

Original article

Effects of acute aerobic exercise on motor response inhibition: An ERP study using the stop-signal task

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Abstract

Purpose: The purpose of this study was to determine the effects of acute exercise on motor response inhibition using both behavioral and electrophysiological approaches.

Methods: The P3 and N1 event-related potential (ERP) components were recorded while performing a stop-signal task in 21 college students following a moderately intense acute exercise bout for 30 min and a sedentary control session that involved reading.

Results: Acute exercise induced a shorter stop signal response time (SSRT) as compared to control; however, the go response time (Go RT) remained unchanged. In examining the ERP data, acute exercise increased both P3 amplitude and latency but did not affect the N1 component.

Conclusion: Acute exercise has a selective and beneficial effect on cognitive function, specifically affecting the motor response inhibition aspect of executive function. Furthermore, acute exercise predominately impacts later stages of information processing during motor response inhibition, which may lead to an increase in attentional resource allocation and confer the ability to successfully withhold a response to achieve motor response inhibition.

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1. Introduction

Previous studies have suggested a beneficial effect on cognition following acute exercise.^{1,2} This observation is supported by meta-analytic reviews in which acute exercise yielded a significant and positive impact on cognitive function, with a mean overall effect size ranging from 0.1 to 0.2.^{3,4} Despite the well-established relationship between acute exercise and cognition, previous studies have focused on basic cognitive functions. Recently, however, some groups have shifted their attention to higher cognitive processes, such as executive function.^{5,6}

Executive function is an essential cognitive process that involves the control and regulation of other more basic cognitive processes. It is responsible for the ability to respond appropriately to situations in which conflicts arise and embraces a large variety of multi-faceted constructs.^{7,8} While several distinct sub-components of executive function have been proposed,⁹ inhibition has been consistently recognized as a primary aspect of executive function. Inhibition requires both the ability to resolve conflicting responses from unrelated or distracting stimuli and the ability to suppress improper behaviors.^{8,10,11} Dysfunctional inhibition has been linked to several psychiatric disorders, including schizophrenia¹² and attention-deficit/hyperactivity disorder.¹³

Recent studies have suggested that acute exercise could potentially impact one's inhibitory ability as measured by various cognitive tasks, such as the Stroop Task,^{14–18} the Eriksen Flanker Task,^{19–21} the go/no-go task^{22–24} and the

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stop-signal task.²⁵ Yet, it is worthy to note that these tasks, which all measure inhibition, may actually measure different particular inhibitory processes.²⁶ For example, the Stroop and Eriksen Flanker tasks are thought to assess the ability to resolve conflicting stimuli and therefore measure a more cognitive form of inhibition called interference inhibition. In contrast, the go/no-go and stop-signal tasks are thought to measure motor response inhibition.¹¹ Based upon the notion that acute exercise might selectively impact specific aspects of executive function as proposed by Etnier and Chang,⁵ acute exercise might affect only a specific inhibitory process or function. If so, the effects would only be observed when using a select task that is sensitive to those effects. Given that Stroop, Eriksen Flanker, and go/no-go tasks have been primarily utilized in studying acute exercise and inhibition, the aim of this study was to examine motor response inhibition using the stop-signal task in order to advance the knowledge base.

The stop-signal task has been widely used to measure motor response inhibition^{27,28} by employing computational modeling of a dynamic tracking algorithm which takes into account participants' strategic adjustments during the task. In contrast to the go/no-go task, which presents either "go" or "no-go" signals and requires participants to stop executing one set and respond to a different set of stimuli, the stop-signal task presents "go" signals in both "go" and "stop" trials and requires participants to terminate an already executed response when a "stop" signal unpredictably appears after a delay in "stop" trials. Therefore, the go/no-go task measures overall motor response inhibition¹¹ and provides an index of inhibition failure,²⁹ whereas the stop-signal task increases the difficulty of inhibiting the "go" response and measures a later stage of inhibition.³⁰ To date, only one study has utilized the stop-signal task to examine the effects of acute exercise on response inhibition.²⁵ In that study, Joyce et al.²⁵ observed that 30 min of acute moderate-intensity exercise failed to affect basic information processes (i.e., go response time (Go RT)) but improved inhibitory performance (i.e., shorter stop signal response time (SSRT)), suggesting that acute exercise has a selectively beneficial effect on overall motor response inhibition.

Due to their precise temporal resolution, measuring event-related potentials (ERPs) could reveal the underlying mechanisms by which acute exercise affects the brain and cognitive performance. ERPs allow researchers to study patterns of neuronal activity by measuring voltage changes in response to or in preparation for an event (i.e., a stimulus). Previous studies examining inhibition have suggested that acute exercise is associated with increased neuronal activity.^{19–21} For example, acute exercise has been shown to increase the amplitude of the largest positive component in the human ERP waveform (i.e., the P3 component), which occurs approximately 300–800 ms after stimulus presentation. Because the amplitude of the P3 component is believed to reflect the allocation of attentional resources during stimulus engagement,^{31–33} acute exercise induces a greater allocation of attentional resources to the given task.^{19–21,34}

Most prior studies have focused on P3 and only a few studies have examined other ERP components, such as the N1. Unlike P3, which is a late and endogenous ERP component, N1 is an exogenous component that is associated with an earlier cognitive processing stage and reflects the initial extraction of sensory information.³⁵ Previous exercise studies have revealed that acute exercise has a limited influence on the N1 elicited by a choice reaction time task; however, no acute exercise study to date has investigated inhibitory processes such as are required in the stop-signal task using this ERP component.^{36,37} This is important because the N1 component is thought to represent the amount of spatial attention that is directed toward a visual stimulus (e.g., stop signal), such that a larger amplitude of N1 would translate to more attention shifted to the stop signal.³⁸ This interpretation of the N1 component suggests that the attention oriented toward the stop signal could profoundly influence the engagement or success of inhibitory processes during the stop-signal task. Taken together, the effect of acute exercise on inhibition in the context of the N1 component elicited by the stop-signal task are still unknown, yet this information about the contribution of early information processing in motor response inhibition is critical to our understanding of acute exercise effects on inhibition and executive function.

The purpose of this study was to clarify the effects of acute exercise on motor inhibition. Specifically, a stop-signal task, requiring a general motor response inhibition, was performed after a single bout of moderately intense aerobic exercise. The precise temporal resolution of motor inhibitory processes was captured by ERPs recorded during the stop-signal task. Our hypothesis was that acute exercise would not only facilitate overall motor inhibition, but would do so by positively influencing specific ERP components that reflect both late (P3) and early (N1) information processing stages.

2. Methods

2.1. Participants

Twenty-one right-handed college students (19–24 years old) were recruited through flyers from regions surrounding Taoyuan, New Taipei City, and Taipei. All participants provided written informed consent prior to their involvement in this study in accordance with the Institutional Review Board of National Taiwan University. All participants completed the Physical Activity Readiness Questionnaire (PAR-Q) and the Health Screening Questionnaire (HSQ) to determine if they had any conditions that would prevent them from participating in acute exercise or the cardiovascular fitness assessment. Only those participants who met the "low risk" criteria set by the American College of Sports Medicine guidelines were eligible to participate in this study.³⁹ Additionally, all participants had normal or corrected-to-normal vision (i.e., 20/20), were non-smokers, were not currently taking any medication, and had no history of substance abuse or mental health disorders.

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