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Effects of a Single Session of Brain Yoga on Brain-Derived Neurotrophic Factor and Cognitive Short-Term Memory in Men Aged 20–29 Years

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Abstract

Purpose : This study aimed to evaluate the effects of a cognitive enhancement brain yoga program on short-term memory and serum brain-derived neurotrophic factor (BDNF) levels according to the cognitive state in men aged 20–29 years.

Methods : Thirty healthy volunteers aged 20–29 years were divided into four groups: brain yoga group, yoga group, combined exercise group, and control group. Seven people were assigned randomly per group. A single-session intervention was conducted over 50 min and consisted of three parts: warm-up, main exercise (brain yoga, yoga, combined exercise, or non-exercise), and cool-down. Serum BDNF levels were measured using enzyme-linked immunosorbent assay, and short-term memory was evaluated using the forward number span test before and after the intervention.

Results : BDNF levels significantly increased within the brain yoga group after the intervention (from 28874.37±5185.57 to 34074.80±7321.12, p=.003), whereas there were no significant differences pre-and post-intervention in the other groups. The inter-group comparison showed a significant interaction between the brain yoga group and the combined exercise group (p=.036) but no significant interaction between any of the other groups. Forward number span scores were significantly increased in the brain yoga group (from 9.43±9.83 to 23±7.92, p=.012) and theyoga group after the intervention (from 13.43±9.41 to 24.14±8.45, p=.011), whereas there were no significant changes after the intervention in any other groups.

Conclusion : Our findings showed that a single-session, 50-minute brain yoga exercise improved short-term memory and increased serum BDNF levels in healthy men aged 20–29 years and that yoga improved only short-term memory in healthy men of this age group.

Key Words : brain-derived neurotrophic factor, cognition, memory, exercise, yoga

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Ⅰ. Intruduction

1. Background

Regular physical activity offers various benefits in many areas other than physical and mental health, such as the environment, society, and economics (Brown et al., 2013). Many studies have reported that increased physical activity exerts positive effects on muscle development, maintains and enhances brain function, and alleviates brain damage by promoting neurogenesis (Lista & Sorrentino, 2010; van der Borght et al., 2009). In addition, Blondell et al., (2014) reported that high levels of physical activity lower the risk of cognitive decline. Moreover, most previous studies have shown that exercise has positive effects on motor function and the cardiovascular system. More recent studies have also focused on the association between exercise and brain development in humans (Lee, 2009).

In the past, it was commonly believed that the function or structure of the brain does not change in adulthood. However, studies conducted by Bach-y Rita (1967) and Bach-y Rita et al. (1969) discovered that neurogenesis occurs in the hippocampus of adult brains (Eriksson et al., 1998). It follows that brain neuroplasticity may improve cognitive function, and many recent studies have addressed this concept. Previous studies have reported that exercise, as an external factor increasing neurogenesis, increases brain nerve plasticity (Cotman et al., 2007) and changes in neurons, which are the basic units of the nervous system. This leads to changes in the brain, including synaptic plasticity (Lo, 1995), neurogenesis and angiogenesis (Cotman et al., 2007), activation of the frontal lobe (Perrey, 2008), increased hippocampal volume (Erickson et al., 2011), improved cognitive function (Colcombe and Kramer, 2003), and improved learning and memory (Aguiar et al., 2011).

Among the brain neuroplasticity factors discovered thus far, brain-derived neurotrophic factor (BDNF) has attracted increasing at tention; it plays a crucial role in neural development, maintenance, and survival of the central and peripheral nervous systems. Aging causes impaired neurogenesis, as it reduces BDNF, and BDNF deficiency, in turn, reduces the generation and survival rate of neurons (Chan et al., 2008).

Exercise increases the expression of BDNF, which is known to promote neurogenesis (Pencea et al., 2001). In particular, aerobic exercise plays a crucial role in facilitating brain function and cognitive ability by increasing brain size, blood flow to the brain, and BDNF solubility (Endres et al., 2003; Swain et al., 2003). Furthermore, exercise improves cognitive ability, body composition, and physical strength and reduces the prevalence of mental diseases (Kim, 2014; Kim & Lee, 2012). Numerous studies have shown that exercise exerts positive effects on memory by increasing BDNF expression (Lee, 2009), while othershave reported that yoga has positive effects on both BDNF and cognitive function (Lee et al., 2014; Yoo et al., 2010).

However, as the subjects from these previous studies were limited to children or adolescents, few studies have been conducted in adults, and few have focused on exercise methods that promote balance between the central and peripheral nervous systems. The brain yoga program was developed to improve co-ordination between the central and peripheral nervous systems.

2. Purpose

The present study aimed to determine the correlation between normal yoga and a combined exercise program as well as to validate the effects of the brain yoga program by measuring and analyzing changes in BDNF and cognitive function after the intervention.

Ⅱ. Methods

1. Participants

Thirty men aged 20~29 years and residing in G state, Korea, were enrolled in the preset study. All 30 were healthy and had not taken any supplements or medications, including antidiabetic drugs, antihypertensive drugs, or cognitive-enhancing drugs, during the previous 4 weeks. None of the participants had any physical or emotional impairments, and none had participated in any regular exercise program during the previous 6 months. After enrollment, all interventions and measurements were performed on the same day. The participants were divided into four groups according to the exercise program :brain yoga, yoga, combined exercise, and control groups. Seven people were assigned randomly per group.

2. Intervention

1) Brain yoga program

Brain yoga is an exercise program developed to improve cognitive function and coordination between the central and peripheral nerves by applying postures from previous yoga programs and the principles of the brain yoga composition. In the present study, to determine the effects of brain yoga on BDNF and cognitive function, the program was executed utilizing eight postures and a brain yoga mat (Fig 1). The six principles of the brain yoga program are as follows. First, flexibility exercises and exercises to enhance reactions and reflexes are performed to promote the secretion of neurotransmitters (Yoo et al., 2010). Second, a lower body (second heart) strengthening exercise is performed to enhance blood flow (Ko et al., 2009). Third, a balance exercise is performed for balanced development (coordination, adaptability, and balance) of the sensory, motor, and central nerves (Kim et al., 1999). Fourth, a "task exercise" is performed − that is, an exercise during which the participant thinks about the next task to be performed; this activates the central nerves simultaneously with the motor and sensory nerves (Yang et al., 2012). Fifth, plyometric training is performed to increase the level of growth hormones (Koh et al., 2015). Sixth, resistance training is performed to increase the proportion of muscles that promote the generation and activation of neurons (Kim & Lee, 2013). The brain yoga program consists of a 5-minute warm-up, 50 minutes of brain yoga, and a 5-minute cool-down (static stretching). With the eight postures all memorized, the program was executed once in sequence, once in reverse sequence, and once in randomized sequence (Table 1). Each of postures was lasted total of 30 seconds; 5 seconds for start position, 20 seconds for performance, 5 seconds for return to rest position.

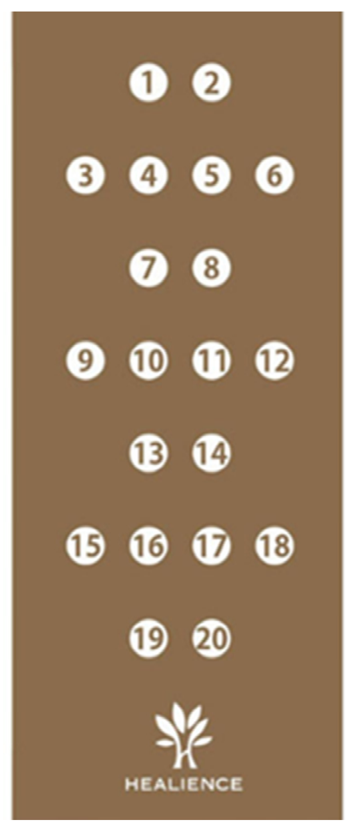

Fig 1. Brain yoga mat

Table 1. Brain yoga program

Variables	Exercise content		Time	Intensity
Warm-up	Static Stretching		5 min	Light
Brain yoga exercise	 Posture 1	-Start: left foot⑲, right foot⑳ -Move: left foot⑯, right foot⑰ -Perform: back extension under inhalation	50 min	11-14 R*
	 Posture 2	-Start: left foot⑯, right foot⑰ -Perform: forward flexion with exhale, left hand⑬, right hand⑭		
	 Posture 3	-Start: left foot⑯, right foot⑰ -Perform: palm walking until left hand④, right hand⑤, and posing the downward facing dog underexhalation		
	 Posture 4	-Start: left knee⑩, right knee⑪, left hand ③, right hand⑥ -Perform: asymmetric stretch the upper and lower extremity		
	 Posture 5	-Start: hip⑯⑰ -Perform: forward flexion with exhale		
	 Posture 6	-Start: hip⑯⑰ -Perform: left foot⑩, left hand⑳, push the left knee by right elbow facing the ⑳ direction		

Variables	Exercise content		Time	Intensity
	 Posture 7	-Start: pelvic⑩⑪, left hand③, right hand⑥ -Perform: abdominal stretching facing the top of the head and prevent the shoulder elevation		
	 Posture 8	-Start: both knees⑦⑧ -Perform: attach both the heel and hip and bend the trunk under exhalation		
Cool-down	Static stretching		5 min	Light

*R: RPE, rating of perceived exertion

2) Yoga program

The Surya Namaskar method was applied in the Yoga program, which consisted of a 5-minute warm-up(static stretching), 5 minutes of the Surya Namaskar posture, anda 5-minute cool-down(static stretching) (Table 2).

Table 2. Yoga program

Variables	Exercise content	Time	Intensity
Warm-up	Static stretching	5 min	Light
Yoga exercise	Pranamasana/4 times/8 sets Hasta Uttanasana/4 times/8 sets Padahastasana/twice/4 sets Santolasana/twice/4 sets Ashtanga Namaskara/twice/4 sets Bhujangasana/4 times/8 sets Parvatasana/twice/4 sets Ashwa Sanchalanasana/twice/4 sets Padahastasana/twice/4 sets Hasta Uttanasana/twice/4 sets Pranasana/twice/4 sets	50 min	11-14 R*
Cool-down	Static stretching	5 min	Light

*R: RPE, rating of perceived exertion

3) Combined exercise program

In the single-session combined exercise program conducted in this study, the aerobic exercise program was adapted and modified from the exercise program used by Joo and Choi (2017), while the anaerobic exercise program was modified from the body weight training used by Son et al. (2016). The foam roller program was modified by the researcher of this study based on a program used in the field. The details of the combined exercise program are shown in Table 3.

Table 3. Combined exercise program

Variables		Exercise content	Time	Intensity
Warm-up		Static stretching	5 min	Light
Yoga exercise	Aerobic exercise	Front step/30 rep/3 set (30 sec) Front knee-up/30 rep/3 set (30 sec) Front leg-raise/30 rep/3 set (30 sec) Side-step/30 rep/3 set (30 sec) Cross-change Step/30 rep/3 set (30 sec) Jumping jack/30 rep/3 se t(30 sec)	15 min	11-14 R*
	Anaerobic exercise	Squat/10 rep/3 set (30 sec) Left and right Lunge/10 rep/3 set (30 sec) Crunch/10 rep/3 set (30 sec) Leg raise/10 rep/3 set (30 sec) Bridge/10 rep/3 set (30 sec) A pair of left and right Bridges/10 rep/3 set (30 sec) Back extension/10 rep/3 set (30 sec) Superman/10 rep/3 set (30 sec) Plank/10 rep/3 set (30 sec)	15 min	
	Foam roll exercise	Stand with your hair on top of the foam roll/30 rep/3 set (30 sec) Standing with one foot forward/30 rep/3 set (30 sec) Standing with one foot in the rear/30 rep/3 set (30 sec) Half squat on foam roller/5 rep/3 set (30 sec) Lying on a foam roller and laying hands on the chest, crossing and balancing/30 rep/3 set (30 sec) Lie on the foam roller/10 sec/3 set (30 sec) Lie on the foam roller and lay the bridge/30 rep/3 set (30 sec)	20 min	
Cool-down		Static stretching	5 min	Light

*R: RPE, rating of perceived exertion

3. Measurement

All assessments were carried out under the same conditions before and after the intervention at the exercise biochemistry laboratory in K University. Height, weight, and body fat percentage were measured using Inbody 720(Inbody, Korea).

A 5-mL blood sample was obtained from the antecubital vein of each participant at rest 1 hour before and again 1 hour after the program. Blood samples were drawn into chilled tubes containing Na_2-EDTA (1 mg/mL) and aprotinin (500 U/mL) and were used to determine serum

BDNF levels. Serum was separated immediately by centrifugation (2000×*g*) at 4 ºC and stored at −70 ºC until assay. Serum BDNF levels were measured using commercial quantitative sandwich enzyme-linked immunosorbent assay (ELISA) kits (Abfrontier, Seoul, Korea), which had a detection limit of 2 pg/mL and inter- and intra-assay coefficients of variation of 5.4 % and 4.1 %, respectively. The samples were collected under the same conditions before and after the intervention, and the ELISA measurements were run twice, with the mean result recorded.

Before and after the intervention, short-term memory was tested using forward number spans (Rabinowitz & Lavner, 2014). The examinee read a sequence of numbers, and then recalled the numbers in the same forward sequence. Novel sequences were provided after the exercise to prevent any familiarity with the number sequences. Participants were asked to repeat the numbers they recalled after each number list, from level 1 to a higher level (Table 4) after 5 seconds of memorization. Number span scores were counted as +2 points if correct and -1 point if wrong. All subjects were tested using the same sets of numbers before and after the intervention (Table 4). No practice trials were included.

Table 4. Forward number span task before exercise program(an example)

Level	Numbers
1	2-3-8
2	1-9-7-2
3	8-7-3-2-4
4	6-8-1-2-3-9
5	2-8-4-9-1-1-4
6	5-8-6-4-3-8-9-7
7	7-4-9-6-8-5-3-1-8
8	6-8-7-9-5-2-3-4-1-5
9	4-7-5-1-3-6-4-9-6-8-2
10	7-6-1-8-2-5-7-6-2-1-9-4

4. Statistical Analyses

Power analysis was carried out using G*Power 3.1; for a two-tailed test at the 0.05 alpha level and at 85 % power, a total sample size of 30 participants would be needed to detect a desirable effect size of 0.5. A Shapiro−Wilk test verified normal distribution for all parameters. Parametric variables that were normally distributed were expressed as mean ±SD, while changes of parameters that were not normally distributed were expressed as median with 95 % confidence interval. A paired-t test was used to compare differences in BDNF levels and short-term memory scores in each group before and after the exercise programs. Two-way analysis of variance was used to determine the effect of the groups and their interaction, while Tukey's test was used for *post hoc* multiple comparisons. Statistical analysis was performed using the Statistical Package for the Social Sciences, ver. 20.0 for Windows (SPSS, Inc., Chicago, USA). Statistical significance was accepted at $P<0.05$.

Ⅲ. Results

1. Basic characteristics of subjects

The mean age of all the subjects was 21.36±1.89 years, and their mean short-term memory score was 11.97±9.69 points. Their mean BDNF level was 27,757.65±6912.57 pg/mL. There was no difference between the four groups in terms of age (20.71±1.25 vs. 22.29±2.06 vs. 20.86±2.27 vs. 21.57±1.99, respectively; p=000, Table 5), short-term memory (8.57±11.80 vs. 13.43±9.41 vs. 9.43±9.83 vs. 16.43±7.72, Table 5), and BDNF 33951.85±11793.06 vs. 25495.07±4956.28 vs. 28874.37±5185.57 vs. 22709.29±5715.38, Table 5).

Table 5. Basic characteristics of subjects

Variables	Age (years)	Height (cm)	Weight (kg)	Body fat (%)	BDNF (pg/mL)	Short-term memory(points)
CG	20.71 ±1.25	176.16±4.73	89.49 ±19.15	27.74 ±10.10	33951.85± 11793.06	8.57±11.8
YG	22.29 ±2.06	172.33±6.01	78.07 ±8.85	25.90 ±8.84	25495.07± 4956.28	13.43±9.41
BYG	20.86 ±2.27	168.44±4.96	70.59 ±15.86	23.24 ±7.48	28874.37± 5185.57	9.43±9.83
CEG	21.57 ±1.99	175.91±5.09	69.50 ±8.67	15.37 ±3.42	22709.29± 5715.38	16.43±7.72

Values are expressed as mean ± SD, CG=Control group, YG=Yoga group, BYG=Brain yoga group, CEG=Combined exercise group

2. Changes in BDNF levels

BDNF levels were significantly increased after brain yoga (from 28874.37±5185.57 to 34074.8±7321.12, p=.003; Table 6), whereas there were no significant changes after the intervention in any other groups. The inter-group comparison showed a significant interaction between the brain yoga group and the combined exercise group (p=.036, Table 7) but no interactions between any other groups.

Table 6. Changes in BDNF levels after intervention in each group

Variables	BDNF (pg/mL)		t	*p*
	Pre	Post		
CG	33951.85±11793.06	23344.92±10961.85	1.674	.145
YG	25495.07±4956.28	25488.63±4583.01	.009	.993
BYG	28874.37±5185.57	34074.80±7321.12	-4.738**	.003
CEG	22709.29±5715.38	20281.37±10128.07	.772	.469

Values are expressed as mean ± SD, CG=Control group, YG=Yoga group, BYG=Brain yoga group, CEG=Combined exercise group, **p<.01

Table 7. Changes in BDNF levels between groups

Source	df	SS	MS	F	*p*	LSD
Group	3	7.716E8	2.572E8	3.033	.049	C > D
Time	1	5.379E7	5.379E7	1.187	.287	
G×T	3	4.553E8	1.518E8	3.348	.036*	
Error	24	1.088E9	4.532E7			
Total	31	18.736	14.001			

C: Brain yoga group, D: combined exercise group, G×T: interaction, *p<.05

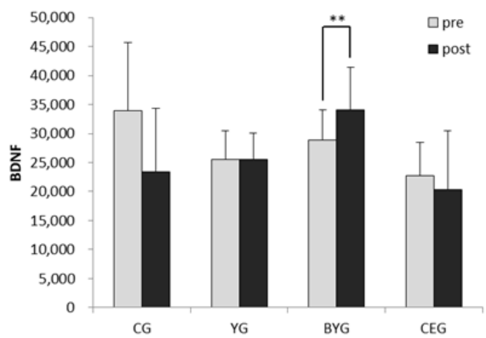

Fig 2. Changes in BDNF levels in each group before and after the intervention

3. Changes in short-term memory

Forward number span scores were significantly increased after brain yoga (from 9.43±9.83 to 23.00±7.92, p=.012) and after yoga (from 13.43±9.41 to 24.14±8.45, p=.011, Table 8), whereas there were no significant changes after any other intervention. There were no significant interactions between groups (Table 9).

Table 8. Changes in short-term memory in each group before and after the intervention

Variables	Short-term memory (points)		t	*p*
	Pre	Post		
CG	8.57±11.8	11.43±10.31	- 0.759	.476
YG	13.43±9.41	24.14±8.45	-3.622*	.011
BYG	9.43±9.83	23.00±7.92	-3.545*	.012
CEG	16.43±7.72	21.29±8.92	-1.695	.141

Values are expressed as mean±SD, CG=Control group, YG=Yoga group, BYG=Brain yoga group, CEG=Combined exercise group, *p<.01

Table 9. Changes in short-term memory between groups

Source	df	SS	MS	F	*p*	LSD
Group	3	727.500	242.500	1.783	.177	NS
Time	1	896.000	896.000	22.367	.000	
G×T	3	261.571	87.190	2.177	.117	
Error	24	3263.429	135.976			
Total	31	5,148.5	1,361.666			

G×T: interaction

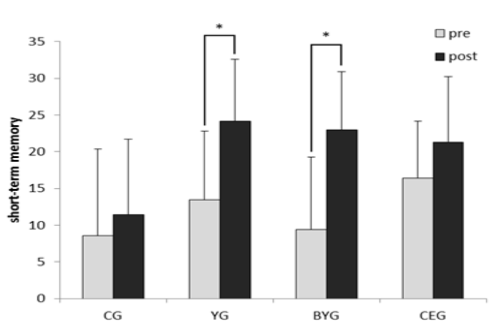

Fig 3. Changes in short-term memory within groups before and after the intervention

Ⅳ. Discussion

BDNF is a neurotrophic factor most abundantly expressed in various regions of the brain. It has critical effects on neuroplasticity, improving the survival of neurons by promoting their growth and development and by increasing their resistance to neurological damage (Mizuno et al., 2000). As BDNF is closely involved in cognitive function, it is considered an important factor for the pathogenesis of dementia (Adlard et al., 2005; Schindowski et al., 2008).

In the present study, analysis of the changes in BDNF levels after the intervention showed that BDNF was significantly increased in the single-session brain yoga group ($p<.01$). There were no statistically significant changes after the intervention in the yoga, control, or combined exercise groups. This result was in line with that of Ahn and Park(2013), who showed that BDNF was increased after yoga among the various types of exercise, albeit without a significant difference. In the study conducted by Shin and Lee (2016) that implemented 12 weeks of exercise in elderly women, BDNF levels were at their highest after yoga, followed by Korean traditional dance and walking, which contradicts our result. The changes in BDNF levels in the combined exercise group were similar to the findings of Goekint et al. (2010), who reported that BDNF levels were increased after 10 weeks of weight training, without a significant difference. The results were also similar to those of the study conducted by Kim (2016) analyzing the effects of a single-session intervention using different types of exercise (task learning type and non-task learning type) on serum BDNF concentration and cognitive function in middle-aged women. The results showed that serum BDNF concentration was not significantly increased after single-session exercise in any exercise group (task learning type and non-task learning type). In this way, our results differed from those of some previous studies. The increased levels of serum BDNF after a single exercise session return to the resting level after a certain period of time. For instance, a meta-analysis conducted by Knaepen et al. (2010) reported that increased BDNF concentrations in the brain and other regions after exercise, as well as those secreted into the blood, return to resting levels within 10~60 minutes after exercise. They also reported that the decrease in serum BDNF concentration was due to migration of BDNF to the peripheral nerves or brain areas in need where it is consumed. In conclusion, our analysis of BDNF changes after intervention showed that BDNF levels were significantly increased after a single session of brain yoga, which suggests that brain yoga increases BDNF and enhances short-term memory.

The mean scores of the forward number span task were significantly increased in the yoga and brain yoga groups after the intervention ($p<.05$ in both cases). The mean scores of the forward number span task were increased in the control and combined exercise groups by 2.86 and 4.86 after the intervention, respectively, but there was no significant difference between these values.

The forward number span task conducted in the present study showed that both brain yoga and yoga contributed to the enhancement of short-term memory. The changes in mean scores of the forward number span task performed in the present study showed partial similarity to a study conducted by Shin and Lee (2016), which executed a 12-week exercise program including Korean traditional dance, yoga, and walking in elderly women and reported that group and timing showed an interactive effect on MMSE-K scores after all three exercises, confirming that exercise had a positive effect and that the efficacies of the interventions could be ranked as follows:(1) Korean traditional dance, (2) yoga, and (3) walking. Our results also showed partial similarity to those of other previous studies regarding cognitive function. The study conducted by Kim et al. (2010), who reported an improvement in verbal memory and delayed recall after walking and yoga in elderly women had partial similarity. Further, the study conducted by Hong (2011), who implemented 24 weeks of yoga and a weight-bearing resistance training program and observed positive effects of exercise on disorientation, memory encoding, and memory retrieval, also had partial similarity. However, the program used by Hong had no significant effect on concentration or calculation. The changes in mean score in the forward number span task in the combined exercise group differed from the results of Eom (2013), who implemented 10 weeks of aerobic exercise and combined exercise in elderly women and reported that both exercises improved cognitive function. However, our study results showed partial similarity to the results of Kim (2016), who showed that a single session of moderate intensity exercise did not significantly increase serum BDNF concentration immediately after the intervention but that it did temporarily enhance some memory abilities in middle-aged women. Furthermore, Colcombe and Kramer (2003) reported that combined exercise is more effective than aerobic exercise alone.

Therefore, the implementation of brain yoga exercise programs significantly increased short-term memory and BDNF in the group, which is considered to be an efficient exercise to improve BDNF and short-term memory.

Ⅴ. Conclusion

In the present study, changes in BDNF and cognitive function were compared after providing a single session of brain yoga and other types of exercise to the patients. The BDNF level significantly changed after brain yoga and combined exercise but not after yoga or in the control group. Considering that BDNF levels significantly increased after brain yoga and that cognitive function was significantly increased after both brain yoga and general yoga, long-term studies are required that implement a long-term brain yoga program, which may lead to changes in BDNF and cognitive function.

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