



Original Article

Increased prefrontal cortex activity on near-infrared spectroscopy after interpersonal counseling in individuals with attention deficit hyperactivity disorder

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Abstract. [Purpose] The number of patients with attention deficit hyperactivity disorder has been increasing. These patients show low activity in the prefrontal cortex, which can be improved by pharmacotherapy and neuro-feedback training. This exploratory study aimed to examine whether the hemodynamic response in the prefrontal cortex during an inhibition response in patients with attention deficit hyperactivity disorder tendencies increased after interpersonal counseling. [Participants and Methods] Participants (n=5) received three interpersonal counseling sessions. Interpersonal counseling focuses on the patient's current problems and devises specific coping strategies, and it can be performed by healthcare personnel such as physiotherapists. Prefrontal cortex activity during a suppression reaction task was measured by using near-infrared spectroscopy at baseline and post-interpersonal counseling. The outcome was a difference in the oxyhemoglobin level from baseline to post-interpersonal counseling. [Results] The oxyhemoglobin level in the prefrontal cortex significantly increased post-interpersonal counseling. [Conclusion] These results suggested that interpersonal counseling could improve the hemodynamic response in the prefrontal cortex under inhibition in individuals with attention deficit hyperactivity disorder tendencies, suggesting that interpersonal counseling may be effective for treating attention deficit hyperactivity disorder symptoms.

Key words: Attention deficit hyperactivity disorder, Near-infrared spectroscopy, Interpersonal counseling

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INTRODUCTION

Recently, the number of patients with attention deficit hyperactivity disorder (ADHD) has been increasing¹⁾. Regardless of whether they have been diagnosed, individuals with ADHD tendencies are prone to psychological problems, such as depression. It is often combined with interpersonal difficulties caused by ADHD-specific symptoms such as inattention, hyperactivity, and impulsivity²⁾. Patients with ADHD tendencies may have difficulty in physiotherapy because of their symptoms. Hence, counseling is needed to motivate such patients for physiotherapy^{3, 4)}. It has been reported that psychotherapy such as psycho-educational approaches, social skills training, and behavioral therapies are preferable for individuals with ADHD tendencies⁵⁾ because they have a higher need for realistic problem-solving⁶⁾. However, psychotherapy requires time and access to psychotherapists and it is not useful in the clinical setting of physical therapy.

Interpersonal counseling (IPC) is structured as a simplified version of interpersonal psychotherapy, and originally, IPC

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was targeted towards individuals with a depressive state that does not meet any diagnostic criteria⁷). IPC is conducted over a limited number of sessions, with the smallest number of sessions being three. These sessions, while providing supportive responses, focus on the client's current problems and advocate specific coping strategies⁷). Moreover, IPC is intended to be performed by healthcare personnel, such as primary care doctors, nurses, physiotherapists, occupational therapists among others^{7, 8}). Therefore, IPC, which can be performed in a short time and by non-psychological experts, is suitable and feasible for counseling to improve the motivation for physical therapy in individuals with ADHD tendencies.

Near-infrared spectroscopy (NIRS) has been applied in brain activity research⁹⁻¹⁵). NIRS is a method of indirectly observing brain activity using near-infrared light to measure changes in hemoglobin concentrations inside the brain¹⁶). NIRS is a simple, non-invasive method of measuring brain activity, and focuses on mental states using simple biological indicators. Studies that have used NIRS on individuals with ADHD have reported that when participants perform the suppression reaction task, their prefrontal cortex (PFC) shows lower activity than that in healthy controls⁹⁻¹²). There are also reports that pharmacotherapy and neurofeedback training could increase the PFC activity¹³⁻¹⁵). Therefore, if IPC is effective in ADHD, the activity in the PFC during suppression reaction task can be improved.

To the best of our knowledge, this is the first study to examine the change in PFC activity by IPC in individuals with ADHD tendencies. The purpose of this exploratory study was to examine whether the hemodynamic response in the PFC during a suppression reaction task increased after IPC in individuals with ADHD tendencies.

PARTICIPANTS AND METHODS

Five participants (1 male, 4 females) were recruited from Kwansai Gakuin university. Mean \pm standard deviation of age was 19.40 ± 1.14 years. All participants scored at or above the cutoff for Part A of the Adult ADHD Self-Report Scale (ASRS)¹⁷) and had some problems (interpersonal relationship: 2, everyday events: 2, health problems: 1). All participants provided written informed consent after an explanation of the study. This study complied with the Declaration of Helsinki and was approved by the Kwansai Gakuin University Regulations for Research with Human Participants (Approval No. 2016-15).

IPC was, in principle, performed once a week, for 50 minutes each, for a total of three sessions⁷). The first session included discussion on the participant's problems and the problem areas were explored. In the second session, specific strategies for the participant's problems were discussed and role-played. In the third session, the strategies were reviewed to make participants understand that the strategy could be continued to be used in the future.

PFC activity during the suppression reaction task was measured using NIRS at pre-IPC (baseline) and post-IPC. Wearable Optical Topography 100 (WOT-100, NeU Inc., Tokyo, Japan) was used for NIRS measurement¹⁸). The WOT-100 is equipped with PFC-dedicated optical topography made from 10 channels (Ch.4–Ch.13)¹⁸). The sampling rate was 200 ms. Changes in oxy-Hb, deoxy-Hb, and total-Hb were measured using two wavelengths: 705 nm and 830 nm¹⁸). WOT-100 measurement controller control software Version 1.04 (HITACHI, Tokyo, Japan) was used for measurements. The BBrainSuite Analyzer (B. R. Systems, Inc., Kanagawa, Japan) was used for data analysis. A moving average (5 seconds) was applied to the measured oxy-Hb signal, and high-frequency noise, such as heartbeat and minute body movements, was eliminated. The difference between the oxy-Hb average value during the pre-task and the real task (Δ oxy-Hb) was used as the hemodynamic response indicator¹⁹). The sum of Δ oxy-Hb at each of the 10 channels was used as the Δ oxy-Hb of the PFC (PFC Δ oxy-Hb). STOP-IT software was used to perform the suppression reaction task²⁰). After 80 seconds of rest, the practice started. After the practice ended, there were 10 seconds of pre-task rest, automatically followed by the 150-second real task. When the real task began, a mark point was manually added. After the real task, 80 seconds of rest time was set, and measurement was completed.

The study outcome was a change in PFC Δ oxy-Hb values from baseline to post-IPC. We confirmed whether each scale score followed a normal distribution using the Shapiro–Wilk test. Paired t-tests were used to examine the differences in PFC Δ oxy-Hb between baseline and post-intervention. The significance level was set at 5%. SPSS for Windows (version 25.0) was used for statistical processing.

RESULTS

All five participants underwent IPC and PFC activity measurement. However, oxy-Hb signal data at baseline and post-intervention in Ch.4, Ch.7, Ch.10, Ch.11, and Ch.13 in one participant (male, 20 years old) and those in Ch.4 in another participant (female, 19 years old) were eliminated because of high-frequency noise. Therefore, the PFC Δ oxy-Hb data at baseline and post-intervention were obtained from the remaining 44 oxy-Hb signal data, even though it had been planned to obtain PFC Δ oxy-Hb data from 50 (10 channels from 5 participants) oxy-Hb signal data.

Table 1 shows the PFC Δ oxy-Hb values at baseline and post-intervention. PFC Δ oxy-Hb was significantly higher post-IPC than at baseline ($t=3.834$, $df=43$, $p<0.001$).

DISCUSSION

The study results indicated that after IPC the hemodynamic response increased in the PFC during the suppression reaction

Table 1. PFC Δ oxy-Hb values at baseline and post-IPC

	Baseline	Post-IPC	p ²⁾
PFC Δ oxy-Hb ¹⁾ [mM-mm] (Mean \pm SD)	0.036 \pm 0.216	0.195 \pm 0.271	<0.001

PFC: prefrontal cortex; IPC: interpersonal counseling; SD: standard deviation.

¹⁾ Each PFC Δ oxy-Hb datum at baseline and post-IPC was obtained from 44 oxy-Hb signal data (3 oxy-Hb signal data at Ch.4, 5 oxy-Hb signal data at Ch.5, 5 oxy-Hb signal data at Ch.6, 4 oxy-Hb signal data at Ch.7, 5 oxy-Hb signal data at Ch.8, 5 oxy-Hb signal data at Ch.9, 4 oxy-Hb signal data at Ch.10, 4 oxy-Hb signal data at Ch11, 5 oxy-Hb signal data at Ch12, and 4 oxy-Hb signal data at Ch13).

²⁾ t-test.

task. A prior study reported the relationship between increased brain activity and improved ADHD tendencies¹⁴⁾. Thus, IPC might cause some changes that lead to improvements in response inhibition, which suggests improvements in ADHD symptoms. Therefore, IPC, which can be provided by non-clinical psychology experts, might be available to improve motivation among individuals with ADHD tendencies to seek physical therapy. Moreover, since the effect of IPC can be shown by NIRS, an objective index, it is useful for non-clinical psychology experts to provide feedback to the patient, as the possibility was shown in another study²¹⁾.

There are some limitations to the present study. First, the sample size was small and limited to university students. Second, we did not evaluate the ADHD symptoms after IPC. NIRS evaluation should be performed while evaluating more detailed ADHD symptoms. Third, we did not compare the activity of PFC between the control and IPC groups. The possibility that the increase in PFC activity is not limited to the effects of IPC has not been ruled out. Therefore, a randomized controlled trial should be performed to confirm the effect of IPC. Fourth, we measured the entire change in hemodynamics in the PFC using a 10 channel NIRS, which is convenient to determine the effect of IPC in clinical setting; however, each part of the PFC should be considered for better physiological understanding.

In conclusion, this study, notwithstanding the small sample size, suggested the possibility that IPC could cause PFC activation and might be effective for ADHD treatment. Considering that it is highly feasible to implement IPC in clinical practice, it is important to prove the effects of IPC using a scientific method such as NIRS.

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Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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