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Research article

Acute aerobic exercise influences the inhibitory process in the go/no-go task in humans

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HIGHLIGHTS

- We investigated the effects of moderate exercise on the no-go-N140.
- Moderate exercise increased the amplitude of no-go-N140 component.
- The amplitudes of go-N140 were not affected by moderate exercise.
- Acute aerobic exercise can affect response inhibition process.

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ABSTRACT

This study evaluated the influence of acute aerobic exercise on the human inhibitory system. For studies on the neural mechanisms of somato-motor inhibitory processing in humans, the go/no-go task is a useful paradigm for recording event-related potentials. Ten subjects performed somatosensory go/no-go tasks in a control condition and exercise condition. In the control condition, the subjects performed the go/no-go task before and after 20 min of rest. In the exercise condition, the subjects performed the go/no-go task before and after 15 min of treadmill running with the exercise intensity set individually for each subject at 50% of peak oxygen intake. We successfully recorded a clear-cut N140 component under all conditions, and found that the peak amplitude of no-go-N140 at Fz and Cz was significantly enhanced during moderate exercise. In contrast, there were no significant changes in Fz and Cz in the control condition. These results suggest that moderate exercise can affect the amplitude of no-go-N140, which could be interpreted as an index of the human inhibition process in the central nervous system. The human inhibitory system is an important cognitive process, and this system may underlie the hypothetical ability of physical exercise to maintain and improve cognitive performance throughout the lifespan.

1. Introduction

It is very important for humans to adequately maintain cognitive performance throughout their lifespan. Psychological studies have recently shown the effect of physical exercise on human cognitive processes and brain functions using various cognitive tasks, such as a simple reaction time task [1], a choice reaction time task [2], or the Stroop task [3]. However, there is currently no consensus on whether physical exercise is effective at improving human cognitive processes.

To assess the neural processes in the central nervous system (CNS), measurement of event-related potentials (ERPs) using time-locked averaging electroencephalography (EEG) is a useful method due to its high time resolution. There are many studies that have evaluated the influence of physical exercise on human cognitive processes with a focus on the P300 component. P300 is an endogenous component that is believed to reflect the brain activity required to maintain working memory when the mental model of a stimulus environment is updated [3]. Kamijo et al. (2004) found that the P300 component's amplitude decreases aftera high-intensity pedaling exercise, increases after a medium-intensity pedaling exercise, and does not change after a low-intensity ped-

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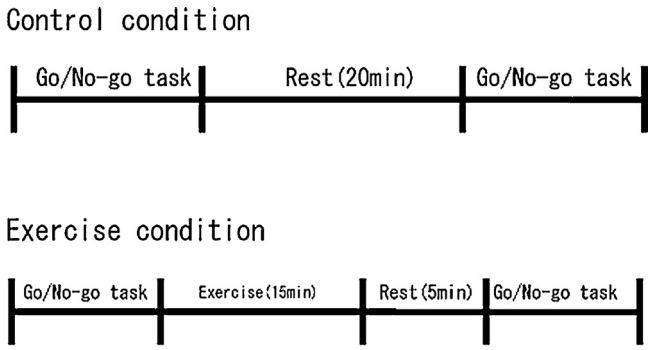

Fig. 1. Schematic illustrations of the time course in the control and exercise conditions.

aling exercise [4]. The authors concluded that the amount of attentional resources devoted to a given task decreases after high-intensity exercise and increases after medium-intensity exercise. However, to the best of our knowledge, there have been no ERP studies focusing on the no-go-N140 component elicited by the go/no-go task. The go/no-go task is a useful technique to study the neural mechanisms involved in response execution and inhibition. In no-go trials, the no-go-N140 component is elicited near the frontocentral electrodes and is interpreted as an indicator of the response inhibitory process in the frontal lobe [5,6]. This component is mainly evoked by visual and auditory stimulation, but our group previously reported that no-go-related brain potentials are also found in the somatosensory system [7,8]. There are also strong relationships between the motor and somatosensory area. Therefore, our exercise task should have strongly affected the motor and/or somatosensory area, and we believe that a change in the N140 amplitude could be elicited by somatosensory stimuli. Studies of the relationship between physical exercise and the no-go-N140 component should reveal the effects of exercise on the human inhibitory process.

Yanagisawa et al. (2010) reported that it is important to control the exercise intensity for each subject during behavioral and ERP studies, since cognitive performance and the brain response are affected by exercise intensity [9]. The authors assessed peak oxygen intake in each subject and defined moderate exercise intensity as 50% of a subject's peak oxygen intake. Therefore, we adopted this method as a means of normalizing exercise intensity for each subject.

Thus, in the present study, we assessed the effects of the inhibitory process with moderate physical exercise on ERPs, using somatosensory go/no-go tasks. We focused on the amplitude of the no-go-N140 component as an indicator of the inhibitory process.

2. Methods

2.1. Subjects

Ten healthy volunteers (all males; mean age, 19.8 years) participated in this study. The subjects were all right-handed and did not have any neurological disorders. The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all subjects.

2.2. Procedure

This experiment was comprised of a control condition and an exercise condition (Fig. 1). In the control condition, the subjects performed a go/no-go task before and after 20 min of rest. In the exercise condition, the subjects performed a go/no-go task before and after 15 min of treadmill running followed 5 min of rest. For each subject, the exercise intensity was set at 50% of their peak oxygen intake. The experiment involving each condition was conducted on a different day. The order of the conditions was randomized among the subjects.

2.3. Go/No-go task

The subjects performed a somatosensory go/no-go task. The go stimulus was delivered to the second digit of the right hand, and the no-go stimulus to the fifth digit of the right hand. The electrical stimulus was a current of constant square-wave pulse 0.2 ms in duration, and the stimulus intensity was 2.5 times the sensory threshold, which yields no pain or unpleasant sensations. The anode was applied to the distal joint and the cathode to the proximal interphalangeal joint of the corresponding digit. The second digit was used for the go stimulus at the probability of 0.5, and the fifth digit for the no-go stimulus at the probability of 0.5. We applied a total of 80 stimuli in each condition, and the inter-trial interval was 3 s. The subjects had to respond to the stimulus by pushing a button with their right thumb as quickly as possible only after presentation of a go stimulus. During the tasks, the subjects were instructed to keep their eyes open and look at a small fixation point positioned in front of them at a distance of approximately 1.5 m.

2.4. EEG and analysis

We placed seven electrodes on the scalp at Fz, Cz, Pz, FC3 (midway between F3 and C3), FC4 (midway between F4 and C4), PC3 (midway between C3 and P3), and PC4 (midway between C4 and P4) according to the International 10–20 System. Each scalp electrode was referenced to linked earlobes. The impedance was maintained at less than 5 kΩ. The bandpass filter of the amplifier was 0.1–100 Hz and the sampling rate was 1000 Hz. To eliminate trials with eye movements or blinks exceeding 100 μV, an electrooculogram (EOG) was recorded bipolarly with a pair of electrodes placed 2 cm lateral to the lateral canthus of the left eye and 2 cm above the upper edge of the left orbit. The analysis epoch for ERPs was 600 ms, including a prestimulus baseline period of 100 ms.

The peak N140 amplitude and latency were measured within time windows of 120–175 ms. The amplitudes were measured from baseline- to- a peak. Slow responses exceeding 500 ms and incorrect responses were excluded from subsequent analysis.

Because N140 is maximal across the midline electrodes, we analyzed signals only from the midline electrodes (Fz, Cz, and Pz) and reference data. For the analysis of go/no-go effects on the somatosensory N140 component, the data on peak amplitude and latency at a middle electrode site (Fz, Cz, and Pz) were subjected to repeated analysis of variance (ANOVA) using Condition (control vs. exercise), Time (before vs. after), Stimulus (go vs. no-go), and Electrode as within-subject factors. The behavioral data on mean response time (RT) and misses (RT > 500 ms) were subjected to repeated measures ANOVA with the factors of condition and time. For all repeated measure factors with more than two levels, we determined whether Mauchly's sphericity assumption was violated. If the result of the Mauchly's test was significant and the assumption of sphericity was violated, we were planning to apply the Greenhouse–Geisser adjustment for sphericity, altering the degrees of freedom using the correction coefficient epsilon. In all cases, sphericity was maintained, and the Greenhouse–Geisser correction was not applied. Statistical significance was set at $P < 0.05$. Eta squared (η^2) is provided as an effect-size measure.