The Role of Cognitive Function. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 60(7), 933-939.
- Moore, A., & Malinowski, P. (2009). Meditation, Mindfulness and Cognitive Flexibility. *Consciousness and Cognition*, 18(1), 176-186.
- Morone, N. E., & Greco, C. M. (2007). Mind-body Interventions for Chronic Pain in Older Adults: A Structured Review. *Pain medicine*, 8(4), 359-375.
- Morris, N., & Jones, D. M. (1990). Memory Updating in Working Memory: The Role of the Central Executive. *British Journal of Psychology*, 81(111-121).
- Morse, C. K. (1993). Does Variability Increase with Age? An Archival Study of Cognitive Measures. *Psychology and Aging*, 8(2), 156-164.
- Motl, R. W., Konopack, J. F., McAuley, E., Elavsky, S., Jerome, G. J., & Marquez, D. X. (2005). Depressive Symptoms Among Older Adults: Long-term Reduction After a Physical Activity Intervention. *Journal of Behavioral Medicine*, 28(4), 385-394.
- Moul, J. L., Goldman, B., & Warren, B. (1995). Physical Activity and Cognitive Performance in the Older Population. *Journal of Aging and Physical Activity*, 3, 134-145.
- Naveen, K. V., Nagarathna, R., Nagendra, R. H. R., & Telles, S. (1997). Yoga Breathing Through a Particular Nostril Increases Spatial Memory Scores without Laterized Effects.

- Psychological Reports*, 81, 555-561.
- Netz, Y. (2009). Physical Activity and Cognitive Functioning in Advanced Age. *Journal of Social & Psychological Gerontology*, (1).
- Netz, Y., Wu, M.-J., Becker, B. J., & Tenenbaum, G. (2005). Physical Activity and Psychological Well-being in Advanced Age: A Meta-analysis of Intervention Studies. *Psychology and Aging*, 20(2), 272-284.
- Nilsson, L-G. (2003). Memory Function in Normal Aging. *Acta Neurologica Scandinavica*, 107, 7-13.
- Nilsson, L-G., Adolfsson, R., Bäckman, L., de Frias, C. M., Molander, B., & Nyberg, L. (2004). Betula: A Prospective Cohort Study on Memory, Health and Aging. *Aging, Neuropsychology, and Cognition*, 11(2-3), 134-148.
- North, T. C., McCullagh, P., & Tran, Z. V. (1990). Effect of Exercise on Depression. *Exercise and Sport Sciences Reviews*, 18, 379-415.
- Nowalk, M. P., Prendergast, J. M., Bayles, C. M., D'Amico, F. J., & Colvin, G. C. (2001). A Randomized Trial of Exercise Programs Among Older Individuals Living in Two Long-term Care Facilities: The Falls Free Program. *Journal of the American Geriatrics Society*, 49(7), 859-865.
- Nystrom, L. E., Braver, T. S., Sabb, F. W., Delgado, M. R., Noll, D. C., & Cohen, J. D. (2000). Working Memory for Letters, Shapes, and Locations: fMRI Evidence Against Stimulus-Based Regional Organization in Human Prefrontal Cortex. *NeuroImage*, 11(5), 424-446.
- O'Connor, P. J., Aenchbacher, L. E., & Dishman, R. K. (1993). Physical Activity and Depression in the Elderly. *Journal of Aging and Physical Activity*, 1, 34-58.
- Oken, B. S., Kishiyama, S., Zajdel, D., Bourdette, D., Carlsen, J., Haas, M., et al. (2004). Randomized Controlled Trial of Yoga and Exercise in Multiple Sclerosis. *Neurology*, 62(11), 2058-2064.

- Oken, B. S., Zajdel, D., Kishiyama, S., Flegal, K., Haas, M., Kraemer, D. F., et al. (2006). Healthy Seniors: Effects On Cognition and Quality of Life. *Alternative Therapies in Health and Medicine*, 12(1), 40-47.
- Panton, L. B., Graves, J. E., Pollock, M. L., Hagberg, J. M., & Chen, W. (1990). Effect of Aerobic and Resistance Training on Fractionated Reaction Time and Speed of Movement. *Journal of Gerontology*, 45, M26-31.
- Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of Visuospatial and Verbal Memory across the Adult Life Span. *Psychology and Aging*, 17(2), 299-320.
- Park, D. C., & Reuter-Lorenz, P. (2009). The Adaptive Brain: Aging and Neurocognitive Scaffolding. *Annual Review of Psychology*, 60, 173-196.
- Pashler, H. (2000). Task Switching and Multitask Performance. In S. Monsell & J. Driver (Eds.), *Attention and Performance XVIII: Control of Cognitive Processes* (pp. 277-307). Cambridge, MA: MIT Press.
- Paterson, D. H., & Warburton, D. E. R. (2010). Physical Activity and Functional Limitations in Older Adults: A Systematic Review Related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity*, 7(38), 1-22.
- Penedo, F. J., & Dahn, J. R. (2005). Exercise and Well-being: A Review of Mental and Physical Health Benefits Associated with Physical Activity. *Current Opinion in Psychiatry*, 18(2), 189-193.
- Penninx, B. W., Rejeski, W. J., Pandya, J., Miller, M. E., DiBari, M., Applegate, W. B., et al. (2002). Exercise and Depressive Symptoms: A Comparison of Aerobic and Resistance Exercise Effects on Emotional and Physical Function in Older Persons with High and Low Depressive Symptomatology. *Journal of Gerontology. Series B, Psychological Sciences and Social Sciences*, 57, 124-132.

- Perrig-Chiello, P., Perrig, W.J., Ehlsam, R., Staehelin, H.B., & Krings, F. (1998). The Effects of Resistance Training on Well-being and Memory in Elderly Volunteers. *Age and Ageing*, 27, 469-475.
- Persson, J., Lustig, C., Nelson, J. K., & Reuter-Lorenz, P. A. (2007). Age Differences in Deactivation: A Link to Cognitive Control? *Journal of Cognitive Neuroscience*, 19(6), 1021-1032.
- Petersen, A. M. W., & Pedersen, B. K. (2005). The Anti-inflammatory Effect of Exercise. *Journal of Applied Physiology*, 1154-1162.
- Petruzzello, S. J., Landers, D.M., Hatfield, B.D., Kubitz, K.A., & Salazar, W. (1991). A Meta-analysis on the Anxiety-reducing Effects of Acute and Chronic Exercise. *Sports Medicine*, 11(3), 143-182.
- Pilkington, K., Kirkwood, G., Rampes, H., & Richardson, J. (2005). Yoga for Depression: The Research Evidence. *Journal of Affective Disorders*, 89(1-3), 13-24.
- Pollock, M. L. (1989). Exercise Prescriptions for the Elderly. *Academy of Physical Education Papers*, 22, 163-174.
- Pontifex, M. B., Hillman, C. H., Fernhall, B. O., Thompson, K. M., & Valentini, T. A. (2009). The Effect of Acute Aerobic and Resistance Exercise on Working Memory. *Medicine & Science in Sport & Exercise*, 41(4), 927-934.
- Posadzki, P., & Ernst, E. (2011). Yoga for Low Back Pain: A Systematic Review of Randomized Clinical Trials. *Clinical Rheumatology*, 30(9), 1257-1262.
- Posner, M. I., & Rothbart, M. K. (1998). Attention, Self-regulation and Consciousness. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 353(1377), 1915-1927.
- Posner, M. I., Sheesea, B. E., Odludaşa, Y., & Tang, Y.-Y. (2006). Analyzing and Shaping Neural Networks of Attention. *Neural Networks*, 19, 1422-1429.

- Powell, L. E., & Myers, A. M. (1995). The Activities-specific Balance Confidence (ABC) Scale. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 50A(1), M28-M34.
- Prull, M. W., Gabrieli, J. D. E., & Bunge, S. A. (2000). Age-related Changes in Memory: A Cognitive Neuroscience Perspective. In F. I. M. Craik & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (2nd ed., pp. 91–153). Mahwah, NJ: Erlbaum.
- Raub, J. A. (2002). Psychophysiologic effects of Hatha Yoga on Musculoskeletal and Cardiopulmonary Function: A Literature Review. *Journal of Alternative and Complementary Medicine*, 8(6), 797-812.
- Raghavendra, R. M., Vadiraja, H. S., Nagarathna, R., Nagendra, H. R., Rekha, M., Vanitha, N., ... & Kumar, V. (2009). Effects of a Yoga Program on Cortisol Rhythm and Mood States in Early Breast Cancer Patients Undergoing Adjuvant Radiotherapy: A Randomized Controlled Trial. *Integrative Cancer Therapies*, 8(1), 37-46.
- Ray, U. S., Hegde, K. S., & Selvamurthy, W. (1986). Improvement in Muscular Efficiency as Related to a Standard Task After Yogic Exercises in Middle Aged Men. *Indian Journal of Medical Research*, 83, 343-348.
- Reitan, R. M., & Wolfson, D. (2004). The Halstead-Reitan Neuropsychological Test Battery For Adults: Theoretical, Methodological And Validation Bases: Background and Development of the Halstead-Reitan Battery (HRB). In G. Goldstein & S. Beers (Eds.), *Comprehensive Handbook of Psychological Assessment. Intellectual and Neuropsychological Assessment* (Vol. 1, pp. 1-38). Hoboken, NJ: John Wiley and Sons.
- Rejeski, W. J., Brawley, L. R., & Haskell, W. L. (2003). The Prevention Challenge: An Overview of this Supplement. *American Journal of Preventive Medicine*, 25(3), 107-109.
- Rejeski, W. J., Focht, B. C., Messier, S. P., Morgan, T., Pahor, M., & Penninx, B. (2002). Obese, Older Adults with Knee Osteoarthritis: Weight Loss, Exercise, and Quality of Life.

- Health Psychology*, 21(5), 419-426.
- Rikli, R. E., & Edwards, D. J. (1991). Effects of a Three-year Exercise Program on Motor Function and Cognitive Processing Speed in Older Women. *Research Quarterly for Exercise and Sport*, 62, 61-67.
- Rikli, R. E., & Jones, C. J. (1997). Assessing Physical Performance in Independent Older Adults: Issues and Guidelines. *Journal of Aging and Physical Activity*, 5, 244-261.
- Rikli, R. E., & Jones, C. J. (2001). *Senior fitness test manual*. Champaign: Human Kinetics.
- Riley, D. (2004). Hatha Yoga and the Treatment of Illness. *Alternative Therapies in Health and Medicine*, 10(2), 20-21.
- Roberts, E. (1972). Coordination between excitation and inhibition: Development of the GABA system. In C. D. Clemente, D. P. Purpura & F. E. Mayer (Eds.), *Sleep and the Maturing Nervous System* (pp. 79-98). New York: Academic Press.
- Roland, K. P., Jakobi, J. M., & Jones, G. R. (2011). Does Yoga Engender Fitness in Older Adults? A Critical Review. *Journal of Aging and Physical Activity*, 19(1), 62-79.
- Roselli, F., Tartaglione, B., Federico, F., Lepore, V., Defazio, G., & Livrea, P. (2009). Rate of MMSE Score Change in Alzheimer's Disease: Influence of Education and Vascular Risk Factors. *Clinical Neurology and Neurosurgery*, 111(4), 327-330.
- Ross, A., & Thomas, S. (2010). The Health Benefits of Yoga and Exercise: A Review of Comparison Studies. *Journal of Alternative and Complementary Medicine*, 16(1), 3-12.
- Sallis, J. F., Hovell, M. F., Richard Hofstetter, C., Faucher, P., Elder, J. P., Blanchard, J., et al. (1989). A Multivariate Study of Determinants of Vigorous Exercise in a Community Sample. *Preventive Medicine*, 18(1), 20-34.
- Salthouse, T. A. (1993). Speed and Knowledge as Determinants of Adult Age Differences in Verbal Tasks. *Journal of Gerontology* 48(1), 29-36.
- Salthouse, T. A., & Ferrer-Caja, E. (2003). What Needs to be Explained to Account for Age-

- Related Effects on Multiple Cognitive Variables? *Psychology and Aging*, 18(1), 91-110.
- Salthouse, T. A. (2007). Implications of Within-person Variability in Cognitive and Neuropsychological Functioning for the Interpretation of Change. *Neuropsychology*, 21(4), 401-411.
- Salthouse, T. A. (2009). When does Age-related Cognitive Decline Begin? *Neurobiology of Aging*, 30(4), 507-514.
- Saper, R. B., Eisenberg, D. M., Davis, R. B., Culpepper, L., & Phillips, R. S. (2004). Prevalence and Patterns of Adult Yoga Use in the United States: Results of a National Survey. *Alternative Therapies in Health and Medicine*, 10(2), 44-49.
- Sapolsky, R. M. (1992). *Stress, the Aging Brain, and the Mechanisms of Neuron Death*. The MIT Press.
- Sapolsky, R. M., Krey, L. C., & McEwen, B. S. (2002). The Neuroendocrinology of Stress and Aging: The Glucocorticoid Cascade Hypothesis. *Science of Aging Knowledge Environment*, 2002(38), 21.
- Sarang, S. P., & Telles, S. (2007). Immediate Effect of Two Yoga-based Relaxation Techniques on Performance in a Letter-cancellation Task. *Perceptual and Motor Skills*, 105(2), 379-385.
- Schaie, K. W. (1996). Intellectual Development in Adulthood. In J. E. S. Birren, K.W. (Ed.), *The Handbook of the Psychology of Aging* (4th ed., pp. 266-286). San Diego: Academic Press.
- Schell, F. J., Allolio, B., & Schonecke, O. W. (1993). Physiological and Psychological Effects of Hatha-Yoga Exercise in Healthy Women. *International Journal of Psychosomatics*, 41(1-4), 46-52.
- Schilbach, L., Eickhoff, S. B., Rotarska-Jagiela, A., Fink, G. R., & Vogeley, K. (2008). Minds at

- rest? Social cognition as the Default Mode of Cognizing and its Putative Relationship to the “Default System” of the Brain. *Consciousness and Cognition*, 17(2), 457-467.
- Schmid, A. A., Van Puymbroeck, M., & Kocejka, D. M. (2010). Effect of a 12-week Yoga Intervention on Fear of Falling and Balance in Older Adults: A Pilot Study. *Archives of Physical Medicine and Rehabilitation*, 91(4), 576-583.
- Seeman, T., & Chen, X. (2002). Risk and Protective Factors for Physical Functioning in Older Adults With and Without Chronic Conditions. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 57(3), S135-S144.
- Sharma, N. R., Yadava, A. & Hooda, D. (2005). Effect of Yoga on Psycho-Physical Functions. *Journal of Indian Psychology*, 23(1), 27-34.
- Sibley, B. A., & Etnier, J. L. (2003). The Relationship Between Physical Activity and Cognition in Children: A Meta-analysis. *Pediatric Exercise Science*, 15, 243-256.
- Sierpowska, A., Ciechanowicz, I., & Wasilewska, G. C. (2006). Functional Fitness Assessment among Elderly Women (60+) Participating in Yoga or Swimming Exercises. *Studies in Physical Culture and Tourism*, 13(Supplement), 81-83.
- Simons, L. A., McCallum, J., Friedlander, Y., & Simons, J. (2000). Healthy Ageing is Associated with Reduced and Delayed Disability. *Age and Ageing*, 29(2), 143-148.
- Singh, N. A., Clements, K. M., & Fiatarone, M. A. (1997). A Randomized Controlled Trial of Progressive Resistance Training in Depressed Elders. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 52A(1), M27-M35.
- Singh, N. A., Clements, K. M., & Singh, M. A. F. (2001). The Efficacy of Exercise as a Long-term Antidepressant in Elderly Subjects. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(8), M497-M504.
- Singh, M. A. F. (2002). Exercise Comes of Age. *The Journals of Gerontology Series A:*

- Biological Sciences and Medical Sciences*, 57(5), M262-M282.
- Smith, P. J., Blumenthal, J. A., Hoffman, B. M., Cooper, H., Strauman, T. A., Welsh-Bohmer, K., et al. (2010). Aerobic Exercise and Neurocognitive Performance: A Meta-analytic Review of Randomized Controlled Trials. *Psychosomatic Medicine*, 72(3), 239-252.
- Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G. F., Casini, a., et al. (2010). Physical Activity and Risk of Cognitive Decline: A Meta-analysis of Prospective Studies. *Journal of Internal Medicine*, 269(1), 107-117.
- Spielberger, C., Gorusch, R., & Lushene, R. (1970). *State-Trait Anxiety Inventory: Test Manual*. Palo Alto, CA: Consulting Psychologists Press.
- Spirduso, W. W. (1975). Reaction and Movement Time as a Function of Age and Physical Activity Level. *Journal of Gerontology*, 30(4), 435-440.
- Spirduso, W. W., & Cronin, D. L. (2001). Exercise Dose-response Effects on Quality of Life and Independent Living in Older Adults. *Medicine & Science in Sport & Exercise*, 33(6), S598-S608.
- Spirduso, W. W., Francis, K. L., & MacRae, P. G. (2004). *Physical Dimensions of Aging* (2nd ed.). Champaign IL: Human Kinetics.
- Streeter, C. C., Whitfield, T. H., Owen, L., Rein, T., Karri, S. K., Yakhkind, A., et al. (2010). Effects of Yoga Versus Walking on Mood, Anxiety, and Brain GABA Levels: A Randomized Controlled MRS study. *Journal of Alternative and Complementary Medicine*, 16(11), 1145-1152.
- Taimini, I.K. (1961) *The Science of Yoga*. Madras: The Theosophical Publishing House.
- Tang, Y.-Y., & Posner, M. I. (2009). Attention Training and Attention State Training. *Trends in Cognitive Sciences*, 13(5), 222-227.
- Telles, S., Raghuraj, P., Arankalle, D., & Naveen, K. (2008). Immediate Effect of High-Frequency Yoga Breathing on Attention. *Indian Journal of Medical Sciences*, 62(1), 20-

- Thompson, W. R., Gordon, N. F., & Pescatello, L. S. (2010). *ACSM's Guidelines for Exercise Testing and Prescription* (8th ed.). Baltimore: Lippincott Williams & Wilkins.
- Tomprowski, P. D. (2003). Effects of Acute Bouts of Exercise on Cognition. *Acta Psychologica*, 112(3), 297-324.
- Tse, S. K., & Bailey, D. M. (1992). Tai Chi and Postural Control in the Well Elderly. *The American Journal of Occupational Therapy*, 46(4), 295-300.
- Tsutsumi, T., Don, B. M., Zaichkowsky, L. D., & Delizonn, L. L. (1997). Physical Fitness and Psychological Benefits of Strength Training in Community Dwelling Older Adults. *Applied Human Science*, 16, 257-266.
- Tucker-Drob, E. M. (2011). Global and Domain-specific Changes in Cognition Throughout Adulthood. *Developmental Psychology*, 47(2), 331-343.
- Uebelacker, L. a., Epstein-Lubow, G., Gaudiano, B. a., Tremont, G., Battle, C. L., & Miller, I. W. (2010). Hatha Yoga for Depression: Critical Review of the Evidence for Efficacy, Plausible Mechanisms of Action, and Directions for Future Research. *Journal of Psychiatric Practice* 16(1), 22-33.
- United Nations Commission on Population & Development (2002). *World Population Ageing, 1950-2050: Executive Summary*.
- U. S. Census Bureau. (2004). U.S. Interim Projections by Age, Sex, Race, and Hispanic Origin. www.census.gov Accessed January 15, 2012.
- U.S. Census Bureau. (2006). American Community Survey. http://factfinder.census.gov/home/saff/main.html?_lang=en Accessed January 15, 2012.
- United States Department of Health and Human Services (2000). *Tracking Healthy People 2010*.
- Upadhyay, A. K., Balkrishna, A., & Upadhyay, R. T. (2008). Effect of Pranayama [Voluntary

- Regulated Yoga Breathing] and Yogasana [Yoga Postures] in Diabetes Mellitus (DM): A Scientific Review. *Journal of Complementary and Integrative Medicine*, 5(article 3).
- Vadiraja, H. S., Rao, M. R., Nagarathna, R., Nagendra, H. R., Rekha, M., Vanitha, N., et al. (2009). Effects of Yoga Program on Quality of Life and Affect in Early Breast Cancer Patients Undergoing Adjuvant Radiotherapy: A Randomized Controlled Trial. *Complementary Therapies in Medicine*, 17(5-6), 274-280.
- van Uffelen, J. G. Z., Paw, C.A., Marijke, J. M., Hopman-Rock, M., & van Mechelen, W. (2008). The Effects of Exercise on Cognition in Older Adults with and without Cognitive Decline: A Systematic Review. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, 18(6), 486-500.
- Waelde, L. C., Thompson, L., & Gallagher-Thompson, D. (2004). A Pilot Study of a Yoga and Meditation Intervention for Dementia Caregiver Stress. *Journal of Clinical Psychology*, 60(6), 677-687.
- Warburton, D.E.R., Nicol, C.W., & Bredin, S.S.D. (2006). Health Benefits of Physical Activity: the Evidence. *Canadian Medical Association Journal*, 174(6), 801-809.
- Wegesin, D. J., Jacobs, D. M., Zubin, N. R., Ventura, P. R., & Stern, Y. (2000). Source Memory and Encoding Strategy in Normal Aging. *Journal of Clinical and Experimental Neuropsychology*, 22(4), 455-464.
- Weinberger, M., Tierney, W. M., Booher, P., & Hiner, S. L. (1990). Social Support, Stress and Functional Status in Patients with Osteoarthritis. *Social Science and Medicine*, 30(4), 503-508.
- West, R., & Alain, C. (2000). Age-related Decline in Inhibitory Control Contributes to the Increased Stroop Effect Observed in Older Adults. *Psychophysiology*, 37(2), 179-189.
- West, J., Otte, C., Geher, K., Johnson, J., & Mohr, D. (2004). Effects of Hatha Yoga and African

- Dance on Perceived Stress, Affect, and Salivary Cortisol. *Annals of Behavioral Medicine*, 28(2), 114-118.
- Williams, P., & Lord, S. R. (1997). Effects of Group Exercise on Cognitive Functioning and Mood in Older Women. *Australian and New Zealand Journal of Public Health*, 21, 45-52.
- Williams, K. A., Petronis, J., Smith, D., Goodrich, D., Wu, J., Ravi, N., et al. (2005). Effect of Iyengar Yoga Therapy for Chronic Low Back Pain. *Pain*, 115(1-2), 107-117.
- Williamson, A., Fletcher, P., & Dawson, K. (2003). Complementary and Alternative Medicine, Use in an Older Population. *Journal of Gerontological Nursing*, 29, 20-28.
- Wolf, S. L., Barnhart, H. X., & Kutner, N. G. (1996). Reducing Frailty and Falls in Older Persons: An Investigation of Tai Chi and Computerized Balance Training. *Journal of American Geriatric Society*, 44, 489-497.
- Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., et al. (1996). Balance and Strength Training in Older Adults: Intervention Gains and Tai Chi Maintenance. *Journal of the American Geriatrics Society*, 44(5), 498-506.
- Wolsko, P. M., Eisenberg, D. M., Davis, R. B., & Phillips, R. S. (2004). Use of Mind-Body Medical Therapies Results of a National Survey. *Journal of General Internal Medicine*, 19, 43-50.
- Wood, C. (1993). Mood Change and Perceptions of Vitality: A Comparison of the Effects of Relaxation, Visualization and Yoga. *Journal of the Royal Society of Medicine*, 86(5), 254-258.
- Woolery, A., Myers, R., Stemlieb, B., & Zeltzer, L. (2004). A Yoga Intervention for Young Adults with Elevated Symptoms of Depression. *Alternative Therapies in Health and Medicine*, 10(2), 60-63.
- Yaffe, K., Fiocco, A. J., Lindquist, K., Vittinghoff, E., Simonsick, E. M., & Newman, A. B., et

- al. (2009). Predictors of Maintaining Cognitive Function in Older Adults: The Health ABC Study. *Neurology*, 72, 2029-2035.
- Yellin, D. (1983). Left Brain, Right Brain, Super Brain: The Holistic Model. *Reading Research and Instruction*, 23(1), 36-44.
- Yesavage, J. A., Rose, T. L., Spiegel, D., Savage, A. Y. E., & Rose, L. (1982). Relaxation Training and Memory Improvement in Elderly Normals: Correlation of Anxiety Ratings and Recall Improvement. *Experimental Aging Research*, 8(4), 195-198.
- Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., et al. (1982). Development and Validation of a Geriatric Depression Screening Scale: A Preliminary Report. *Journal of Psychiatric Research*, 17, (1), 37-49.
- Yesavage, J. A., & Jacob, R. (1984). Effects of Relaxation and Mnemonics on Memory, Attention and Anxiety in the Elderly. *Experimental Aging Research*, 10(4), 211-214.
- Zacks, R. T., Hasher, L., & Li, K. Z. H. (2000). Human Memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The Handbook of Aging and Cognition* (2nd ed., pp. 293-357): Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.
- Zigmond, A. S., & Snaith, R. P. (1983). The Hospital Anxiety and Depression Scale. *Acta Psychiatrica Scandinavica*, 67(6), 361-370.

TABLES

Table 1: Inclusion and exclusion criteria for participation in the study

	Inclusion	Exclusion
1	55 – 79 years of age	Below 55 years of age or over 79
2	Sedentary (no regular physical activity in 6 last months)	Active (self-reported physical activity 2 times per week) in last 6 months
3	Not a regular practitioner of yoga, tai-chi or other mind-body forms of exercise	Regular practitioner of yoga, tai-chi or other mind-body forms of exercise
4	Capable of performing exercise and getting on and off the floor	Any physical disability that prohibits stretching
5	Personal physician's consent to participate in testing and exercise intervention	Non consent of physician
6	Adequate performance on the TICS-M	Inadequate performance on the TICS-M
7	Initial depression score on GDS-15 below clinical level (<5)	Depression score on GDS-15 indicative of clinical depression (≥ 5)
8	Not involved in physical activity or cognitive training study	Part of a physical activity or cognitive training study
9	Corrected (near and far) acuity 20/40 or better	Corrected (near and far) acuity of greater than 20/40

Table 2: Enrollment table

Total enrollment: N=118			
Gender			
Ethnic Category	Male	Female	Total
Hispanic or Latino	1	3	4 (3.39%)
Not Hispanic or Latino	25	89	114 (96.61%)
			118 (100%)
Racial Categories			
White or Caucasian	23	74	97 (82.20%)
Black or African American	2	9	11 (9.32%)
Asian	1	3	4 (3.39%)
American Indian/Alaskan Native	0	2	2 (1.69%)
More than one race	0	4	4 (3.39%)
			118 (100%)

Table 3: Participant demographics by group

	Yoga n=61	Control n=57
Age	62.1 (5.82)	62.0 (5.39)
Sex		
Females	49 (80.3%)	43 (75.4%)
Males	12 (19.7%)	14 (24.6%)
Education		
< College degree	23%	43.80%
> College degree	77%	56.20%
Income		
< 40,000	17.90%	28.20%
> 40,000	82.10%	71.80%
Marital status		
Married	55.70%	68.40%
Separated/Divorced	24.60%	19.30%
Widowed	11.50%	7%
Single	4.90%	3.50%
Partnered/Significant other	3.30%	1.80%
Employment status		
Retired	21.30%	22.80%
Working part time	24.60%	22.80%
Working full time	52.50%	52.60%
Unemployed	0.016	0.018
Yoga experience		
Had tried it in the past	29.50%	35.10%
Would probably try it	70.50%	64.90%

Table 4 : Means and standard deviations of the cognitive performance variables by group and time-points

		Yoga		Control	
	Units	Pre n=61	Post n=58	Pre n=57	Post n=50
Task Switching					
Single RT	msec	724.01 ±100.47	714.97 ±121.53	730.29 ±111.10	747.00 ±114.07
Single AC	%	0.94 ±.10	0.98 ±.05	0.92 ±.09	0.94 ±.11
Repeat RT	msec	998.00 ±169.35	941.48 ±147.51	1003.33 ±191.02	994.59 ±190.00
Repeat AC	%	0.89 ±.14	0.95 ±.07	0.86 ±.22	0.88 .21
Switch RT	msec	1344.60 ±214.61	1227.55 ±198.08	1299.25 ±213.59	1246.86 ±203.36
Switch AC	%	0.85 ±.18	0.93 ±.09	0.83 .23	0.87 ±.21
Mixed RT	msec	1171.30 ±176.86	1084.52 ±163.48	1151.29 ±182.78	1120.73 ±153.98
Mixed AC	%	0.87 ±.16	0.94 ±.08	0.84 ±.22	0.88 ±.21
Attention Network					
Neutral RT	msec	576.72 ±112.25	547.98 ±95.49	602.02 ±91.75	579.48 ±77.97
Neutral AC	%	0.99 ±.01	0.99 ±.04	0.99 ±.02	0.99 ±.01
Congruent RT	msec	582.71 ±117.00	556.39 ±86.52	603.87 ±81.30	591.33 ±86.41
Congruent AC	%	0.99 ±.02	0.99 ±.01	0.99 ±.02	0.99 ±.01
Incongruent RT	msec	739.35 ±148.39	690.24 ±131.39	790.62 ±137.25	770.43 ±182.16
Incongruent AC	%	0.93 ±.09	0.97 ±.08	0.91 ±.15	0.93 ±.11
Running Span					
Partial recall	#	15.61 ±6.86	17.97 ±6.68	16.89 ±5.85	16.76 ±6.81
Total recall	#	29.48 ±8.93	31.64 ±8.71	29.30 ±8.32	29.68 ±9.24

Table 4 (cont.)

		Yoga		Control	
	Units	Pre n=61	Post n=58	Pre n=57	Post n=50
N-Back					
1-back RT	msec	726.95 ±123.49	728.23 ±130.57	738.79 ±106.89	727.60 ±117.17
1-back AC	%	0.97 ±.05	0.98 ±.03	0.96 ±.05	0.97 ±.06
2-back RT	msec	1057.56 ±179.23	1052.12 ±177.83	1044.50 ±141.66	1054.74 ±151.75
2-back AC	%	0.80 ±.18	0.87 ±.11	0.84 ±.13	0.82 ±.17
Trail Making					
Part A	sec	29.06 ±9.50	25.86 ±8.89	31.82 ±9.19	28.26 ±12.65
Part B	sec	64.69 ±23.02	55.56 ±19.66	66.47 ±19.93	66.40 ±25.91
Part B-A	sec	35.63 ±19.12	29.69 ±16.79	34.65 ±15.04	38.15 ±18.78
Pattern Comparison					
Recognition	#	35.00 ±5.48	41.66 ±7.15	34.28 ±5.13	35.46 ±5.87
Errors	#	3.38 ±2.65	3.00 ±2.79	2.93 ±2.66	3.10 ±2.25

Table 5: Means and standard deviations of the functional outcomes by group and time-points

		Yoga		Control	
		Pre	Post	Pre	Post
		n=61	n=58	n=57	n=50
Balance					
Left leg	sec	20.63	23.42	18.2	17.69
		± 11.25	± 10.04	± 11.42	± 11.14
Right leg	sec	21.32	23.54	18.64	21.31
		± 10.86	± 10.25	± 10.36	± 10.83
Four square step	sec	7.54	6.7	7.68	7.01
		± 1.41	± 1.03	± 1.69	± 1.28
Strength					
Arm curls	# reps	16.31	20.52	15.04	18.62
		± 4.41	± 4.63	± 4.91	± 5.33
Chair stands	# reps	11.7	14.3	11.2	13.04
		± 2.28	± 3.17	± 2.85	± 3.37
Mobility					
4m gait speed	sec	3.83	3.49	4.04	3.44
		$\pm .72$	$\pm .56$	$\pm .81$	$\pm .53$
8-ft up and go	sec	5.69	5.23	5.93	5.52
		$\pm .91$	$\pm .80$	± 1.40	± 1.03
Stairs up	sec	8.3	7.72	8.26	7.77
		± 1.71	± 1.45	± 2.22	± 1.62
Stairs down	sec	7.39	6.98	7.93	7.38
		± 1.51	± 1.63	± 2.41	± 1.87
Flexibility					
Back scratch -left	inches	-5.66	-4.24	-5.97	-5.13
		± 4.66	± 4.34	± 5.01	± 4.76
Back scratch - right	inches	-2.99	-2.04	-3.89	-3.44
		± 4.53	± 4.14	± 5.28	± 4.96
Sit-n-reach - left	inches	-2.23	0.12	-1.44	0.4
		± 4.41	± 3.71	± 3.82	± 3.28
Sit-n-reach - right	inches	-2.12	0.2	-1.46	0.36
		± 4.43	± 3.82	± 4.04	± 3.51

Table 6: Means and change scores for salivary cortisol and psychosocial measures

	Yoga		Control	
	Pre	Post	Pre	Post
Salivary cortisol				
Pre-stressor	.16 (.08)	.18 (.07)	.17 (.09)	.16 (.07)
Post-stressor	.16 (.16)	.16 (.07)	.16 (.16)	.18 (.09)
Anxiety				
STAI-T	33.93 (9.3)	31.57 (9.0)	34.88 (11.2)	32.94 (10.0)
STAI-S	33.10 (9.3)	30.71 (9.7)	32.77 (8.9)	30.80 (9.7)
Stress				
PSS	12.11 (6.4)	10.67 (5.6)	13.95 (7.2)	12.18 (6.4)
Change scores				
	Yoga		Control	
Salivary cortisol				
Pre-stressor	-.004 (.12)		-.019 (.09)	
Post-stressor	-.026 (.07)		.028 (.07)	
Anxiety				
STAI-T	2.26 (4.4)		2.16 (5.5)	
STAI-S	2.38 (8.0)		2.45 (8.6)	
Stress				
PSS	1.38 (4.7)		1.96 (5.5)	

Note: STAI-T - State Trait Anxiety Inventory - trait subscale; PSS - Perceived Stress Scale

Table 7: Multiple regression results for the working memory change scores

Yoga Group									
Predictors	Running Span - partial score			Running Span - total score			N-back - 2back accuracy		
	β	t	p	β	t	p	β	t	p
PSS change	-.06	-.36	.72	-.10	-.69	.50	-.27	-1.77	.08
STAI-T change	.00	.02	.99	.14	.94	.35	.07	.46	.65
STAI-S change	.11	.729	.47	-.07	-.49	.62	.07	.47	.64
Post-stressor cortisol change	.10	.70	.49	.35	2.47	.02	-.10	-.70	.49
Stretching Group									
	β	t	p	β	t	p	β	t	p
PSS change	-.04	-.24	.81	.00	.01	.99	.13	.95	.35
STAI-T change	-.03	-.18	.86	-.11	-.64	.52	-.23	-1.42	.16
STAI-S change	-.15	-.95	.35	-.15	-.98	.33	-.12	-.85	.39
Post-stressor cortisol change	-.24	-1.61	.12	-.16	-1.03	.31	-.19	-1.38	.18

Note: PSS - Perceived Stress Scale; STAI-T - State Trait Anxiety Inventory - trait subscale; STAI-S - State Trait Anxiety Inventory - state subscale

Table 8: Multiple regression results for the task switching and paper pencil measures

Yoga Group									
Predictors	Trail making - part B time			Pattern comparison - recognition score			Task switching - mixed reaction time		
	β	t	p	β	t	p	β	t	p
PSS change	.04	.29	.77	-.07	-.42	.68	-.03	-.21	.84
STAI-T change	-.35	-2.36	.02	.08	.47	.64	-.03	-.17	.87
STAI-S change	.15	1.09	.28	.13	.89	.38	-.17	-1.18	.25
Post-stressor cortisol change	.09	.64	.52	.05	.31	.76	.10	.64	.52
Stretching Group									
	β	t	p	β	t	p	β	t	p
PSS change	-.19	-1.09	.28	-.28	-1.60	.12	-.18	-1.01	.32
STAI-T change	.03	.15	.88	.19	1.07	.29	-.06	-.35	.73
STAI-S change	-.05	-.30	.77	.11	.70	.49	-.03	-.19	.85
Post-stressor cortisol change	.06	.39	.69	.14	.95	.35	-.15	-1.02	.31

Note: PSS - Perceived Stress Scale; STAI-T - State Trait Anxiety Inventory - trait subscale; STAI-S - State Trait Anxiety Inventory - state subscale

Table 9: Multiple regression results for the attention network measures

Yoga Group									
Predictors	Neutral RT			Congruent RT			Incongruent RT		
	β	t	p	β	t	p	β	t	p
PSS change	-.11	-.71	.48	-.11	-.67	.51	-.10	-.65	.52
STAI-T change	-.04	-.24	.81	.02	.12	.91	-.05	-.30	.76
STAI-S change	.00	.01	.99	.09	.61	.55	.28	1.95	.06
Post-stressor cortisol change	.01	.06	.95	-.02	-.10	.92	.03	.24	.82
Stretching Group									
	β	t	p	β	t	p	β	t	p
PSS change	-.25	-1.43	.16	-.26	-1.47	.15	-.43	-2.68	.01
STAI-T change	.10	.62	.54	.15	.89	.38	.04	.23	.82
STAI-S change	.25	1.70	.10	.23	1.54	.13	.21	1.53	.13
Post-stressor cortisol change	.21	1.43	.16	.16	1.10	.28	.24	1.77	.09

Note: ANT - Attention Network Task, RT - reaction time; PSS - Perceived Stress Scale; STAI-T - State Trait Anxiety Inventory - trait subscale; STAI-S - State Trait Anxiety Inventory - state subscale

FIGURES

Figure 1: Participant flow through the study

