

Kundalini Yoga Intervention Increases Hippocampal Volume in Older Adults: A Pilot Randomized Controlled Trial

Abstract

Background: Among a rapidly aging population, there is increased need for neuroprotective interventions promoting healthy neurological aging. Mind-body interventions, such as Kundalini yoga, are actively being explored as accessible means to encourage healthy aging. However, little remains known about the neurobiological effects of Kundalini yoga. **Aims:** This pilot randomized-controlled trial (RCT) examined the potential neuroprotective effects of Kundalini yoga in older adults. **Methods:** We conducted an RCT with 11 healthy meditation-naïve older adults. Participants were randomized to a Kundalini yoga or psychoeducation intervention. Structural magnetic resonance imaging data were obtained at baseline and 12-week follow-up. The primary outcome measure was gray matter volume of the bilateral hippocampi and bilateral posterior cingulate cortex. **Results:** We found significant right hippocampal volume increases specific to the Kundalini yoga group ($P = 0.034$, $\eta_p^2 = 0.408$). **Conclusions:** These findings provide initial neurobiological support for the neuroprotective effects of Kundalini yoga.

Keywords: Gray matter volume, Kundalini yoga, mind-body intervention, neuroimaging, neurological aging

Introduction

Given our rapidly aging population, there is an urgent need to explore protective interventions against age-related cognitive decline. Yoga interventions have been found to be feasible, safe, and effective in preventing cognitive decline and were found to display potential neuroprotective effects.^[1,2] Kundalini yoga integrates meditation, yoga postures, and breathing exercises (pranayama). It has been reported to promote healthy neurological aging. For instance, a 12-week Kundalini yoga program was shown to improve executive functioning and memory in older adults ($n = 81$) with mild cognitive impairment (MCI).^[3] Another study found that an 8-week Kirtan Kriya meditation program (derived from Kundalini yoga) improved mood and decreased anxiety in older adult participants ($n = 15$) with memory loss.^[4] The clinical and neurological benefits of Kundalini yoga appear promising.

However, the neurobiological effects of Kundalini yoga remain understudied,

with no published studies examining structural neurobiology in healthy older adults. Thus, here we report results from a pilot randomized-controlled trial (RCT) examining the neurobiological effects of a 12-week Kundalini yoga intervention, compared to a 10-week psychoeducation intervention, among healthy older adults. In particular, we examined the effects of Kundalini yoga on gray matter volume (GMV) of the hippocampus and posterior cingulate cortex (PCC), two brain regions whose atrophy is associated with cognitive decline in neurotypical aging and early Alzheimer's disease.^[5]

Methods

Participants

Fourteen participants were randomized with seven participants allocated to Kundalini yoga and 7 to psychoeducation [Figure 1]. Three participants withdrew from the psychoeducation intervention, stating they would have preferred to be in the yoga group. Eleven participants completed the study ($n = 7$ yoga, $n = 4$ psychoeducation).

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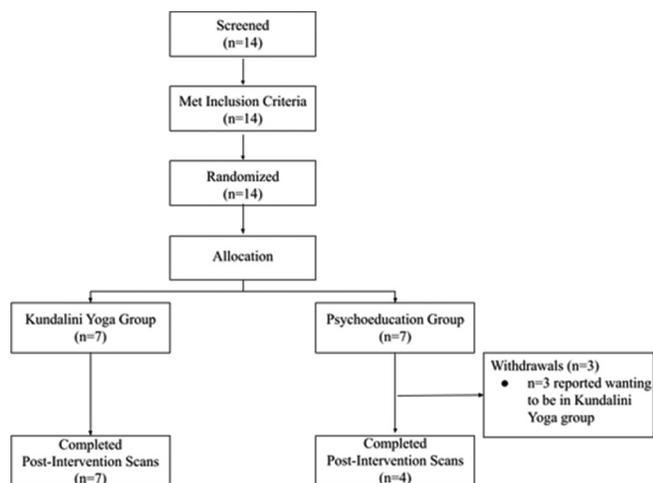


Figure 1: Number of participants screened, recruited, and randomized

Participants were aged 62–74 ($M = 66.4$, standard deviation [SD] = 3.1) with Mini-Mental State Exam (MMSE) scores between 28 and 30 ($M = 29.7$, $SD = 0.6$). In the yoga group, participants were aged 62–74 ($M = 66.86$, $SD = 3.761$), 57.1% were male and 42.9% reported a medical condition (e.g., high cholesterol, history of major depression, urinary incontinence, and high blood pressure which was being controlled) and taking medication (e.g., blood pressure medication). In the psychoeducation group, participants were aged 64–67 years ($M = 65.50$, $SD = 1.291$), 50.0% were male and 25.0% reported a medical condition (prior myocardial infarction and high blood pressure which was being controlled) and taking blood pressure medication. No significant baseline differences were found between groups for age, MMSE scores, or GMV for ROIs ($P_s > 0.35$). We found that all scans were unremarkable (Schentens scores ≤ 1) after rating images for white matter hyperintensities and atrophy of the hippocampal formation.

Participants were recruited through newspaper advertisements and from the Douglas Mental Health University Institute (Montréal, Canada). Participants were prescreened to ensure they were eligible for the study based on the inclusion and exclusion criteria. This screening process included the administration of the MMSE to assess cognitive functioning before participation.^[6] We excluded participants who had prior experience with meditation, regularly consumed alcohol or tobacco, had magnetic resonance imaging (MRI) contraindications, diabetes, cardiovascular or respiratory illness, or any active psychiatric/neurological illness.

Written informed consent was obtained from all participants. The study protocol was approved by the research and ethics office of the Centre Intégré Universitaire de Santé et de Services Sociaux de l'Ouest-de-l'Île-de-Montréal (CIUSSS-ODIM)/Douglas Institute and was in accordance with the Helsinki Declaration of 1975.

Intervention groups

Participants were randomized 1:1 to a Kundalini yoga intervention or psychoeducation intervention. Participants were matched across groups for gender and age. Sessions were led by trained interventionists at the Douglas Mental Health University Institute. The Kundalini yoga intervention lasted for 12 weeks, and the psychoeducation intervention lasted for 10 weeks. The discrepancy in program length was the result of scheduling complications in which the interventionist leading the psychoeducation group was unable to complete a 12-week duration. Each group had one session per week which lasted 2 hours. Interventions were conducted bilingually in French and English.

The Kundalini yoga intervention was customized for participant safety and included a mixture of postures, pranayama, and meditation. In addition, participants were encouraged to practice at home for 30 min per day.

The psychoeducation intervention consisted of a psychoeducation program in which participants were taught about memory and healthy aging. Each of the weekly sessions included learning about prospective memory, working memory, and executive functions such as problem-solving and decision-making. As in the Kundalini Yoga intervention, participants in the psychoeducation group were encouraged to complete homework for 30 min per day.

Structural magnetic resonance imaging acquisition

A structural MRI scan was obtained before and after participation in the intervention. A structural MRI scan was obtained before and after participation in the intervention. We used a T1-weighted sequence. Images were acquired on a 3T Siemens Magnetom using a standard head coil. A volumetric magnetization prepared rapid gradient echo MRI (TR: 2300 ms, TE: 2.98 ms) sequence was employed to obtain a high-resolution T1-weighted anatomical image of the entire brain (9 degree flip angle, sagittal orientation, 1 mm \times 1 mm in-plane resolution of 1 mm slab thickness). A parallel acquisition technique of GRAPPA was used.

Data processing and analysis

Structural MRI data were obtained at baseline and 12 weeks. We calculated GMV in four predetermined regions of interest (left and right hippocampus and left and right PCC) using the standard preprocessing pipeline and voxel-based morphometry toolbox in SPM12.^[7] Regions of interest were defined based on the Desikan-Killiany-Tourville atlas.^[8] The DARTEL algorithm was used to spatially normalize scans. We spatially registered and segmented scans into gray matter, white matter, and cerebrospinal fluid using the tissue probability maps in SPM12. Total intracranial volume was calculated, and data were smoothed using an 8 mm full width at half maximum Gaussian kernel. The final voxel size was 1.5 \times 1.5 \times 1.5 mm.

For each region of interest, we conducted a two-way repeated-measures ANOVA to examine the effects of condition (Kundalini yoga versus psychoeducation) and time (baseline vs. postintervention) on volume using JASP (<https://jasp-stats.org/>). An alpha of 0.05 was used for statistical tests. Levene’s test for equality of variance was used to ensure the assumption of homogeneity was met for each region of interest. All participants who completed the study were included in the data analysis.

Results

A group-by-time ANOVA yielded a significant interaction effect on right hippocampal volume ($F(1,9) = 6.210, P = 0.034, \eta_p^2 = 0.408$). In the left hippocampus, this interaction effect was not statistically significant ($F(1,9) = 4.747, P = 0.058$). No significant changes were found in the PCC. Results are outlined in Table 1 and Figures 2 and 3.

Scheffe’s test was used for *post hoc* analysis to decompose the significant interaction on volume of the right hippocampus. These *post hoc* tests yielded no significant differences between the cells. To further explore the data, we also conducted two simple contrasts that we felt were most relevant using a *t*-test (comparing pre- to post-intervention volume within each intervention type). For these two contrasts, we applied Bonferroni correction to adjust the alpha to 0.025 (critical alpha 0.05 divided by 2 tests). Results from these analyses showed an increase in volume of the right hippocampus from pre- to post-intervention in the Kundalini yoga group ($t(6) = 3.109, P = 0.021$), but not the psychoeducation group.

Discussion

To our knowledge, this is the first RCT using neuroimaging to investigate Kundalini yoga as a protective intervention against neurological aging in healthy older adults. We found that participants in the 12-week Kundalini yoga intervention showed significant

increases in right hippocampal volume. Notably, the only other structural neuroimaging study of Kundalini yoga found no significant effect in hippocampal volume; however, that study compared Kundalini yoga to memory enhancement training and focused on participants with MCI.^[9] These factors may have overshadowed the effect of Kundalini yoga and may explain why our results are more positive, corresponding with neuroimaging findings from other forms of yoga that similarly showed increases in hippocampal volume.^[10]

Age-related atrophy of the hippocampus has been linked to age-related declines in short-term memory.^[11] These neurotypical atrophies are often exacerbated in Alzheimer’s disease, with hippocampal atrophy acting as a marker for the early stages of Alzheimer’s.^[12] The right hippocampus

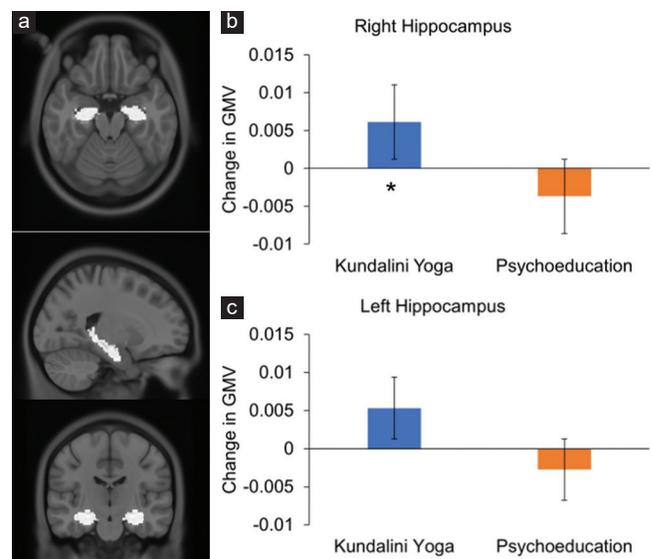


Figure 2: (a) Bilateral hippocampus ROIs defined using the DKT atlas. (b) Mean change in GMV in the right hippocampus. Asterisk notes a statistically significant difference in mean volume of the Kundalini yoga group from pre to post intervention ($t(6) = 3.109, P = 0.021$). (c) Mean change in GMV in the left hippocampus. Error bars show standard error. DKT: Desikan-Killiany-Tourville, GMV: Gray matter volume, ROIs: Regions of Interest

Table 1: Mean gray matter volume (mm³) with standard deviation of regions of interest at pre-and post-intervention for each intervention group

| Region | Mean GMV±SD | | | | Statistics | |
|----------------------------------|----------------------------|-------------|-----------------------------|-------------|---------------------------------|----------------------------|
| | Kundalini yoga group (n=7) | | Psychoeducation group (n=4) | | Group × time interaction effect | Effect size (η_p^2) |
| | Pre | Post | Pre | Post | | |
| Right hippocampus | 0.492±0.025 | 0.498±0.027 | 0.485±0.045 | 0.482±0.049 | $F(1,9)=6.210$ $P=0.034^*$ | 0.408 |
| Left hippocampus | 0.417±0.023 | 0.422±0.022 | 0.429±0.059 | 0.426±0.056 | $F(1,9)=4.747$ $P=0.058$ | 0.345 |
| Right posterior cingulate cortex | 0.371±0.036 | 0.376±0.038 | 0.392±0.048 | 0.393±0.046 | $F(1,9)=1.898$ $P=0.202$ | 0.174 |
| Left posterior cingulate cortex | 0.347±0.038 | 0.353±0.041 | 0.372±0.047 | 0.372±0.045 | $F(1,9)=2.284$ $P=0.165$ | 0.202 |

*Significant effect at $P<0.05$. Results for the group-time interaction effect are also shown alongside the partial-eta squared effect size. SD: Standard deviation, GMV: Gray matter volume

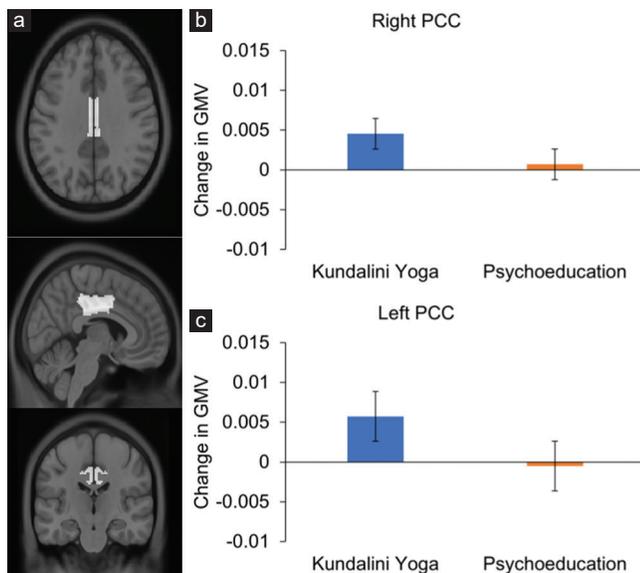


Figure 3: (a) Bilateral PCC ROI defined using the atlas. (b) Mean change in GMV in the right PCC. (c) Mean change in GMV in the left PCC. Error bars show standard error. PCC: posterior cingulate cortex, DKT: Desikan-Killiany-Tourville, GMV: Gray matter volume. ROIs: Regions of Interest

in particular seems to be relevant to cognitive decline. For example, one study found that right hippocampal GMV correlated to scores on the MMSE and Montreal Cognitive Assessment.^[13] A previous study reported that atrophy of the right hippocampus appears to be greater and occurs earlier than the left hippocampus, with right hippocampal atrophy possibly preceding a diagnosis of Alzheimer's years in advance.^[14] According to the National Institute on Aging and Alzheimer's Association, the ideal time to intervene is during the early pre-clinical phase of Alzheimer's.^[15] Thus, our preliminary finding that Kundalini yoga increases right hippocampal volume should encourage further research examining this intervention as a way to promote healthy neurological aging.

This pilot study had two important limitations due to our logistical constraints: the small sample size ($n = 11$) and the discrepancy between intervention durations (12 weeks for the Kundalini yoga intervention compared to 10 weeks for the psychoeducation intervention). While promising, our results would need to be confirmed in a larger trial with more stringent experimental controls.

Concluding remarks

We examined the neurobiological effects of Kundalini yoga in a pilot neuroimaging RCT with healthy meditation-naïve older adults. We found a significant increase in volume of the right hippocampus after participation in the 12-week Kundalini yoga intervention, but not in the psychoeducation group. While preliminary, these findings encourage future full-scale trials to assess the potential of Kundalini yoga as a neuroprotective intervention.

Ethical statement

Written informed consent was obtained from all participants. The study protocol has been approved by the research and ethics office of CIUSSS-ODIM/Douglas Institute. ClinicalTrials.gov: NCT04726072.

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Marim Ibrahim and Joseph Therriault are co-first authors and Soham Rej and Michael Lifshitz are co-senior authors in this paper.

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Conflicts of interest

There are no conflicts of interest.

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