



# The Effect of Yoga on Basic Cognitive Functions in Children with ADHD: A Three-Month Follow-up Study

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## Abstract

**Introduction:** Yoga is a form of relaxation and refers to integration of coordinated movements of the body with the mind. It is a mixture of specific physical movements, breathing and mental concentration and many of its movements are used in rehabilitation and physiotherapy. Evidence suggests that yoga can improve several cognitive areas, for instance working memory, attention and behavioral control and a range of executive functions including cognitive flexibility and problem-solving.

**Objectives:** We studied the effect of an 8-week yoga program along with methylphenidate, on the basic cognitive functions of children with ADHD, including attention and working memory, during three months.

**Methods:** Those patients who had not received medication for at least 6 months were randomly divided into the methylphenidate group (n=21), who received only methylphenidate from the beginning to the end of the study, or the methylphenidate + yoga group (n=19), who also participated in an 8-week yoga program. Selective and divided attention, working memory, and plasma concentrations of methylphenidate were assessed at the beginning of the study (pre-test), and one month (post-test) and three months (follow up) after the end of the yoga program in all patients.

**Results:** The results showed that yoga exercise combined with Methylphenidate led to an increase in Working Memory, selective and divided attention. Also, there was a significant positive correlation between plasma concentrations of methylphenidate and basic cognitive functions.

**Conclusion:** It seems that adjusting the dose of methylphenidate as well as the duration of the yoga program can stabilize the improvement. Future studies will shed light on this issue.

**Keywords:** Child, ADHD, Methylphenidate, Yoga, Attention

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## 1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder characterized by a combination of persistent symptoms, including inattention, hyperactivity, and impulsivity. Moreover, ADHD, especially in children, may lead to unstable relationships, low work and educational efficiency, low self-esteem, poor planning and time management skills (1). Furthermore, it has been shown that basic cognitive functions, particularly working memory, are impaired in children with ADHD (2). Symptoms usually start in early childhood and continue into adulthood. However, most of children with ADHD may not be aware of their disorder and their parents seek treatment for their children only when they encounter significant challenges in performing their daily tasks (1,3).

Although the causes and risk factors for ADHD are not exactly identified, it has been suggested that genetic and environmental factors are involved. Family and twin studies showed heritability of 74% for ADHD (4). In addition, exposure to environmental toxins, such as lead and polychlorinated biphenyls, maternal drug use, alcohol use or smoking during pregnancy, preterm labor, high blood pressure and head injury at a young

age are among the most central environmental risk factors known for ADHD (5-8). Overall, it is believed that a combination of genetic and environmental factors contributes to the development of ADHD (9,10).

Stimulants such as methylphenidate or amphetamine, which boost the levels of dopamine and norepinephrine, are typically the most commonly prescribed medications for treatment of ADHD (11). Other standard treatments involve education about the disorder, skills training, and psychotherapy including cognitive-behavioral and family therapy (3,12,13). Reports have also shown that physical activity and sport-based therapy programs, especially aerobic exercise, can significantly alleviate symptoms of ADHD (14-17). Meanwhile, yoga has been one of the therapeutic approaches that recently been in the spotlight.

Yoga is a form of relaxation and refers to integration of coordinated movements of the body with the mind. It is a mixture of specific physical movements, breathing and mental concentration and many of its movements are used in rehabilitation and physiotherapy (18). Evidence suggests that yoga can improve several cognitive areas, for instance working memory (19), attention and behavioral control (20), and a range of executive functions including cognitive flexibility (21)



and problem-solving (22,23). Yoga exercises can increase several neurotransmitters and hormones such as GABA, serotonin, and dopamine, and improve melatonin levels, help initiate sleep and increase sleep quality, and increase the amount of oxytocin hormone (23). It seems that yoga exercises are effective by balancing the activity of the parasympathetic and sympathetic systems (increasing the parasympathetic tone and decreasing the sympathetic firing) and it does this by increasing the activity of GABA and the GABAergic activity leads to inhibition of the cerebral cortex, which can help to improve cognitive performance and emotional regulation (23,24). In recent years yoga has been recognized as a potential treatment for children with ADHD (22-24). In this regard, it has also been pointed out the effect of cognitive approaches to improve planning action in reducing the symptoms of people suffering from attention deficit/hyperactivity disorder (22-24). Some studies have also suggested that yoga exercises can be an effective intervention for people with attention and inhibition problems (20,24). For example, it has been suggested that alternative therapies such as yoga exercises can be complementary to behavioral interventions for children with attention and inhibition problems (24).

Since children do not have much insight into their problems and do not have the ability to express themselves, they are not able to express their main problem and direct training and usual psychotherapies are less effective for them. Thus, there is considerable evidence supporting the effects of yoga on attention, hyperactivity, and impulsivity; But in the field of studies that have examined the effects of yoga in combination with other interventions in ADHD children, there were few studies, especially in Iran. Therefore, the necessity of the current research is to fill the existing scientific gap so that it can be useful in planning and making decisions for intervention programs and provide the possibility of treating and solving the problems of ADHD children. Hence, this study was designed to investigate the effects of a yoga-training program along with methylphenidate, as the first-line choice, on the basic cognitive functions (including attention and working memory) of children with ADHD, given that methylphenidate or amphetamine, which boost the levels of dopamine and norepinephrine, plasma concentrations of the methylphenidate were also measured and its correlation with children's cognitive performance was evaluated.

## 2. Methods

### 2.1. Participants

In G power software, based on statistical power 0.80, alpha error .05 and effect size of 0.34 for two groups with

three stages of measurement was calculated 48 people, which 52 Children with ADHD due to the length of the research and to prevent the dropout of subjects were selected and included in the study with informed Parental consent according to DSM-5 criteria and the approval of two experienced psychiatrists. In addition, all participants scored above 12 on the ADHD Self-Report Scale (ASRS). The patients were between 12 and 15 years old ( $13.7 \pm 1.5$ ), did not have any other major psychiatric or neurological disorders, had not received any medication affecting the central nervous system for at least 6 months. Participants who were not able to learn and perform the tests or unwilling to continue to the study were excluded from the study.

### 2.2. Design

The patients were randomly assigned into two groups including 1) the group for which only methylphenidate treatment (Based on physician's opinion) was prescribed (the Methylphenidate group) and 2) the group that also participated in an eight-week yoga training program in addition to receiving methylphenidate (Methylphenidate + Yoga group). All patients were assessed using the selective and divided attention test (SDA) and the n-back test before the intervention, as well as one month and three months after the end of the yoga program. Because the psychiatrists believed that the patients needed to continue methylphenidate-based treatment, all patients continued to take methylphenidate at all stages of the study. 20 milligrams of methylphenidate were administered for each patient in divided doses 2 times a day, 30 to 45 minutes before meals (25). All assessments were performed near sunset

### 2.3. Yoga training program

Following the commencement of the research and subsequent to the initial evaluation, the Methylphenidate + Yoga group participated in a thirty-minute group yoga session three times a week, led by two qualified yoga instructors. Each session included respiratory, postural, relaxation, and concentration training. The breathing exercises and poses were consistently practiced throughout the intervention. A serene and cozy room, maintained at a temperature of  $25 \pm 2^\circ\text{C}$ , was designated for the yoga sessions. The yoga program, outlined below, was adapted from works by Nagendra, Mohan, and Shriram (1988), and Saraswati (1990), and was successfully tested in a preliminary study by Jensen (2002). The program encompasses traditional yogic techniques as presented in Table 1.

Yoga Techniques	Descriptive
Respiratory Training	The purpose of utilizing specific oral and nasal passages for respiratory flow is to enhance the child's awareness of their breath and teach them to breathe naturally through both nostrils. Each session included multiple repetitions of these exercises, performed in a regulated and rhythmic manner.
Postural Training	Flexibility exercises such as stretching, weight-bearing movements, flexion in various directions, and extensions and inversions were executed while seated, standing, lying on the back, and lying on the stomach. These exercises were paired with breathing exercises in both stationary and moving positions.
Relaxation Training	Developing an increasing awareness of and unwinding various body parts while also tensing and releasing muscles
Concentration Training	Trataka is a method in which individuals concentrate on a specific word or shape, then visualize the image with eyes closed, and finally maintain the image on a blank sheet of paper.

## 2.4. Measures

### 2.4.1. N-Back

The n-back task was utilized to measure working memory and working memory capacity (27). In the computerized version of this test, a sequence of visual stimuli appears on the screen step by step and randomly. The participant has to check whether the currently presented stimulus is the same as the stimulus  $n$  steps earlier. In the present study, we used the 1-back paradigm using numbers 1 to 9. To perform the test, the participant sat in front of a 15.6-inch monitor that was 60 cm away. The numbers appeared in the center of the monitor with an interval of 1000 ms and were displayed for 1000 ms. Participants performed 20 trials in the training phase and 120 trials in the main phase. Test scores included the number of correct responses, the number of incorrect responses, the number of non-responded items, and the mean reaction time.

### 2.4.2. Selective and divided attention test (SDA)

The SDA is a continuous performance test that consists of two parts, the selective attention assessment and the divided attention assessment. In the computerized selective attention test, a picture is displayed on the screen at any time, and the participant should press the space key only in the face of a predetermined picture (a candle), and in the face of other pictures, refrain from pressing the button. In the computerized divided attention test, the participant was asked to press the "Z" button if the picture of the candle is on the left, and the "?" button if the picture of the circle is on the right. If the picture of the candle is on the left and the circle on the right at the same time, the participant should press both buttons simultaneously. Otherwise, the participant should not press any button. The pictures appeared in the center of the monitor within a  $100 \times 50$  mm matrix. Participants performed 20 training trials and 168 test trials in both tests. Using test-retest, we measured the reliability of this test in this study, where its Pearson correlation coefficient was obtained as  $r=0.83$ .

### 2.4.3. Measurement of plasma methylphenidate concentrations

After each cognitive assessment, 3 ml of blood was collected in an EDTA tube from each participant, centrifuged, and promptly stored at  $20^{\circ}\text{C}$ . Methylphenidate was extracted from plasma samples and derivatized to avoid thermal decomposition in the gas chromatograph. Then, employing a nitrogen phosphorous detector, a methylphenidate assay was performed using gas chromatography (28). Methylphenidate was quantitatively measured with high accuracy down to the  $0\pm 5$  ng/ml level. Independently repeating analyses on the same sample showed that high correlation between two analyses ( $r=0.995$ ), indicating high reliability for the test.

## 2.5. Statistical analysis

Descriptive indices, including frequency, range, mean and standard deviation were utilized to describe the data. 2-factor Analysis of Covariance (ANCOVA) with repeated measurements in the time factor was applied to compare the means of groups in attention, working memory and methylphenidate. In addition, Pearson

correlation test was applied to detect any possible relationship between methylphenidate concentrations and patients' scores in cognitive tests.

## 3. Results

Initially, 52 patients (39 boys and 13 girls) participated in the study. Then, 27 patients were randomly placed in the methylphenidate + yoga group (20 boys and 7 girls) and 25 patients were placed in the Methylphenidate group (19 boys and 6 girls). However, the number of patients in the second stage of evaluation (one month after the intervention) dropped to 22 patients (17 boys and 5 girls) for the methylphenidate + yoga group and 23 patients (17 boys and 6 girls) for the Methylphenidate group and in the third stage of evaluation (3 months after the intervention), dropped to 19 patients (15 boys and 4 girls) for the methylphenidate + yoga group and 21 patients (15 boys and 6 girls) for the Methylphenidate group. The results showed that the two groups did not differ significantly in any of the stages of the study in terms of boys/girl ratio.

As shown in Table 2, the results of 2-factor Analysis of Covariance (ANCOVA) with repeated measurements in the time factor showed that the main effect of time on selective attention was significant ( $F_{(1,37)}=25.2$ ,  $P=0.000$ ,  $\eta^2=0.40$ ) and also, the main effect of group on selective attention was not significant ( $F_{(1,37)}=3.11$ ,  $P=0.086$ ,  $\eta^2=0.07$ ) and finally, the interactive effect of time and group on selective attention was significant ( $F_{(1,37)}=30.08$ ,  $P=0.000$ ,  $\eta^2=0.44$ ). The results of simplifying the interactive effects based on the comparison of the adjusted averages of the two groups in the post-test and follow-up showed that yoga combined with Methylphenidate led to an increase in selective attention in the post-test ( $P=0.003$ ) but no significant difference was observed between the two selective attention of the two groups in the follow-up test ( $P=0.917$ ).

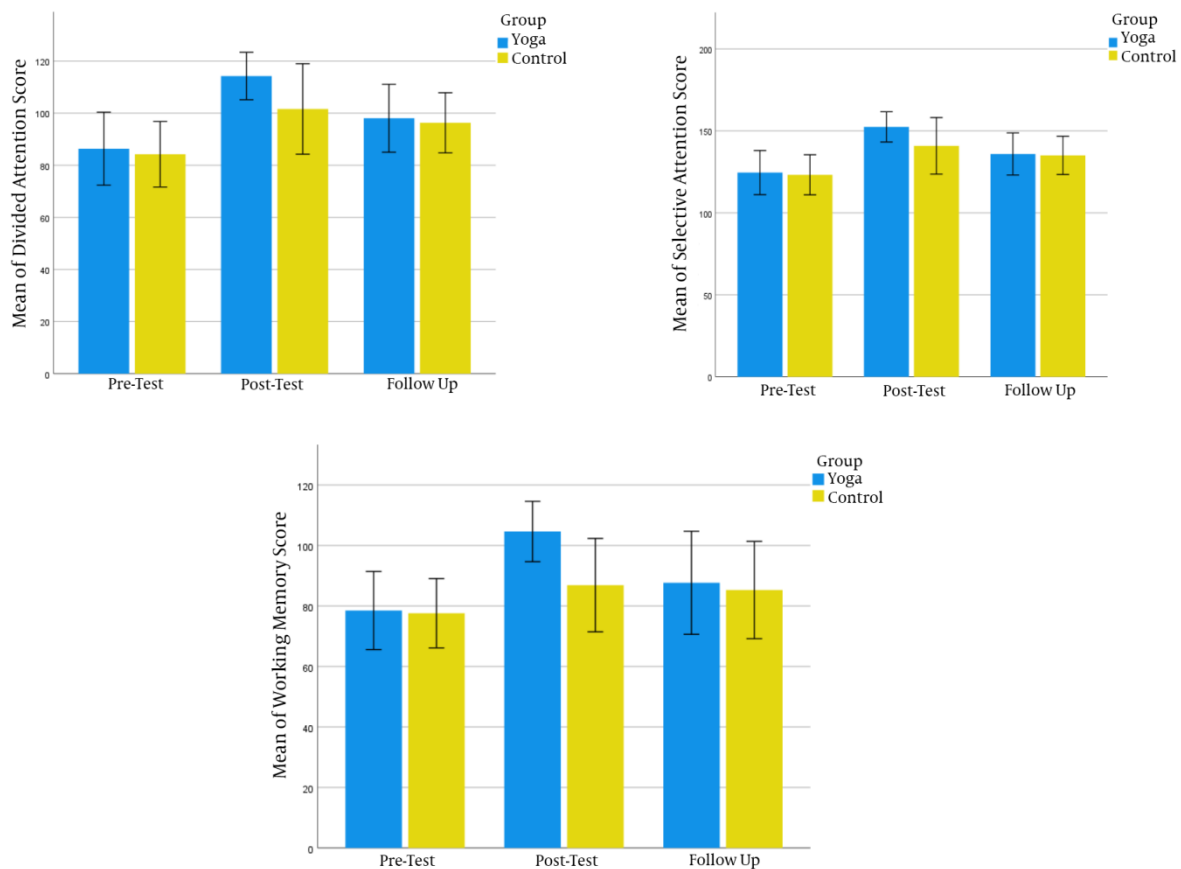
Result showed that the main effect of time on Divided Attention was significant ( $F_{(1,37)}=30.4$ ,  $P=0.000$ ,  $\eta^2=0.45$ ) and also, the main effect of group on Divided Attention was not significant ( $F_{(1,37)}=3.58$ ,  $P=0.066$ ,  $\eta^2=0.08$ ) and finally, the interactive effect of time and group on Divided Attention was significant ( $F_{(1,37)}=29.22$ ,  $P=0.000$ ,  $\eta^2=0.44$ ). The results of simplifying the interactive effects based on the comparison of the adjusted averages of the two groups in the post-test and follow-up showed that yoga combined with Methylphenidate led to an increase in Divided Attention in the post-test ( $P=0.002$ ) but no significant difference was observed between the two Divided Attention of the two groups in the follow-up test ( $P=0.964$ ).

Result showed that the main effect of time on Working Memory was not significant ( $F_{(1,37)}=0.045$ ,  $P=0.832$ ,  $\eta^2=0.00$ ) and also, the main effect of group on Working Memory was significant ( $F_{(1,37)}=12.8$ ,  $P=0.001$ ,  $\eta^2=0.25$ ) and finally, the interactive effect of time and group on Working Memory was significant ( $F_{(1,37)}=4.37$ ,  $P=0.043$ ,  $\eta^2=0.10$ ). The results of simplifying the interactive effects based on the comparison of the adjusted averages of the two groups in the post-test and follow-up showed that yoga combined with Methylphenidate led to an increase in Working Memory in the post-test ( $P=0.001$ ) but no significant difference was observed between the two Working

Memory of the two groups in the follow-up test (P=0.688).

**Table 2.** Comparison of Basic Cognitive Functions of the Two Groups in Three Stages of Assessment.

Variables	Source	SS	df	MS	F	P-Value	Partial Eta Squared
Selective Attention	Time	517.069	1	517.069	25.294	0.000	0.406
	Time*Group	615.018	1	615.018	30.086	0.000	0.448
	Error	756.365	37	20.442			
	Group	568.386	1	568.386	3.114	0.086	0.078
	Error	6754.499	37	182.554			
Divided Attention	Time	695.951	1	695.951	30.439	0.000	0.451
	Time*Group	668.285	1	668.285	29.229	0.000	0.441
	Error	845.973	37	22.864			
	Group	691.403	1	691.403	3.586	0.066	0.088
	Error	7133.658	37	192.802			
Working Memory	Time	12.083	1	12.083	0.045	0.832	0.001
	Time*Group	1162.863	1	1162.863	4.377	0.043	0.106
	Error	9830.146	37	265.680			
	Group	1878.875	1	1878.875	12.800	0.001	0.257
	Error	5430.975	37	146.783			



**Figure 1.** Mean Graph of Variables in Three Stages in Two Research Groups.

In addition, the results showed that the plasma concentration of Methylphenidate had a significant positive correlation with their overall scores selective attention, Divided Attention and Working Memory. In

general, with increasing plasma concentration of methylphenidate, individuals' performances improved (Table 3).

**Table 3.** Correlation of Plasma Concentration of Methylphenidate with Selective Attention, Divided Attention and Working Memory.

	MPH Plasma Concentration (microg/L)
Selective Attention	0.666 (<0.001)
Divided Attention	0.667 (<0.001)
Working Memory	0.482 (<0.001)

#### 4. Discussion

In this study, the effects of an eight-week yoga training program with the combination of amphetamine on basic cognitive functions of children with ADHD was investigated. It was found yoga exercise

combined with Methylphenidate led to an increase in Working Memory, selective and divided attention. On the other hand, it was found that there is a significant positive correlation between plasma concentrations of methylphenidate and basic cognitive functions. This finding is consistent with other similar studies that

have shown the positive relation of methylphenidate with the working memory and attention of individuals with ADHD. For example, it has been found that methylphenidate improves ADHD symptom and working memory and attention (25,29). Moreover, a case study reported that symptoms of ADHD in a patient with a co-occurring obsessive-compulsive disorder improved significantly after administration of a higher-than-normal dose of methylphenidate (30).

Unlike regular physical activity, yoga improves performance on attentional tasks through meditation and breathing, regular meditation practice is associated with visual attention processing and improved attentional skills (31). Therefore, yoga has the potential to improve attention deficit in ADHD children; In addition, yoga can improve hyperactivity and impulsivity in children and reduce ADHD symptoms, thereby improving cognitive performance in school children (32) and also, attention deficit and hyperactivity disorder in kindergarten children. children (33). The disorder in the inhibition of ADHD children's behavior causes confusion in the proper implementation of four executive functions of the brain, including working and long-term memory, emotional self-regulation, internalization of speech, and analysis and synthesis; Deficiency of attention and concentration is a transitional stage of problems related to lack of inhibition in working memory and self-regulation. Therefore, it seems that considering that flexibility, self-control, and inhibition of concentration are part and parcel of yoga training, yoga helps ADHD children to control the symptoms of their disorder by combining physical relaxation with mental alertness (34). Research in the field of brain imaging showed that calming the mind due to yoga practice reduces the activities of the frontal area and other areas of the cerebral cortex (35). In fact, yoga exercises increased the power of alpha and theta waves in the anterior and central frontal region, leading to the deactivation of neural circuits unrelated to maintaining attention and concentration (36). Also, increasing blood supply to the brain as a result of physical activity, increasing the efficiency of deep receptors as a result of yoga stretching movements (37). may also be among the reasons for improving Cognitive Functions. Finally, combining yoga exercises with medication led to improvement Cognitive Functions, which makes perfect sense because the combination of the two meant that children benefited both from the positive effects of medication and yoga exercises; On the one hand, drugs have a stimulating effect on the central nervous system by blocking the reabsorption of two neurotransmitters, norepinephrine and dopamine, and on the other hand, Yoga exercises improve the four executive functions of the brain, including working and long-term memory, emotional self-regulation, internalization of speech, and analysis and synthesis (34). and the combination of these two positive features of medicine and yoga has led to greater effectiveness of this treatment. This result is consistent with the results of a prior research (38), however, in that research, feedback was combined with drug therapy, and they observed that the combination of the two methods is more effective than each of the methods alone.

At the end of the first month after the intervention, the performance of the Methylphenidate + Yoga group was better than the Methylphenidate group in almost all factors which shows Effects of yoga in combination

with methylphenidate compared to methylphenidate alone improving patients' attention and working memory.

In fact, these findings point two issues. First, the effects of methylphenidate decrease significantly over time. Thus, although studies have demonstrated the positive effects of methylphenidate in improving the cognitive symptoms of children with ADHD (39-42), this effect may be much more prominent early on than later (i.e., when several months have passed). One possible cause of this phenomenon is drug tolerance. Studies have shown that the development of drug tolerance to methylphenidate is not uncommon and the severity of this tolerance depends on the dose, time of use, frequency of daily use, and age of use (43,44). Second, although yoga intensifies the effects of methylphenidate, however, this effect is also not permanent and is observed only for a short time after the intervention. Thus, although, similar to methylphenidate, the effects of yoga on improving cognitive abilities in children with ADHD has also been shown (24,45), such effect also fades over time. Thus, similar to methylphenidate, the frequency and intensity of yoga exercises may need to be carefully adjusted. On the other hand, although it has been reported that even short-term yoga interventions can cause epigenetic modifications (46), eight weeks may not be enough time for these modifications to persist. Studies on the effects of yoga on long-term epigenetic modifications can shed light on this issue.

Yoga may sequester methylphenidate and reduce its availability for elimination (47). Additionally, yoga may reduce renal blood flow and, therefore, increase the plasma concentrations of methylphenidate, which is primarily eliminated by the kidneys (47,48).

To find out how effective the yoga program was, it would be better if one group only participated in the yoga program, but since all participants were clinically ill, it was not morally right for them not to be prescribed medicine. On the other hand, if the duration of yoga programs was longer, its effect may be more persistent. Therefore, this issue can also be a line for future research. In addition, as personalized medical research has shown, the optimal dose of medication can be different for everyone. Therefore, drug resistance may not develop if each person receives the appropriate dose based on their genetic and physiological characteristics.

#### 4.1. Conclusions

In summary, this study showed that methylphenidate can improve basic cognitive functions, namely attention and working memory, and this positive effect is exacerbated by participating in a yoga program. However, the effects of methylphenidate and the boosting effects of Yoga diminished after about 3 three months, although this decrease was less obvious in the group that participated in the yoga program. It seems that adjusting the dose of methylphenidate as well as the duration of the yoga program can stabilize the improvement. Future studies will shed light on this issue.

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## Footnotes

**Authors' Contribution:** This study was carried out solely by the corresponding author.

**Conflict of Interests:** The researcher confirms that there is no conflict of interests in this study with any participant.

**Data Availability:** The data that support the findings of this study are openly available upon request from the corresponding author.

**Ethical Approval:** Approval for this study was obtained from the university. The author confirms that all steps . The requirements of this study comply with ethical guidelines. Participants were informed about the characteristics of the study and gave written informed consent.

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