The Effects of an 8-Week Hatha Yoga Intervention on Executive Function in Older Adults

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Background. Few scientific studies have examined movement-based embodied contemplative practices such as yoga and their effects on cognition. The purpose of this randomized controlled trial was to examine the effects of an 8-week Hatha yoga intervention on executive function measures of task switching and working memory capacity.

Methods. Community-dwelling older adults (N = 118; mean age = 62.0) were randomized to one of two groups: a Hatha yoga intervention or a stretching–strengthening control. Both groups participated in hour-long exercise classes 3×/week over the 8-week study period. All participants completed established tests of executive function including the task switching paradigm, n-back and running memory span at baseline and follow-up.

Results. Analysis of covariances showed significantly shorter reaction times on the mixed and repeat task switching trials (partial η² = .04, p < .05) for the Hatha yoga group. Higher accuracy was recorded on the single trials (partial η² = .05, p < .05), the 2-back condition of the n-back (partial η² = .08, p < .001), and partial recall scores (partial η² = .06, p < .01) of running span task.

Conclusions. Following 8 weeks of yoga practice, participants in the yoga intervention group showed significantly improved performance on the executive function measures of working memory capacity and efficiency of mental set shifting and flexibility compared with their stretching–strengthening counterparts. Although the underlying mechanisms need to be investigated, these results demand larger systematic trials to thoroughly examine effects of yoga on executive function as well as across other domains of cognition, and its potential to maintain or improve cognitive functioning in the aging process.

Key Words: Yoga intervention—Cognition—Older adults—Working memory.

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YOGA is a commonly practiced, mind–body activity that has components centering on meditation, breathing, and postures. In recent U.S. 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 (1,2). The use of yoga and other complementary and alternative medicine 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 (3–6). Although yoga practice involves physical postures that mimic stretching, balance, and strength exercises, which result in physical benefits (7), it also includes an active attentional component of breathing and meditation practice. Given the age-related declines in cognitive function (8), little is known about the potential of yoga in maintaining or enhancing cognitive function in older adults.

A considerable corpus of research exists that has extensively examined the effects of physical activity on cognition and executive functions. However, majority of these studies have examined the role of aerobic training. Colcombe and Kramer (9) in their meta-analysis reviewed randomized controlled trials (RCTs) conducted with sedentary healthy older adults and found that executive control processes (g = 0.68, p < .05) showed the largest benefit from aerobic fitness training. More recently, Smith and colleagues (10) conducted a meta-analysis to examine this relationship and reported that individuals randomly assigned to receive aerobic exercise training demonstrated modest improvements in executive function (g = 0.123, p < .018) and working memory (g = 0.128, p < .026). Regardless of the methodological differences, both these meta-analyses suggest that participation in aerobic physical activity can help improve cognitive function. However, compared with...
this extensive body of work on aerobic training and cognition, far fewer scientific studies or RCTs have examined movement-based embodied contemplative practices such as yoga (11–14) or tai-chi (15). Oken and colleagues (12) conducted a RCT examining the effects of yoga on cognition in healthy older adults, but found no relative improvements in cognitive function.

The authors acknowledged two major reasons that explain these null findings: (i) recruitment of physically active seniors that may have resulted in a ceiling effect and (ii) the dose of exercise that was one session per week is lower compared with more frequent sessions employed in other successful RCTs (9,10). More recently, Hariprasad and colleagues (14) conducted a 6-month RCT with residents of elderly homes and found significant cognitive improvements in attention and processing speed, verbal and visual memory, working memory, and inhibitory control. The authors acknowledged the lack of an active control group, high dropout rate, and the need to examine effects of yoga on community-dwelling older adults.

Given the paucity of yoga–cognition RCTs and to address limitations of previous studies, the purpose of this RCT was to examine the effects of an 8-week Hatha yoga intervention on executive function in community-dwelling older adults. We recruited sedentary healthy older adults and structured the dose of exercise to match the physical activity literature with training sessions held 3×/week. We also used three established measures of executive function that have been extensively used in physical activity research: the task switching paradigm (16), the n-back task (17,18), and the running memory span task (19). The primary outcomes were mean reaction time (RT) and accuracy (AC) scores on the three executive function measures. We hypothesized that regular, structured Hatha yoga practice, which included components of physical movements, breathing, and meditation, would lead to significant improvements on executive function measures following the 8-week trial in a sample of sedentary healthy community-dwelling older adults.

METHODS

Participants

Figure 1 shows the flow of participants through the trial. Participants (N = 118, males = 26; mean age = 62.0±5.6) were low active, healthy community-dwelling older adults who volunteered to participate in an 8-week exercise-based RCT. They were recruited between March 2012 and January 2013 through University of Illinois LISTSERV, flyers, community groups, and postings and screened to determine eligibility for the study. In order to participate in the trial, participants had to be between 55 and 79 years of age, English speaking, report being sedentary for at least the previous 6 months (<2 days per week of structured physical activity), have no on-going regular yoga practice, be able to get up and down from the floor, have good or corrected vision (20/40), and be willing to be randomized into one of two exercise groups. As the primary outcomes included neurocognitive variables, all participants were screened to rule out possible cognitive deficiency using the modified Telephone Interview for Cognitive Screening (20) with a cut-off of 21, and for depressive symptomology using the shortened version of the Geriatric Depression Scale (21), which has a cut-off point of greater than or equal to 5. Individuals who responded to advertisements completed a telephonic prescreening interview to determine whether they met these inclusion criteria and consented to have their physician contacted for approval to participate in the exercise study. Individuals were excluded from participation if they did not meet the previously mentioned criteria or their physician refused to provide approval for participation.

Procedures

After obtaining the physician’s consent, participants were scheduled to complete baseline cognitive assessments and provided with a questionnaire to collect basic demographic information. After all baseline data were obtained, participants were stratified by age and sex and randomized into one of two groups: Hatha yoga or stretching–strengthening exercise. For both groups, classes met three times a week for an hour over the 8-week period. The instructors in both groups monitored participants’ attendance over the course of the 8-week program.

Hatha Yoga Group

The yoga intervention was designed as a beginner, but progressive 8-week program involving supervised group sessions led by certified yoga instructors. Within the three 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 yoga mats, yoga blocks, and belts during the sessions. Some of the yoga exercises practiced by the participants included: warrior pose, easy lotus pose, sun salutations, deep breathing exercises such as alternate nostril breathing, and meditative exercises focusing on thoughts, breath, and mantra repetitions.

Stretching and Strengthening Control Group

This group served as an active exercise control group to the yoga intervention for the period of 8 weeks. Participants received the same level of interaction with the research staff and same opportunities for social interaction with others in their group and the certified trainer as the Hatha yoga group. No Hatha yoga postures, breathing, and meditative exercises
were practiced by this group ensuring that it served as a true attentional exercise control to the yoga intervention. Participants in this group also met on the same days and times at a separate exercise studio, to engage in stretching and strengthening exercises that met the Center for Disease Control anaerobic recommendation (22). 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. Similar to the yoga intervention, the exercises were progressive over the course of 8 weeks, and resistance bands, blocks, and chairs were used to perform the exercises, which included bicep curls, tricep extensions, flutter kicks seated in the chair, and so on. These exercises targeted all major muscle groups but did not involve any yoga-based postures, breathing, or meditative elements.

**Measures**

*Demographic and participant information.*—Participants completed a basic demographic questionnaire including age and date of birth, sex, marital status, occupation, income, education, and past experience with yoga. Self-reported leisure time physical activity was assessed using the item from Godin Leisure Time Exercise Questionnaire (23) “Considering a 7-day period (a week), during your leisure time, how often do you engage in any regular physical activity long enough to work up a sweat (heart beats rapidly)?” Participants rated their overall health by responding to “In general, would you say your health is: Excellent, Very Good, Good, Poor, Very Poor.” This Likert item was scaled from 1 to 5, with 1 being excellent and 5 being very poor.
Cognitive assessments.—We employed three established computer-based tests using E-prime 2.0 (Psychology Software Tools, Inc., Sharpsburg, PA) to assess the executive functions of working memory and task switching. All study participants completed these tests at baseline and following the 8-week intervention.

Task switching.—There are multiple versions of the task switching paradigm; however, for this study, we employed the version used by Kramer and colleagues (24) and Pashler (16). 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 (ie, smaller or larger than 5). If the background was blue, participants reported as quickly as possible whether the letter was high or low using their left hand. If the background was pink, participants used their right hand to report whether the number was odd or even. Participants completed four single task blocks (two blocks of odd/even and two blocks of high/low) of 24 trials each. Finally, they completed a “mixed” block of 120 trials during which the task for each trial was randomly chosen. AC and RT on single and mixed blocks as well as repeat (trials when the preceding trial involved the same task, eg, blue followed by blue) and switch trials (when the preceding trial was of the other task, eg, blue followed by pink) were examined.

Running memory span.—Participants completed the letter version of the running memory span test was used (19). They 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. One trial for each target length presented lists in which m = 1 and 2 distractors preceded the target. The participants were informed at the start of a block how many letters to report from each list in that block. After the inputs terminated for a trial, the participants made their recall responses by clicking the cells of a 3 × 4 grid displaying all letters from the set of possible letters. To maintain the correct serial position of recalled items with respect to their position in the presentation list, the participants were instructed to click on a blank option for each item that could not be recalled. One point was assigned for each item correctly chosen in the correct serial position. 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 also assessed with a modified serial n-back task (17,18) that involved two consecutive phases: 1-back and 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. 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 1,500 ms intertrial interval. AC on the 1- and 2-back conditions was examined.

Data Analysis

Data were analyzed using SPSS 20.0 (IBM Corp., Armonk, NY). Prior to all hypothesis testing, independent sample t-tests were conducted to examine whether significant mean differences existed in demographic, health, and performance and physical activity variables among the two groups at baseline. A series of repeated measures analyses of covariance controlling for age, education, attendance, and baseline performance were employed to explore intervention effects for all the executive function measures.

RESULTS

Participant Characteristics

Of the 118 participants, n = 61 were randomized to the yoga intervention group and n = 57 to the stretching–strengthening control as shown in Figure 1. The mean Telephone Interview for Cognitive Screening score for the total sample was 30.65 (range = 24–38, ±3.27), which was well above the cut-off of 21, which is considered indicative of cognitive deficiency. Individuals were also screened for depressive symptomology using the Geriatric Depression Scale and scored below the cut-off point of greater than or equal to 5 with a mean of 1.05 (range = 0–4, ±1.22).

Table 1 shows the participant characteristics by group. Within both groups, the majority of the participants were female, married, working full time, well-educated, and relatively affluent. Approximately 20% of the study participants represented minority groups. An independent samples t-test showed no significant differences between conditions on any of these characteristics (all p ≥ .20) including baseline Telephone Interview for Cognitive Screening, Geriatric Depression Scale, self-reported health, or leisure time physical activity (all p ≥ .19). Approximately, one third of the participants in both groups had tried yoga previously (range: 6–40 years ago, between 1 and 12 yoga classes) but were no longer practicing at the time of the trial. The average attendance at the yoga classes was 80.82% (19.2 ± 3.8 sessions) and was not significantly different from the stretching–strengthening exercise classes at 81.29% (19.4 ± 3.8 sessions). The overall attrition rate was 8.47% with 108 participants successfully completing the intervention and follow-up assessments. A series of t-tests were conducted to determine whether the completers differed from the dropouts (n = 10) on any demographic or baseline measures.
Cognitive Outcomes
The mean RT, AC, and test scores for the executive function measures are presented in Table 2. Adjusted follow-up means from the analysis of covariances are also presented in Table 2. No significant baseline differences were found between the two groups (all \(p > .05\)), and the RT variables from the task switching test were normally distributed (Shapiro–Wilk statistic \(p \geq .13\)).

Task Switching
The analysis of covariance showed a significant group effect on mixed and repeat RT conditions of the task switching paradigm. A significant mean difference favoring the yoga group was observed on the mixed block \([F(1,101) = 3.98, p = .04, \text{partial } \eta^2 = .04]\). The yoga participants were more efficient in switching between the odd-even and low-high tasks compared with the controls. Within the mixed block of trials, the yoga group also showed significantly faster RTs on the repeat \([F(1,101) = 4.16, p = .04, \text{partial } \eta^2 = .04]\) trial. A significant mean difference favoring the yoga group was also observed on mixed block AC \([F(1,101) = 5.09, p = .02, \text{partial } \eta^2 = .05]\). The yoga group was more accurate on the single block and a similar trend although nonsignificant was observed on the mixed block of trials \([F(1,103) = 2.96, p = .09, \text{partial } \eta^2 = .02]\).

Running Memory Span
The repeated measures analysis of covariance showed a significant group effect for the partial recall score \([F(1,101) = 5.09, p = .02, \text{partial } \eta^2 = .02]\) with the yoga participants demonstrating higher partial recall scores compared with the controls. The total recall score on the running span approached significance \([F(1,101) = 2.49, p = .11, \text{partial } \eta^2 = .02]\) indicating a similar trend favoring the yoga group.

N-Back Task
No significant mean differences were observed on 1-back AC \([F(1,101) = 1.82, p = .18, \text{partial } \eta^2 = .02]\). However,
a significant group difference was seen on 2-back AC \(F(1,101) = 9.24, p = .003, \text{partial } \eta^2 = .08\), with the participants in the yoga group exhibiting higher AC on the 2-back condition at follow-up compared with the stretching–strengthening controls. Although the yoga group showed improved AC, no speed-AC trade-off or group differences were observed on RTs for either conditions of the n-back.

**Discussion**

The purpose of this RCT was to investigate the efficacy of an 8-week Hatha yoga intervention for improving cognition, particularly executive function in a healthy, low active community-dwelling adult population. Following 8 weeks of regular structured yoga practice, participants in the yoga intervention group showed significantly improved performance on the executive function measures of working memory capacity and efficiency of mental set shifting and flexibility as compared with their stretching–strengthening counterparts. Executive functions are multifaceted, and in an effort to mirror the aerobic training and cognition findings, established cognitive tasks representing domains of executive function were employed in this study. The results are promising and demand rigorous RCTs to replicate these findings and examine cognitive benefits of yoga across other established cognitive measures used in the physical activity literature.

Using Cohen’s (25) classification of magnitude of effect sizes, this study demonstrates a small to moderate effect of yoga on executive function. The partial \(\eta^2\)‘s in this study ranged from .02 to .08 for the cognitive variables. Some variables approached significance (total recall from the running span, mixed AC from task switch, 1-back AC from the n-back) but did not show a significant group difference in this sample. These borderline results may be explained by potential ceiling effects as our sample consisted of healthy older adults without any cognitive impairment, the sample size, and short-term duration (8 weeks) of the study. However, all the results of this trial, taken together, should serve as a platform to design and power future trials to thoroughly investigate yoga effects on executive function as well as other domains of cognition.

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 (26). It requires focused effort in moving through the poses, controlling the body, and breathing at a steady rate. In addition, breathing and meditation exercises are practiced to calm and focus the mind and develop greater self-awareness (27). It is plausible that this focus on one’s body and mind during yoga practice may have generalized to situations outside of the yoga classes resulting in an improved ability to focus and sustain attention on the task at hand without getting distracted. 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.

A growing body of research evidence supports the belief that certain yoga techniques may improve physical and mental health through downregulation of the hypothalamic–pituitary–adrenal axis and the sympathetic nervous system (28). Yoga has been shown to have immediate psychological effects including decreased anxiety (29), depression (30), and stress (31) and positive changes in perceived quality of life (32). These studies suggest that yoga has an immediate quieting effect on the sympathetic nervous system/hypothalamic–pituitary–adrenal axis response to stress. It is well known that stress and anxiety affect cognitive performance, and the 8-week yoga intervention may have resulted in improved psychological states, which led to enhanced cognitive performance on the executive function tasks.

In the physical activity–cognition literature, experiencing novel activities (33) and anaerobic interventions have been shown to have unique cognitive benefits on brain structure and function (34). 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, the regions that are active when individual is at rest but not focused on the outside world (35,36). There is evidence that supports a relationship between the default mode network and executive function, where increased activation has been associated with better working memory performance in young adults (36), and better performance on a range of executive function tasks in older adults (34,37–39). Although participants in both groups learnt new postural exercises, the breathing and meditative practices of yoga closely parallel the self-referential thoughts and involve learning and consolidation functions that have been associated with the default mode network. Future research should explore the structural and functional brain changes as a result of yoga in an effort to identify the neurobiological underpinnings of the yoga–cognition relationship.

This 8-week trial systematically examined the effect of Hatha yoga on executive function in sedentary, healthy, community-dwelling older adults. The intervention involved a combination of postures, breathing, and meditative exercises. The multifaceted nature of this intervention is intriguing as it demands further enquiry to identify the active agent leading to improved cognitive performance. Further scientific efforts that compare yoga with other physical activity interventions that have been demonstrated to improve executive function are warranted. Another strength of this work is the stretching–strengthening control group that served as
an active control exercise group, which has been a drawback of the sparse yoga–cognition literature. Although this study contributes to the scarce yoga–cognition literature, there are some limitations to this work. The sample primarily consisted of Caucasian females with a fair representation of minority groups. From a generalizability and dissemination perspective, similar trials need to be implemented for larger samples of minority groups, males as well as older adults from lower socioeconomic status and educational levels. The participation rate was comparable to physical activity interventions targeting community-dwelling older adults (12,15,40). Individuals who were physically active were excluded from this study (n = 31). Walking is a common form of activity for older adults, and the effects of yoga in conjunction with walking for such active older adults needs to be investigated. Although this trial was successful in examining short-term effects of yoga, the absence of a longer follow-up timeframe is a limitation, which should be addressed in future trials. Determining the duration and frequency of yoga practice will enable researchers to establish standards and clinicians to recommend yoga practice to patients. Future RCTs need to explore the possible underlying mechanisms and neuroscientific and biophysiological determinants of the yoga–cognition relationship.

In conclusion, the 8-week Hatha yoga intervention was successful in improving working memory capacity and mental set flexibility among older adults. Although this RCT successfully demonstrated the beneficial effects following 8 weeks, a longer follow-up period will enable researchers to thoroughly examine trajectories of change over the life span. Clearly, yoga research is still in its nascent stages, and with its increasing popularity, researchers need to adopt rigorous systematic approaches and advanced neuroimaging techniques to examine its cognitive benefits and underlying mechanisms.

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