

## Research Article



# The Effectiveness of Cognitive Rehabilitation on Planning and Working Memory of Executive Functions in Cochlear Implanted Children

Karim Gharashi , Reza Abdi\* 

Department of Psychology, Faculty of Education and Psychology, Azarbaijan Shahid Madani University, Tabriz, Iran



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## Highlights

- Importance of executive functions in cochlear implant children
- Cognitive rehabilitation, spatial planning and working memory in deaf children
- Cognitive rehabilitation intervention in deaf children

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## ABSTRACT

**Background and Aim:** Today, hearing loss affects various aspects of executive functions and cognitive rehabilitation is important in increasing planning capacity and working memory. The purpose of this study was to investigate the effectiveness of cognitive rehabilitation on planning and working memory of executive functions in cochlear implanted children.

**Methods:** This study was a semi-experimental clinical trial. Using the purposive sampling method, 24 hearing-impaired children with cochlear implants were randomly divided into two groups: an experimental group (12 subjects) and a control group (12 subjects). The experimental group received 12 treatment sessions based on a protocol of cognitive rehabilitation program for executive functions (spatial planning and working memory), while the control group did not participate in this program. We assessed executive function using the Cambridge Neuropsychological Test Automated Battery (CANTAB), which assessed the Stockings of Cambridge (SOC) and Attention switching task (AST).

**Results:** The results of MANCOVA were shown to be effective at the post-test stage for improving executive function in the experimental group ( $p \leq 0.001$ ). But there was no significant difference in stockings of Cambridge problem solve and stockings of Cambridge move 4 between two groups after the intervention.

**Conclusion:** There was a significant increase in spatial planning and spatial working memory of the experimental group. Cognitive rehabilitation can be a useful intervention to improve spatial planning and spatial working memory in cochlear implanted hearing-impaired children.

**Keywords:** Cognitive rehabilitation; executive function; hearing-impaired; cochlear implant

## \* Corresponding Author:

Department of Psychology, Faculty of Education and Psychology, Azarbaijan Shahid Madani University, Tabriz, Iran.  
R.Abdi@Azaruniv.ac.ir



## Introduction

The inability of or weakness in executive functions is one of the problems that has long been considered by psychologists, neuroscience and medicine. Hearing-impaired children, despite their normal intelligence, may have difficulty with this. Regarding the cause of this problem, as with other disorders, various theories have been proposed, and it is self-evident that the main cause of this disorder remains unknown. So far, various definitions of executive function have been proposed, but according to one of the most complete definitions, Executive functions of the brain refer to higher cognitive and metacognitive functions that are responsible for a set of superior abilities, inhibition, self-regulation, strategic planning, cognitive flexibility, and impulse control. They are responsible for the tasks such as organizing, decision making, working memory, motor control, sense and perception of time, anticipation, reconstruction, internal language, and problem-solving [1]. Working memory and spatial planning are the most important components of executive function in children. Working memory holds information during the execution of other cognitive functions, such as taking notes during a lecture or paraphrasing information we hear or read about. Planning is a higher-level cognitive function that includes executive functions (EF) processes involved in the formulation, evaluation, and selection of actions required to attain a goal [2].

Working memory is a comprehensive system that coordinates the functions and subsystems of long-term and short-term memory and consists of three components: a phonological loop that is responsible for storing verbal and auditory information, visual screen - a space that stores visual-spatial information and the central executor, which is used as a system to control and regulate cognitive processes [3].

There is evidence that hearing-impaired children have problems in memory and spatial planning. This problem causes impairments in executive functions from early childhood and can lead to impaired concentration, control, planning, working memory, as well as stress and anxiety [4, 5].

One of the most effective methods of intervention in increasing the ability of executive functions is cognitive rehabilitation (CR) [6]. Cognitive rehabilitation is a special treatment method that is used to strengthen and develop cognition, especially in children. This method is based on Luria theory to restore cognitive function

through learning communication and cognitive re-training exercises [7]. This program can be defined as the set of techniques and procedures that are aimed to improve intellectual efficiency, and the adjustment to labour environments, social, familiar, and of people suffering special impairments [8]. To assess the impact of cognitive rehabilitation on planning and working memory in this study Cambridge Neuropsychological Test Automated Battery (CANTAB) was used. This test was selected due to its productivity benefits, access to fully standard facilities and automatic response recording, as well as its ease of implementation in children. It was built in 1980 at Cambridge University by a computer system and provides cognitive assessment for the patient. It evaluates executive performance without dependence on language and culture with the help of five subtests. The internal consistency reliability of this test was uniformly high in children aged 4-12 years and was reported from 0.73 to 0.95, which is acceptable even for the youngest children [9].

Various studies on the effectiveness of cognitive rehabilitation have been conducted on a wide range of individuals, most of them have confirmed the significant effect of this intervention method [10]. Many of these studies show that enhancing memory and various learning strategies using cognitive rehabilitation are useful and effective in improving the performance of executive functions [11].

A study by Welsh et al. using path analysis showed that even after controlling language skills, the growth of executive function (verbal working memory, inhibitory control, and attention shift) between pre-kindergarten and kindergarten uniquely predicted reading and planning capacity acquirement in kindergarten [12].

Based on a study by Kronenberger et al. on 22 cochlear implanted children and 25 normal-hearing children in the age range of 8-12 years, it was found that cochlear implanted hearing-impaired children had lower levels of executive function compared to their peers [13]. A study by Figueras suggested that severe to profound hearing loss, especially at the age of language learning and critical development, has a negative effect on brain and system development due to hearing impairment and lack of hearing experience [14]. A study by Cleary et al. showed that the visual and expressive working memory function of cochlear implanted children was lower than the normal-hearing children [15]. According to a study on visual memory skills of children with hearing aids and cochlear implants, diagnostic memory, delayed recall, and learning memory skills were significantly correlated

with their language skills [16]. Research investigated the effectiveness of cognitive rehabilitation programs on auditory perception and verbal intelligibility of hearing-impaired children. The results indicated that the rehabilitation intervention significantly improved the auditory perception and verbal intelligibility of hearing-impaired children in the experimental group [17]. Vatandoost et al. in their study emphasized the importance of hearing comprehension training in improving dyslexia in children [18]. Shokoohi-Yekta et al. emphasized the effectiveness of cognitive education on the working memory function of such children, and they expressed the need for rehabilitation based on their auditory perception and cognitive education [19]. Also, in the study of Najarzadegan et al., it has been shown that cognitive rehabilitation strengthens the working memory of children with attention deficit hyperactivity disorder but there is no significant effect on their attention [20].

In general, various studies have been conducted on the effectiveness of cognitive rehabilitation on executive functions. However, given that the effect of cognitive rehabilitation on all aspects of executive functions in cochlear implanted children has not been studied, we do not know, what aspects have been studied; On the other hand, due to the very close relationship between the auditory system and speech and language and executive functions of the brain in children along with the importance of cognitive rehabilitation intervention, the need for this study was felt more than ever., this study was conducted to investigate the effect of cognitive rehabilitation on executive functions (spatial planning and working memory) of hearing-impaired children with cochlear implants.

## Methods

The design of the present study was semi-experimental, pre-and post-test with experimental and control groups. The statistical population of this study included all hearing-impaired children with cochlear implants aged 8 to 11 years referred to the Rehabilitation Center for Children with Hearing Disorders in Tabriz, Iran in 2020. The study sample consisted of 24 hearing-impaired children with cochlear implants. In this study, after coordination with the management of the Rehabilitation Center, out of 200 cochlear implanted children, 24 were selected using a purposive sampling method. The parents of subjects declared their consent before conducting the research. Intelligence test using Wechsler test for children [21] and pretests related to executive skills using CANTAB software were administrated; the subjects were then randomly assigned into two groups of experi-

mental (n=12) and control (n=12). Inclusion criteria: a) profound hearing loss in both ears (90 dB higher in the better ear); b) age range 8-11 years; c) age of surgery to receive a cochlear implant to be under 4 years old; d) absence of disease or other disabilities; e) normal intelligence in the range of 110-190; f) no medication; g) parents with hearing loss; h) deafness before language comprehension.

Exclusion criteria: a) cancellation of continued participation in the project; b) absence in more than one session of cognitive rehabilitation programs.

After selecting the samples, first, the children's families in the experiment group were given complete and clear explanations about the goals and methods of the research, and it was emphasized that the subjects' information would remain anonymous and confidential. Due to ethical considerations, after the completion of the research and the results, the cognitive rehabilitation treatment plan was included in the control group. The treatment session protocol was performed individually by an experienced psychologist. This protocol was performed on the experimental group for 12 consecutive sessions of 90 minutes for 4 consecutive weeks in three sessions per week Table 1. The cognitive rehabilitation program used was based on the hierarchical model of Sholberg and Mateer [22] and was performed using Goldstein and Levin [23] methods according to the following explanations. At the end of the sessions, a post-test was performed for both groups.

For the CANTAB test, participants sat in front of a computer screen and were instructed to complete the tests by touching the screen or pressing the laptop mouse. Before each CANTAB test, participants were given a practice session to learn how to perform the test.

To evaluate the executive function variables of cochlear implanted children, tests were used that required minimal non-verbal and verbal answers, this enabled children to learn and perform these tests easily. As the structure of executive function includes a wide range of skills, in this study, due to the special circumstances of cochlear implanted children, tests that were mostly related to language skills and abilities of these children were used. The tests used in this study to evaluate the performance of cochlear implanted children include:

### Stockings of Cambridge

Stockings of Cambridge (SOC) is a test of spatial planning and spatial working memory, which gives a mea-

sure of frontal lobe function. The subject is shown two displays containing three coloured balls. The displays are presented in such a way that they can easily be perceived as stacks of coloured balls held in stockings or socks suspended from a beam. This arrangement makes the 3-D concepts involved apparent to the subject and fits with the verbal instructions. The subject must use the balls in the lower display to copy the pattern shown in the upper display. The balls may be moved one at a time by touching the required ball, then touching the position to which it should be moved. The time taken to complete the pattern and the number of moves required are taken as measures of the subject's planning ability. At first, it is only necessary to move one ball, the number being increased in steps to four moves. At this point, a procedure controlling for motor performance is inserted. The upper display moves one ball at a time, repeating the moves made by the subject in the corresponding previous planning phase. The subject must follow the upper display by moving the balls in the lower display. Again, the number of moves increases from 2 to 4. The difference in time taken to complete (but more especially, to initiate) each problem is taken as an index of the additional time taken to plan the solution of the copying task, as distinct from the following task. Should the subject make more than double the number of moves necessary for the simplest solution, the problem is terminated. Should the computer terminate three problems in a row, the entire test ends. There is no time limit. The first problem is for demonstration by the tester. After that, subjects must make all the moves themselves [24].

### One Touch Stockings of Cambridge

One Touch Stockings of Cambridge is a spatial planning test variant based upon the CANTAB Stockings of Cambridge test. This test measures the function of the frontal lobe. Two displays containing three colored balls are shown to the participant. The screens are presented in such a way that they can be easily understood as stacks of colored balls placed in stockings or socks hanging from a beam. This arrangement reveals the three-dimensional concepts involved to the participant and complies with the verbal instructions. There is a row of numbered boxes along the bottom of the screen. The test administrator first demonstrates to the participant how to move the balls in the lower display to copy the pattern in the upper display and completes one demonstration problem, where the solution requires one move. The participant must then complete three further problems, one each requiring two moves, three moves and four moves. Next, the participant is shown further problems and must work out in their head how many moves the

solutions require and then select the appropriate box at the bottom of the screen to indicate their response. Outcome measures include the number of problems solved on the first choice, mean number of choices to reach the correct answer, mean latency (speed of response) to the first choice and mean latency to the correct one. Each of these measures may be calculated for all problems or problems with a specified number of moves (one move to five or six moves) [24].

### Data analysis

Statistical analysis was performed using SPSS (version 23.0). First, Shapiro-Wilk test was used to analyze the normality of the distribution of variables; independent t-test was used to analyze the homogeneity of the control group; Box test was used to check the homogeneity of the covariance matrix; Leven test was also used to check the variance equality of variance. Dependencies were used in the groups and all the necessary preconditions for performing the analysis of covariance were appropriate. In the next step, we examined the mean scores of executive functions of cochlear implanted children after cognitive rehabilitation intervention and by controlling the underlying variables including IQ, age of receiving cochlear implant prosthesis and age of onset of rehabilitation intervention using multivariate analysis of variance (MANCOVA).

### Results

Descriptive findings showed 24 hearing-impaired children with cochlear implants in the age group of 8-11 years 13 girls (54%) and 11 boys (46%) with mean age and standard deviation of the experimental group (mean age=9.62 years, SD=0.98) and the control group (mean age=9.23, SD=0.89). Hearing loss in both ears of all participants was over 90 dB and their language of communication was bilingual in Turkish and Persian. The mean IQ was as follows: the experimental group (mean IQ =102.08, SD=2.84) and the control group (mean IQ=102.33, SD=2.71). The mean age of receiving cochlear implant prosthesis in experimental group (mean age=2.93 years, SD=0.70) and control group (mean age=2.97 years, SD=0.84) (Table 1).

Table 2 shows the mean and standard deviation of pre-test and post-test scores of SOC and one-touch stockings (OTS) tests in experimental and control groups. Accordingly, the mean of all scores of executive function components in SOC, OTS tests of the experimental group except stockings of Cambridge problem solved (SOC. PS) and stockings of Cambridge move 4 (SOC.M 4) af-

**Table 1.** The content of cognitive rehabilitation program sessions

Session	Context of sessions
1	Communicating and acquainting children with cognitive methods and exercises, providing explanations of cognitive rehabilitation.
2	Reminiscing exercise of the previous session (getting feedback from the previous session), attention exercises including listening to the rhythm of hearing aids (numbers, words, sentences).
3	Providing explanations of cognitive rehabilitation, attention and concentration exercises including attention retention, increase the skills of attention elements.
4	Teaching concentration and attention tasks including visual, visual, numerical, shapes, letters and memory exercises (selective attention and attention processing exercises).
5	Attention and memory change exercises and comprehension exercises.
6	Teaching homework in descending and ascending order to maintain attention and read an article to understand the content and simultaneously search for pre-determined letters, words and meanings.
7	Auditory, visual memory exercises according to the content of numbers and letters, words, shapes, sentences and logical memory.
8	Verbal, visual memory tasks, making couple associations and verbal organization.
9	Executive function exercises include considering a simple task and expressing mental plans with its signs. Mentoring exercises, memory strengthening training (illustration) are other exercises in this session.
10	Executive function exercises including classification, differentiation and problem solving and self-instruction in problem solving.
11	Motor memory exercises and motor instructions (one-step to multi-step).
12	Preparing the subject for the exit phase of the cognitive rehabilitation training program and reviewing the cognitive exercises of attention, memory and executive function.

ter cognitive rehabilitation intervention showed significant changes ( $p < 0.001$ ) while the mean of these scores in the control group did not show significant changes. Also, the adjusted means indicate that the number of one-touch stockings of Cambridge problems solved (OTS.PS) component in the experimental group is significantly higher than the control group. Also, the number of one-touch stockings of Cambridge mean choices (OTS.MEAN.C) and one-touch stockings of Cambridge mean latency (OTS.MEAN.L) components in the experimental group is significantly less than The control group. Therefore, it is concluded that cognitive rehabilitation has a significant positive effect on increasing OTS.PS and decreasing OTS.MEAN.C and OTS.MEAN.L.

Multivariate analysis of covariance (MANCOVA) was used to determine the significance of the differences between the studied variables (Table 3). Accordingly, the probability of accepting the null hypothesis for comparing the experimental and control groups in the post-test OTS.PS, OTS.MEAN.C and OTS. MEAN.L is less than 0.01. Therefore, there is a significant difference between the groups in the scores of OTS.PS, OTS.MEAN.C and OTS. MEAN.L after removing the pretest effect in the post-test stage, which is respectively for OTS.PS ( $F_{(1,19)} = 16.13, p \leq 0.001$ ), OTS.MEAN.C ( $F_{(1,19)} = 29.45, p \leq 0.001$ ) and OTS. MEAN.L ( $F_{(1,19)} = 27.47, p \leq 0.001$ ). Also, the results of analysis of covariance for the components of the SOC test showed that the scores of SOC.M 4, SOC.PC and SOC.M 5 were SOC.PC ( $F_{(1,19)} = 3.43,$

**Table 2.** Demographic characteristics and descriptive statistics for experimental and control participants

Variable	Category	Experimental group (n=12)	Control group (n=12)	p
Sex	Female	5 (42%)	6 (50%)	0.747
	Male	7 (58%)	6 (50%)	
Age	Mean (SD)	9.42 (0.13)	9.71 (0.22)	0.319
Hearing threshold levels	dB	<90	<90	
Age of cochlear implant	Mean (SD)	2.93 (0.70)	2.97 (0.84)	0.914
IQ	Mean (SD)	102.08 (2.84)	102.33 (2.71)	0.827
Age of intervention	Mean (SD)	13.33 (7.57)	19.08 (8.37)	0.092

**Table 3.** Mean, standard deviation and Eta of one touch stockings of Cambridge and stockings of Cambridge in the pretest and post-test stages in both the experimental and control groups

Variables	Group	Mean (SD)		p	Eta
		Pretest	Post-test		
OTS	Experimental	12.75 (1.96)	16.50 (1.31)	0.001	0.459
	Control	14.58 (2.31)	14.50 (2.11)		
OTS.MEAN.C	Experimental	2.02 (0.22)	1.44 (0.30)	0.001	0.608
	Control	2.06 (0.34)	2.04 (0.36)		
OTS.MEAN.L	Experimental	21973.58 (1833.99)	19283.83 (940.12)	0.001	0.591
	Control	21632.08 (1905.92)	21234.08 (1258.08)		
SOC.PS	Experimental	8.50 (1.00)	9.00 (0.95)	0.079	0.153
	Control	8.83 (0.94)	8.83 (1.03)		
SOC.M 4	Experimental	6.15 (0.58)	5.70 (0.54)	0.579	0.016
	Control	5.79 (0.56)	5.85 (0.39)		
SOC.M 5	Experimental	6.32 (0.51)	5.32 (0.32)	0.001	0.818
	Control	6.67 (0.49)	6.67 (0.37)		

OTS; one touch stockings, OTS.MEAN.C; one-touch stockings mean choices, OTS.MEAN.L; one-touch stockings mean latency, SOC.PS; stockings of Cambridge problem solved, SOC.M 4; stockings of Cambridge move 4, SOC.M 5; stockings of Cambridge move 5

$p \leq 0.079$ ), SOC.M 4 ( $F_{(1,19)} = 0.31$ ,  $p \leq 0.579$ ) and SOC.M 5 ( $F_{(1,19)} = 85.41$ ,  $p \leq 0.001$ ) which only in SOC.M 5 component the effect of the group is significant at 99% probability level ( $p \leq 0.01$ ). That is, after adjusting the pretest scores, the amount of SOC.M 5 component in the post-test in the experimental group and the control group has a significant difference. On the other hand, the adjusted means indicate that the amount of SOC.M 5 in the experimental group was significantly lower than the control group. In SOC.PS and SOC.M 4 components, the effect of the group at 95% probability level was not significant ( $p \leq 0.05$ ). Therefore, it is concluded that cognitive rehabilitation has a significant positive effect on reducing the rate of SOC.M 5. But it has no significant effect on SOC.PS and SOC.M 4 components.

## Discussion

This study aimed to investigate the effect of cognitive rehabilitation on executive functions (spatial planning and spatial working memory) of cochlear implanted hearing-impaired children. Based on the results, spatial planning and spatial working memory post-test scores in the experimental group were significantly increased,

while there was no significant difference between pretest and post-test in the level of spatial planning and spatial working memory of the control group. The effectiveness of cognitive rehabilitation on spatial planning and spatial working memory in experimental and control groups before and after the intervention was investigated, both hypotheses were confirmed.

The findings of this study are consistent with the results of research by Thorell et al. entitled The effect of education on executive functions in preschool children [6], Surowiecki et al. on the visual memory, executive function (attention shifting, spatial working memory), and language in a group of 6- to 14-year-olds with hearing aids or cochlear implants [16]; Shokoohi-Yekta et al. on the effect of cognitive education on the working memory performance of dyslexic children [19]; Najaradegan, et al. entitled Determining the effect of cognitive rehabilitation on the executive functions of children with attention-deficit/hyperactivity disorder, which has shown that cognitive rehabilitation strengthens the working memory of these children but there is no significant effect on their attention [20]. Shao et al. entitled the study of the effect of cognitive rehabilitation on memory, speech processing and executive functions [11]; and finally, Ashori

et al. entitled the effectiveness of cognitive rehabilitation program on auditory perception and verbal intelligibility of hearing-impaired children [17].

Cognitive rehabilitation is a special treatment method to increase the capacity and capabilities of cognitive function, according to which recovery and improvement of cognitive function can be achieved through new communications learned through cognitive retraining exercises [25]. Various programs have been developed to promote cognitive abilities, the most promising is cognitive rehabilitation for children. In this method of cognitive rehabilitation, training is in the form of games due to the principles of neuroscience and information technology [26]. It is used to improve cognitive programs in the field of executive functions such as perception, attention, alertness, memory [27].

Since the left posterior regions of the brain are responsible for language functions, the abnormalities in these areas, due to lack of growth of areas related to the auditory system and changes in the middle and frontal areas of the motor and pre-motor cortex [28], cause language abnormalities, attention problems, poor executive function, and auditory processing deficits in such children [5]. Also, working memory latency, especially verbal working memory may lead to some challenges in most children with cochlear implantation (due to the vital importance of working memory for language learning) [16]. To reduce the negative effects of these problems, cognitive rehabilitation by emphasizing the components of working memory and spatial planning can strengthen them, which in turn can improve and increase the level of performance of hearing-impaired children. In other words, training appropriate to the components of working memory verbally and visual-spatially using shapes and games activate a part of the brain concerning memory [25]. The results of the cognitive rehabilitation intervention obtained from this study indicate that targeting and applying the appropriate cognitive practice to improve executive function in cochlear implant children is of particular importance. And this intervention has a significant effect on the components of planning and working memory of the experimental group compared to the control group.

To explain the difference between the executive function scores of the pretest and post-test groups and the significant effect of cognitive rehabilitation on the executive function components of cochlear implanted children, it can be argued that cognitive rehabilitation emphasizes the formability and self-healing of the brain through arousal. This intervention is considered an educational and therapeutic method for cognitive problems,

and it can address impaired functions through improving training strategies, repetition, and practice. The difference between the mean scores of the pretest and post-test groups can indicate that cognitive rehabilitation with the development of spatial planning and spatial working memory of such children, also brings a better performance of executive functions.

Since executive functions are excellent cognitive and metacognitive abilities, cognitive rehabilitation creates a process that leads to the improvement of these abilities in the forehead. It seems that improving the function of the forehead increases the capacity of executive functions in cochlear implanted children. Executive functions (change, update, and response inhibition) are weak in cochlear implanted children, and training and strengthening executive functions through cognitive rehabilitation increase the capacity of neurological processes such as executive function and develop skills [1]. Thus, cognitive rehabilitation intervention in cochlear implanted hearing-impaired children can increase the ability of components related to the performance of executive functions by increasing spatial planning and working memory and speech abilities. According to the results of this study, it can be inferred that the independent variable of this study, namely cognitive rehabilitation intervention, has been able to improve the capacity of spatial planning and working memory in cochlear implanted children aged 8-11 years.

This study, like other studies, has faced limitations so in this study, cognitive rehabilitation intervention was performed only on children aged 8-11 years with cochlear implantation and it cannot be considered as an intervention on other hearing-impaired children. Therefore, generalizing the results to other people may be difficult. It is suggested that other studies should be conducted on the effect of cognitive rehabilitation interventions on other groups of hearing-impaired children, including children with hearing aids, to determine the generalizability of the results accurately. Therefore, identifying specific disorders in hearing-impaired children using standardized tests and cognitive rehabilitation measures tailored to individual needs will help compensate for cognitive impairments. Other limitations of this study include the small sample size. Therefore, it is suggested that the effect of rehabilitation intervention on other components of brain functions should be done with larger samples.

## Conclusion

Cognitive rehabilitation is a special treatment method that is used to strengthen and develop cognition, especially in children. This method aims to restore cognitive

function through learning communication and cognitive retraining exercises can be a useful intervention to improve spatial planning and spatial working memory in hearing-impaired cochlear implant children.

## Ethical Considerations

### Compliance with ethical guidelines

This study has a certificate of research ethics under the number IR.IAU.TABRIZ.REC.1399.0151 from the Research Ethics Committee of the Islamic Azad University of Iran.

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### Authors' contributions

KG: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; RA: Study design, interpretation of the results, and drafting the manuscript.

### Conflict of interest

The authors declare that they have no conflict of interest.

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