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Movement-based mind-body practices and cognitive function in middle-aged and older adults: Findings from the Midlife in the United States (MIDUS) study

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This paper is dedicated to our co-author Dr. Kathryn Hyer, who passed away on January 1, 2021.

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ABSTRACT

Objectives: Cognitive function is a key component of healthy aging. While conventional physical activities (walking, jogging, etc.) have been shown to support physical and cognitive health in late-life, it remains unclear whether traditional Eastern movement-based mind-body practices (MBP) have long-term cognitive benefits above and beyond conventional leisure physical activities. This study examines the relationship between movement-based MBP and cognitive function in middle-aged and older adults during a 10-year follow-up period.
Methods: We used data from Waves 2 (2004−05) and 3 (2013−14) of the Midlife in the United States (MIDUS) study. MIDUS initially surveyed a national probability sample of community-living adults aged 24–75 years in 1995 (Wave 1). Tests of cognitive functioning measuring executive function and episodic memory were added in Wave 2 and repeated in Wave 3. We estimated multivariable linear regression models to examine the effect of MBP (Wave 2) on the episodic memory and executive function (Wave 3) while controlling for covariates (sociodemographic factors, health, and cognitive function at Wave 2).
Results: A total of 2097 individuals aged 42–92 years ($M = 64 \pm 11$, 56 % women) were included. After controlling for sociodemographic factors, health and functional status, and prior levels of cognitive function, engaging in MBP was independently associated with a smaller decline in episodic memory ($b = 0.11$, $p = .03$), but not executive function ($b=0.03$, $p = .34$).
Discussion: The findings provide the first large population-based evidence supporting the cognitive benefits of MBP over a 10-year period among middle-aged and older adults. Future research should examine whether MBP are effective non-pharmacological intervention to attenuate age-related cognitive decline.

1. Introduction

It is well-documented that cognitive performance declines with age in adulthood.[1–4] The number of persons with dementia globally is expected to rise from 46.8 million in 2015 to 131.5 million in 2050.[5] With the expected increase in disease burden for patients and their families, how to attenuate age-related cognitive decline has become a major public health challenge. Research has widely documented that non-pharmacological interventions focusing on physical activity are effective in improving cognitive function in older adults.[6–8] The goal of the present study is to examine whether mind-body practices (MBP), consisting of physical movement, breathing exercises, and meditative components, are associated with more favorable long-term change in cognitive function in middle-aged and older adults.

1.1. Mind-body practice

MBP is an umbrella term referring to practices that consist of physical movement and meditative components that interact closely between the body and the mind, potentially affecting both brain and behavior.[9] There are several types of MBP, such as yoga, tai chi, mindfulness meditation, Pilates, qigong, guided imagery, and massage therapy. Yoga is an ancient Indian technique of mind-body interrelated practice that consists of physical movement (asanas), breathing exercises (pranayama), and meditation (dhyana).[10–12] Tai chi is a Chinese martial art practiced primarily for defense training but is also used for its meditative health benefits.[13–15] Pilates is another physical exercise method consisting of low-impact flexibility and muscular strength and endurance movements.[16–18] These practices by increasing muscular strength and

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body flexibility help individuals gaining various physiological and psychological benefits.[19] MBP go beyond mere flexibility training: In addition to practicing the ability to move muscles and joints to their maximum range, they reduce tensions from our body and mind enable practitioners to go deeply into meditation.[19] While MBP increased in popularity in the United States during the last two decades,[20,21] the participation rate remained low: NHIS survey data indicated that MBP (primarily yoga, tai-chi) was practiced by 14 %–15 % of the population in 2017.[22]

A growing body of research suggests that physical activity has the potential to yield beneficial effects on various cognitive domains, including executive function, attention, processing speed, and episodic memory.[7,23–25] Conventional physical activity includes various sports (e.g., gymnastics, swimming), dance, various daily job activities, chores, and leisure activities.[26] Physical activity in the form of aerobic exercise or resistance training has positive impacts on cognitive maintenance, even among the so-called "oldest-old" adults.[8] In a meta-analysis of 18 randomized studies, Colcombe and Kramer found that sedentary older adults without dementia showed a consistent improvement in their cognitive performance after aerobic exercise.[7] MBP may complement conventional physical activity with their high adaptability to individual capabilities, cost-effectiveness, and engaging various physiological systems, both cognitive and physical, at the same time.

Episodic memory refers to the type of memory associated with individuals' recollection of personal experiences specific to time and place.[27] In large-scale studies, episodic memory is typically measured with word recall tests.[28,29] Episodic memory declines throughout the lifespan but shows the largest decline in old age.[28,29] Executive function consists of various cognitive functions, such as planning, organizing, reasoning, and problem-solving, related to the neuroanatomical coherence of the brain.[30] Many of these functions typically show age-related decline.[28] Recent evidence from randomized control trials suggests that MBP may be effective in improving cognitive function in middle-aged and older adults.[15] In a randomized control trial with 81 participants with mild cognitive impairment (55+ years old),[31] Eyre and colleagues found that both groups participating in Kundalini yoga (intervention group) and memory enhancement training (active control group) improved in memory at 12- and 24-weeks follow-up. However, only the group practicing Kundalini yoga improved in executive function, suggesting that this improvement may be due to yoga. In another study with 25 participants, Eyre and colleagues[31] found that yoga may be as effective as memory enhancement training (active control group) in improving functional connectivity concerning verbal memory performance. However, the yoga group demonstrated a statistically significant improvement in depression and visuospatial memory. The effects of yoga training were also examined in a randomized controlled trial by.[32] They found improvement in executive function in participants who trained in Hatha yoga (intervention group) in comparison to participants who received stretching and strength training (active control group). In a randomized control trial with 87 older adults in an assisted living facility, Hariprasad and colleagues found that the yoga group participants, who performed physical postures, breathing exercises, and meditation, showed significant improvement in both immediate and delayed recall of verbal and visual memory, attention, and executive function compared to the waitlisted participants (control) at the end of 6-months.[11] In a cross-sectional study with 16 older adults, Tsang and colleagues found that older adults who practiced tai chi had higher brain activity, measured with spectroscopy, than a body-focused exercise group.[15] While these promising results are derived from studies of relatively small sample sizes and shorter follow-up periods, if MBP supports healthy cognitive aging as suggested by these experimental studies, we should observe similar benefits in large population-based studies with longer follow-up periods.

It has been argued that reduction in blood flow in different areas of the brain due to vascular disorders acts as one of the principal factors underlying age-related cognitive decline in various cognitive functions.[33] Bridging between mind and body, MBP has been proposed to influence the vagus nerve, which plays a vital role linking the cardiovascular, respiratory, digestive, musculoskeletal, and nervous systems.[34] Through its parasympathetic activity, vagal stimulation increases the cerebral blood flow and consequently affects the hypothalamus-pituitary-adrenal (HPA) axis, which in turn, reduces the production of inflammatory neurotransmitters and decreases the risk of inflammation-related disorders.[35]

1.2. Purpose of the study

Most mind-body interventions involve inexpensive practices and are especially suitable for large-scale adoption due to their favorable, cost-effective, and safety profiles.[36–38] Population-based studies on MBP can help inform the public about its use and help researchers develop intervention modalities for community use. The present study aims to examine the effects of habitual yoga and other MBP on long-term changes in cognitive function. Our study adds to previous research by using longitudinal data from a nationally representative sample of middle-aged and older adults in the United States while controlling for well-documented correlates of MBP, including sociodemographic and health factors.[21,38] We hypothesized that MBP would be associated with more favorable trajectories of cognitive change in the domains of episodic memory and executive function.

2. Method

2.1. Study design

We used data from the national survey of Midlife in the United States (MIDUS), a large-scale longitudinal study spanning 20 years. MIDUS started in 1995–1996 (wave 1), with 7108 English-speaking participants between the ages of 24 and 75 years (m = 46, sd = 13) recruited through random digit dialing of US households in the 48 contiguous states.[39] Wave 2 of the longitudinal study was conducted between 2004 and 2005 among 4963 participants (75 % of the original respondents in Wave 1) aged between 35 and 86 years (m = 55, sd = 11).[40] Wave 3 was conducted in 2013−14 with 3294 participants (including 77 % of Wave 2 participants).[22] In Wave 3, participants were aged between 42–92 years (m = 64, sd = 11), and 55 % of the sample were women.[41] All waves of MIDUS datasets contain primary data collected directly from respondents.

2.2. Participants

The present study uses data from waves 2 and 3 (2004–2014), which included cognitive tests measuring executive function and episodic memory. In the current study, we included data from 2097 individuals who participated both at waves 2 and 3. Both waves 2 and 3 were conducted through the phone. In addition, participants were asked to complete a mailed self-administered questionnaire (SAQ).

2.3. Measures and procedure

2.3.1. Independent variable

The MBP was used as the key independent variable. Participants answered to the question, "In the past 12 months, either to treat a physical health problem, to treat an emotional or personal problem, to maintain or enhance your wellness, or to prevent the onset of illness, how often did you use – exercise or movement therapy (yoga, pilates, tai chi, etc.)?" on a 5-point Likert scale ranging from 1 ("performing a lot") to 5 ("never"). Responses indicating any MBP ("a lot," "often," "sometimes," or "rarely") were coded as 1, responses indicating no practice ("never") were coded as 0.

2.3.2. Dependent variable

Episodic memory and executive function were assessed at waves 2 and 3 with the Brief Test of Adult Cognition by Telephone (BTACT).[42] Episodic memory was measured with two tests (immediate and delayed free recall of 15 words). Executive function was measured by inductive reasoning (measured by number series completion), category verbal fluency (measured by verbal ability and fluency in 60 s), working memory span (measured by backward digit span), processing speed (measured by 30-Second and Counting Task, or 30-SACT), and attention switching and inhibitory control (measured by Stop and Go Switch Task, or SGST, calculating reaction times).[43] Results of factor analyses for cognitive tests in MIDUS are reported by.[43] The tests were z-scored (M = 0; SD = 1) according to means and standard deviations of the Wave 2 full sample. As per Lachman et al.,[44] a composite score was calculated for both episodic memory and executive function as the mean of the z-scored measures.

2.3.3. Covariates

Sociodemographic variables included age, gender, race, marital status, education, and employment. Age was split in six categories (1 = <35, 2 = 35−44, 3 = 45−54, 4 = 55−64, 5 = 65−74, 6 = ≥75). Gender (1 = male, 2 = female) was a binary variable. Race (1 = White, 2 = Black, 3 = Other) was measured in three categories, while marital status (1 = married, 2 = separated/divorced, 3 = widowed, 4 = never married) and educational level (1 = no/some school, 2 = high school graduate/in college, 3 = graduated from college, 4 = having master's/professional degree) were measured in four categories. Employment status was measured in five categories (1 = currently working, 2 = self-employed, 3 = retired, 4 = unemployed, 5 = other). *Health and functional status* were indicated by several variables. Previous research has shown that they are related to both MBP and cognitive function.[44,45] Participants rated their current physical and mental health on a five-point scale ranging from 1 (excellent) to 5 (poor). Participants were asked, through a functional status questionnaire, whether they had difficulty (functional limitations) in activities of daily living (ADL) and instrumental activities of daily living (IADL). Responses indicating difficulty ("a little" to "a lot") were coded as 1, responses indicating no difficulty were coded as 0.[46] *Conventional physical activities* were measured with several questions. Participants were asked about their participation in vigorous and moderate physical activities with the question, "How often do you engage in vigorous physical activities that cause your heart to beat so rapidly that you can feel it in your chest and you perform the activity long enough to work up a good sweat and to breath heavily?", and "How often do you engage in moderate physical activities, that is not physically exhausting, but it causes your heart rate to increase slightly and you typically work up a sweat?", respectively, on a 6-point Likert scale ranging from 1 ("several times a week or more") to 6 ("never") for both summer and winter. Responses indicating regular physical activity ("several times a week or more" or "once a week") were coded as 1 and responses indicating no regular physical activity (in lesser frequency or never) were coded as 0. Responses indicating regular physical activity in one or both seasons, either in moderate or vigorous intensity, were coded as 1. Other responses were coded as 0. We included other variables related to health, including body mass index (BMI; 1 = underweight [<18.5], 2 = normal [18.5−24.9], 3 = overweight [>24.9-29.9], and 4 = obese [>29.9]), tobacco and alcohol use (1 = regular tobacco/alcohol user, or 0 = not), and a count of the number of chronic conditions (within past 12 months), including (but not limited to) high blood pressure, stroke, heart problems, diabetes, cancer, aches/joint stiffness, and chronic sleep problem. Participants responded to 7 items from the DEPCON scale, administered by telephone, asking about depressive symptoms that lasted for more than two weeks in the past 12 months.[47] Supplementary Table 3 presents the DEPCON scale measuring depressive symptoms.

2.4. Statistical analysis

Statistical analyses were conducted with Stata 15.1 (College Station, TX). To examine the effect of MBP on long-term cognitive change, we estimated multivariable linear regression models by predicting episodic memory and executive function at wave 3 (dependent variables) while controlling for covariates at wave 2 (sociodemographic factors, health and functional status, and cognitive function). Statistical significance was evaluated at $p < .05$ (two-sided). Unstandardized regression coefficients (b) and 95 % confidence intervals (CI) are reported.

3. Results

Descriptive statistics of the dependent and independent variables, including demographic variables and health and functional status at Wave 2, are shown in Table 1. A total of 2097 individuals who completed both Wave 2 and Wave 3 of MIDUS were included in the analysis. This cohort of participants was aged 33–83 years (m = 55, sd = 11) in Wave 2 and 42–92 years (m = 64, sd = 11) in Wave 3. Overall, 83 % reported that they have never used MBP in the past 12 months. Women made up 56 % of the sample, 57 % were employed, and 94 % were White. 77 % of the sample had at least one chronic disease, and 13 % had five or more. Substantial proportions of participants were overweight (39 %) or obese (27 %).

Table 1 also shows differences between those who used MBP vs. those who did not use it at baseline (Wave 2). The MBP was more common among younger individuals, women, unmarried, and those with higher education. Body mass index (BMI) was significantly higher among those who did not engage in MBP. Tobacco use was significantly higher among those who did not engage in MBP. Those who engaged in MBP reported higher rates of regular physical activity and better self-reported health. At the same time, they were more likely to report sleep problems and feelings of depression. Those who engaged in MBP scored higher in both episodic memory and executive function at wave 3.

Table 2 shows descriptive statistics and correlations for the cognitive variables over time. The retest correlation over 10 years is higher for executive function (r = 0.75) than for episodic memory (r = 0.53), suggesting that individual differences in executive function are very stable in this sample.

Table 3 shows the results of zero-order models examining associations between MBP at baseline (Wave 2) on episodic memory and executive function at follow-up (Wave 3), respectively, while controlling for baseline episodic memory and executive function, respectively. MBP was associated with more favorable change in episodic memory (b = 0.16, $p < 0.01$). The same effect was not found for executive function (b = 0.02, $p = 0.39$).

Table 4 shows the results of multivariable linear regression models estimating the effect of MBP (Wave 2) on episodic memory and executive function (Wave 3), respectively, while controlling for baseline levels of cognitive scores and covariates (sociodemographic factors and health at Wave 2). After controlling for sociodemographic factors, health, and prior levels of cognitive function, the MBP was independently associated with a more favorable change in episodic memory (b = 0.11, $p = 0.03$). The same effect was not found for executive function (b = 0.03, p = 0.34).

Women and participants with a master's or professional degree showed more favorable change in episodic memory. In contrast, 65+ years old participants and participants who were Black showed less favorable change in episodic memory. Participants who reported good mental health showed relatively more decline in episodic memory than participants who reported excellent mental health (reference category). Participants who were 55+ years old, Black, who were self-employed, retired, or had another occupational status (relative to working), and underweight participants showed more decline in executive function. Relative to participants who reported no chronic conditions (reference

Table 1
Comparison of respondent characteristics of US adults in MIDUS wave 2 (n = 2097).

Variable	Wave 2 Overall status (n = 2097)	Based on mind-body practice: Mind-body practice (n = 353; 16.8 %)	No mind-body practice (n = 1744; 83.2 %)	*p*-value
Age mean year (sd)	55.1 (10.9)	54.2 (10.8)	55.2 (10.9)	.20
<35 (%)	1.0	1.1	1.0	
35−44 (%)	18.0	20.7	17.4	
45−54 (%)	30.1	27.2	30.7	
55−64 (%)	29.5	32.6	28.8	
65−74 (%)	17.1	15.6	17.4	
≥75 (%)	4.4	2.8	4.7	
Women (%)	55.6	73.1	52.1	**<.01**
Race/ethnicity (%)				.97
White	93.9	93.8	93.9	
Black	2.3	2.3	2.4	
others	3.8	4.0	3.7	
Marital status (%)				**<.01**
married	73.7	66.2	75.2	
separated/divorced	13.2	17.3	12.3	
widowed	5.6	5.7	5.6	
unmarried	7.6	10.8	6.9	
Education (%)				**<.01**
no/some school	3.8	1.4	4.5	
graduated from school/in college	44.2	36.3	45.8	
graduated from college	33.3	40.2	31.9	
Master's/professional degree	18.6	22.1	17.8	
Employment (%)				.63
working	57.3	55.5	57.7	
self-employed	12.2	13.0	12.0	
retired	20.5	19.8	20.7	
unemployed	2.0	2.8	1.8	
other	8.0	8.8	7.9	
Health and functional status (past 12 months)				
BMI mean (sd)	27.8 (5.5)	27.1 (5.6)	27.9 (5.5)	**<.01**
underweight (<18.5) (%)	0.7	1.1	0.6	
normal (18.5−24.9) (%)	30.4	39.1	28.6	
overweight (25−29.9) (%)	38.6	34.3	39.5	
obese (>29.9) (%)	26.5	22.7	27.3	
missing (%)	3.8	2.8	4.0	
Tobacco-user (%)	12.8	7.9	13.8	**<.01**
Alcohol-user (%)	37.7	37.4	38.1	.62
Regular physical activity (sum./win., mod./vig.) (%)	47.2	64.3	43.7	**<.01**
Self-reported physical health mean (sd)	2.3 (0.9)	2.1 (0.8)	2.3 (0.9)	**.01**
excellent (%)	20.0	21.3	19.7	
very good (%)	43.4	49.3	42.3	
good (%)	27.5	23.5	28.3	
fair/poor (%)	9.0	6.0	9.7	
Self-reported mental health mean (sd)	2.0 (0.9)	2.1 (0.8)	2.0 (0.9)	.18
excellent (%)	30.3	26.9	31.0	
very good (%)	39.6	44.2	38.7	
good (%)	25.4	23.5	25.8	
fair/poor (%)	4.7	5.4	4.6	
Difficulty in ADL (%)	24.5	27.2	23.9	.19
	73.7	70.3	74.4	.10

Table 1 (*continued*)

Variable	Wave 2 Overall status (n = 2097)	Based on mind-body practice: Mind-body practice (n = 353; 16.8 %)	No mind-body practice (n = 1744; 83.2 %)	*p*-value
Difficulty in IADL (%)				
Number of chronic condition/s mean (sd)	2.0 (1.7)	2.3 (1.7)	1.9 (1.6)	**<.01**
0 (%)	23.1	18.1	24.1	
1 (%)	21.5	18.7	22.1	
2 (%)	20.3	22.4	19.9	
3 (%)	14.0	12.8	14.2	
4 (%)	8.4	9.6	8.1	
5/more (%)	12.7	18.4	11.6	
Had sleep problem (%)	9.6	14.5	8.6	**<.01**
Had diabetes/high blood sugar (%)	**7.7**	7.7	7.7	.98
High blood pressure diagnosed (%)	27.6	26.1	27.9	.48
Had stroke (%)	2.0	1.7	2.0	.70
Had cancer (%)	12.7	15.3	12.2	.11
Heart problem diagnosed (%)	15.0	16.2	14.8	.51
Pain/joint stiffness (%)	85.0	86.7	84.7	.33
Felt sad/depressed for >2 weeks (%)	17.6	25.8	16.0	**<.01**
Episodic memory mean (sd)	0.15 (1.0)	0.35 (1.0)	0.11 (0.9)	**<.01**
Executive functioning mean (sd)	0.22 (0.9)	0.31 (0.8)	0.20 (0.9)	**.04**

Note. BMI = body mass index; sd = standard deviation; sum. = summer; win. = winter; mod. = moderate; vig. = vigorous; ADL = activities of daily living; IADL = instrumental activities of daily living.

Table 2
Descriptive statistics and correlations of cognitive variables (n = 2097).

	mean	sd	EM (wave 2)	EM (wave 3)	EF (wave 2)	EF (wave 3)
EM (wave 2)	0.15	1.00	1.00	–	–	–
EM (wave 3)	0.03	1.00	.53	1.00	–	–
EF (wave 2)	0.22	0.90	.35	.33	1.00	–
EF (wave 3)	−0.10	0.70	.30	.39	.75	1.00

Note. sd = standard deviation; EF = executive function; EM = episodic memory.

Table 3
Zero-order linear regression model to estimate the effect of mind-body practice (wave 2) on the cognitive episodic memory (wave 3) and executive function (wave 3) (n = 2097).

Variables in wave 2	Episodic memory (wave 3) b	*p*	95 % CI	Executive function (wave 3) b	*p*	95 % CI
Episodic memory	0.53	**<.01**	(0.50, 0.57)	–	–	–
Executive function	–	–	–	0.59	**<.01**	(0.57, 0.61)
Mind-body practices	0.16	**<.01**	(0.07, 0.26)	0.02	.39	(-0.03, 0.08)

Note. b = unstandardized regression coefficient; CI = confidence interval.

Table 4
Multivariable linear regression model to estimate the effect of mind-body practice (wave 2) on the cognitive episodic memory (wave 3) and executive function (wave 3) (n = 2097).

Variables in wave 2	Episodic memory (wave 3)			Executive function (wave 3)		
	b	*p*	95 % CI	b	*p*	95 % CI
Age (ref. < 35)						
35–44	0.09	.62	(-0.26, 0.43)	−0.02	.81	(-0.22, 0.17)
45–54	0.02	.92	(-0.32, 0.36)	−0.09	.36	(-0.28, 0.10)
55–64	−0.17	.35	(-0.51, 0.18)	−0.20	**.04**	(-0.39, -0.01)
65–74	−0.50	**.01**	(-0.86, -0.15)	−0.38	**<.01**	(-0.58, -0.18)
≥75	−0.87	**<.01**	(-1.26, -0.48)	−0.49	**<.01**	(-0.71, -0.27)
Female	0.34	**<.01**	(0.26, 0.42)	−0.02	.37	(-0.06, 0.02)
Race/ethnicity (ref. White)						
Black	−0.40	**<.01**	(-0.62, -0.18)	−0.16	**.01**	(-0.29, -0.04)
other	−0.09	.34	(-0.27, 0.09)	−0.04	.47	(-0.14, 0.06)
Marital Status (ref. married)						
separated/ divorced	−0.07	.18	(-0.18, 0.03)	−0.04	.19	(-0.10, 0.02)
widowed	0.14	.08	(-0.02, 0.30)	−0.09	.06	(-0.17, 0.00)
never married	0.04	.58	(-0.09, 0.17)	−0.04	.34	(-0.11, 0.04)
Education (ref. no/ some school)						
graduated from school/in college	0.09	.33	(-0.09, 0.26)	0.01	.80	(-0.09, 0.11)
graduated from college	0.14	.14	(-0.04, 0.32)	0.06	.23	(-0.04, 0.16)
Master's/ professional degree	0.21	**.03**	(0.02, 0.40)	0.09	.09	(-0.01, 0.20)
Employment (ref. working)						
self-employed	−0.05	.34	(-0.16, 0.06)	−0.10	**<.01**	(-0.16, -0.04)
retired	−0.02	.68	(-0.13, 0.09)	−0.12	**<.01**	(-0.18, -0.06)
unemployed	−0.15	.22	(-0.40, 0.09)	−0.11	.11	(-0.25, 0.03)
other	−0.01	.84	(-0.15, 0.12)	−0.08	**.03**	(-0.16, -0.01)
BMI (ref. normal)						
underweight (<18.5)	−0.14	.51	(-0.54, 0.27)	−0.28	**.01**	(-0.51, -0.06)
overweight (25–29.9)	0.04	.35	(-0.05, 0.12)	−0.01	.75	(-0.05, 0.04)
obese (>29.9)	0.04	.44	(-0.06, 0.13)	0.00	.91	(-0.06, 0.05)
missing	0.04	.64	(-0.14, 0.23)	−0.03	.57	(-0.13, 0.07)
Tobacco user	−0.06	.30	(-0.16, 0.05)	−0.05	.09	(-0.11, 0.01)
Alcohol user	−0.03	.35	(-0.11, 0.04)	0.01	.80	(-0.04, 0.05)
Physical activity	0.00	1.00	(-0.07, 0.07)	0.01	.56	(-0.03, 0.05)
SR physical health (ref. excellent)						
very good	0.10	.06	(0.00, 0.21)	0.01	.83	(-0.05, 0.06)
good	0.07	.27	(-0.05, 0.19)	0.00	.91	(-0.06, 0.07)
fair/poor	0.03	.71	(-0.14, 0.21)	−0.01	.80	(-0.11, 0.08)
SR mental health (ref. excellent)						

Table 4 (*continued*)

Variables in wave 2	Episodic memory (wave 3)			Executive function (wave 3)		
	b	*p*	95 % CI	b	*p*	95 % CI
very good	−0.08	.08	(-0.17, 0.01)	−0.03	.20	(-0.08, 0.02)
good	−0.12	**.03**	(-0.23, -0.01)	−0.03	.28	(-0.09, 0.03)
fair/poor	−0.10	.29	(-0.29, 0.09)	−0.02	.68	(-0.13, 0.08)
Difficulty in ADL	−0.06	.18	(-0.16, 0.03)	−0.01	.75	(-0.06, 0.04)
Difficulty in IADL	−0.03	.51	(-0.12, 0.06)	0.01	.72	(-0.04, 0.06)
Number of chronic conditions (ref. 0)						
1	−0.01	.86	(-0.11, 0.09)	0.01	.77	(-0.05, 0.07)
2	−0.01	.91	(-0.11, 0.10)	−0.05	.11	(-0.11, 0.01)
3	0.08	.21	(-0.04, 0.20)	−0.02	.52	(-0.09, 0.05)
4	−0.04	.56	(-0.19, 0.10)	−0.08	**.04**	(-0.16, 0.00)
5/more	−0.08	.27	(-0.21, 0.06)	−0.05	.18	(-0.13, 0.02)
Felt sad/depressed	−0.07	.16	(-0.17, 0.03)	0.01	.84	(-0.05, 0.06)
Episodic memory	0.42	**<.01**	(0.38, 0.46)	–	–	–
Executive function	–	–	–	0.50	**<.01**	(0.47, 0.52)
Mind-body practices	0.11	**.03**	(0.01, 0.20)	0.03	.34	(-0.03, 0.08)

Note. b = unstandardized regression coefficient; CI = confidence interval; BMI = body mass index; SR = self-reported; ADL = activities of daily living; IADL = instrumental activities of daily living.

category), those with four chronic conditions showed less favorable change in executive function.

Follow-up analyses were conducted to examine associations between the frequency of MBP and cognitive variables. Results are presented in Supplementary Tables 1 (zero-order model) and 2 (full model). The pattern of findings indicated that differences in episodic memory were primarily between those who endorsed categories "never" vs. "some": In the zero-order model, those who reported some engagement in MBP showed more favorable change in episodic memory compared with those who never used MBP (b = .26; p = <.01). The same effect was found in the full model including socio-demographic and health variables as covariates (b = .17; p = .03). The frequency of MBP at Wave 2 was unrelated to executive function at wave 3, both in the zero-order and full models. The findings of these additional analyses need to be interpreted with the caveat that sample sizes per category were small (i.e., between 4–6 % for each category of MBP other than "never").

4. Discussion

The current study provides the first population-based longitudinal evidence that movement-based MBP has positive effects on episodic memory change in the US middle-aged and older adult population over ten years. The rate of MBP in our study was comparable to previous reports in the literature.[21,38] The results suggest that MBP may be an effective non-pharmacological intervention to attenuate age-related episodic memory decline in middle-aged and older adults. MBP was independently associated with better change in episodic memory, but our hypothesis was not supported for executive function. Focusing on habitual MBP in participants' daily lives and a 10-year follow-up interval, our study added to previous research showing that interventions including aerobic exercises/yoga program are associated with improvement in cognitive functioning,[48–52] especially in episodic memory.[53]

The MBP may translate to better episodic memory by increasing physical activity, reducing stress, and increasing wellbeing. Negative effects of stress on cognitive function are well-documented.[54,55] Stress triggers an individual's sympathetic nervous system, which in turn releases signaling molecules (such as inflammatory cytokines) and inflammatory neurotransmitters (such as acetylcholine, dopamine) with adverse effects on (cognitive) health.[35,56] MBP, such as yoga, has a down regulatory effect on the sympathetic nervous system and the HPA axis in response to stress.[11,57] Bridging between mind and body, through various neuronal circuits, MBP may regulate the production of both pro-inflammatory neurotransmitters, such as dopamine, acetylcholine, and inhibitory neurotransmitters, such as GABA.[35,57] Research suggests that MBP is associated with structural changes in different brain regions, such as the prefrontal cortex, insula, striatum, and amygdala, which may enhance wellbeing through the neural circuits that regulate cognitive functions.[58] Individuals may turn to yoga for these stress-reducing effects: For example, we found a higher prevalence of depressive symptoms, sleep problems, and joint pain among participants who used MBP than those who did not practice. These participants may have turned to MBP for relief from these complaints. As a physical activity, the practice of yoga can enhance muscle strength and body flexibility and improve respiratory and cardiovascular functions.[19] Both factors have been linked with higher levels of cognitive function in previous studies.[19,59,60] In line with the vascular hypothesis, MBP was associated with a lower proportion of vascular risk factors as well as vascular diseases, such as stroke.

A recent systematic review of 11 studies suggests that MBP is associated with hippocampal volume, which in turn is related to learning and memory functions.[61] MBP is also associated with higher cortical thickness and increasing gray matter volume.[62,63] Tai chi has been found to be associated with higher brain activity by enhancing prefrontal oxygenation identified by infra-red spectroscopy, indicating its effectiveness in cognitive performances.[15] A randomized control trial with 110 older adults reveals Pilates as a potential mind-body training to improve cognitive and functional abilities.[64] However, there are very few randomized control trials (with active control groups) that examine neural mechanisms underlying the effects of MBP.

Our findings show that the retest correlation is higher for executive function than for episodic memory, which means that individual differences in executive function are very stable in this sample over 10 years. This is in line with the findings of a study by Zimprich and Mascherek,[65] where the authors found higher retest stability for fluid ability ($r = .94$) and processing speed ($r = 0.91$) compared with episodic memory ($r = 0.58$) in middle-aged adults. The high level of stability in individual differences may be a possible reason why MBP was not found to affect executive function in our study. Participants' age-range may also play a role here. Compared to the average age in our study, the average age of other studies, which found more positive effects on executive function, are higher.[11,50] It is possible that the stability of individual executive function over time is lower in older adults.

4.1. Limitations

A number of limitations should be considered in interpreting the findings. First, MIDUS did not collect information on the duration and level of experience in MBP. Future population-based surveys should collect more in-depth information regarding these practices to examine potential dose-response relationships supporting a causal relationship between MBP and cognition. Second, our analyses were based on two data points on cognitive function, which precluded the analysis of nonlinear trends (e.g., accelerated cognitive decline). Third, because MIDUS participants were not screened initially for cognitive impairment, we cannot rule out that individuals with neurocognitive disorders existed in our sample. Also, MIDUS did not collect data on medication use. Fourth, MBP was assessed as "exercise or movement therapy" in the last 12 months, with yoga, tai chi, and Pilates being provided as examples. This may have created unclarity among participants regarding other activities that would be considered as MBP. Also, the broad question precluded us from examining the effects associated with specific types of practice. Another limitation is related to recall bias because responses were collected retrospectively. Furthermore, the question focused on MBP in the last 12 months; however, the effects of MBP may be long-lasting, even after stopping it for more than a year.[66] Finally, this paper concentrated on movement-based MBP. Future research should focus on measures of pure meditative practices (like mindfulness, automatic self-transcending meditation, or concentration-based meditation) and associations with cognitive function.

4.2. Conclusions

Taken together, our findings suggest that MBP is associated with the maintenance of episodic memory in US middle-aged and older adults, while the same effect was not found for executive function. Despite its health-promoting potential, MBP is practiced by a small segment of the population, with potential for additional growth as a complementary approach to support conventional care and activities to promote physical and mental health in late life. Future research considering more frequencies of different variables and shorter follow-up periods should elucidate whether these findings can be replicated in other populations and if confirmed, interventions should incorporate a broader range of physical activities in community-living older adults to maintain and improve cognitive health in the second half of life.

Author statement

The authors' responsibilities were as follows: **KKB:** Design, conceptualization, methodology, analysis, writing - original draft of the article. **GH:** Involved in interpreting the data, review and editing the article, supervision. **HM:** Involved in reviewing the analysis and interpreting the data and editing the article, supervision. **KH:** Involved in reviewing the analysis, editing the article, supervision.

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Declaration of Competing Interest

The authors report no declarations of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ctim.2021.102751.

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