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# Self-selected music-induced reduction of perceived exertion during moderate-intensity exercise does not interfere with post-exercise improvements in inhibitory control

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ABSTRACT

Acute aerobic exercise improves inhibitory control (IC). This improvement is often associated with increases in perceived exertion during exercise. However, listening to music during aerobic exercise mitigates an exercise-induced increase in perceived exertion. Thus, it is hypothesized that such effects of music may interfere with exercise-induced improvements in IC. To test this hypothesis, we examined the effect of music on post-exercise IC improvements that were induced by moderate-intensity exercise. Fifteen healthy young men performed cycle ergometer exercise with music or non-music. The exercise was performed using a moderate-intensity of 60% of $VO_{2\ peak}$ for 30 min. The music condition was performed while listening to self-selected music. The non-music condition involved no music. To evaluate IC, the Stroop task was administered before exercise, immediately after exercise, and during the 30-min post-exercise recovery period. The rate of perceived exertion immediately before moderate-intensity exercise completed was significantly lower in music condition than in non-music condition. The IC significantly improved immediately after exercise and during the post-exercise recovery period compared to before exercise in both music and non-music conditions. The post-exercise IC improvements did not significantly differ between the two conditions. These findings indicate that self-selected music-induced mitigation of the increase in perceived exertion during moderate-intensity exercise dose not interfere with exercise-induced improvements in IC. Therefore, we suggest that listening to music may be a beneficial strategy in mitigating the increase in perceived exertion during aerobic exercise without decreasing the positive effects on IC.

## 1. Introduction

Executive function involves three aspects: shifting of mental sets, monitoring and updating of working memory representations, and inhibition of prepotent responses [1]. Inhibitory control (IC) is defined as the suppression of behavior in response to either internal or external stimulus [2], which is often necessary to adequately prevent ourselves from executing an inappropriately prepared action [3]. The IC can be measured using various tasks, including the Stroop task [4]. When using the Stroop task, the IC can be evaluated utilizing the Stroop interference effect [5]. Previous studies have reported that an acute bout of aerobic exercise can improve executive function, such as reduced reaction time during the Stroop task [6–14]. Additionally, we and others previously determined that acute aerobic exercise can decrease the Stroop interference effect [6,8,10–14]. Thus, aerobic exercise is known to be an effective strategy to improve executive function, including IC.

Endo et al. [7] reported that improvement in immediate post-aerobic exercise executive function, which was evaluated using reaction time of the Stroop task, was higher in moderate-intensity exercise than in low-intensity exercise. This difference in improved executive function between the exercise intensities corresponded to that of rate of perceived exertion (RPE) immediately after exercise. Additionally, in a recent study, we demonstrated that high-intensity interval exercise could sustain the improvements of the Stoop task-measured IC during the post-exercise recovery period longer than volume-matched

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continuous moderate-intensity exercise [11]. The post-exercise IC improvements were in line with increases in RPE during exercise [11]. More recently, we examined the effects of exercise intensity and duration on IC improvements during the post-exercise recovery period [13]. This study demonstrated that these exercise variables, especially exercise intensity, were important factors in the IC improvements by showing that post-exercise IC improvements were better sustained after moderate-intensity exercise (i.e., 60% $VO_{2\ peak}$) with a relatively short duration (i.e., 20 min) than after low-intensity exercise (i.e., 30% $VO_{2\ peak}$) with a relatively long duration (i.e., 40 min), despite an equivalent exercise volume between the two conditions [13]. These results were also similar to that of RPE during exercise [13]. Thus, the improvement in executive function, including IC, after aerobic exercise may be associated with increases in perceived exertion during the exercise.

Aerobic exercise-induced IC improvements may be due to enhanced cerebral neural activity in the brain, especially the dorsolateral prefrontal cortex region [6,8,14]. Previous studies have reported that enhanced cerebral neural activity during exercise corresponded with increased RPE [15,16]. These previous findings propose that exercise-induced enhancement in cerebral neural activity could be involved in the sensation that generates perceived exertion [16,17]. Thus, the exercise-induced improvements in IC can be, at least partially, explained by increased RPE, which may be due to enhanced dorsolateral prefrontal cortex activity. Interestingly, a series study by Ferreni et al. [18,19] determined that listening to music may induce a decrease of neural activity in the dorsolateral prefrontal cortex region. Additionally, previous studies reported that music during aerobic exercise mitigated the exercise-induced increase of RPE [20–23]. Based on these findings, it is speculated that music during aerobic exercise may interfere with exercise-induced improvements in IC, by potentially inhibiting the enhancement in dorsolateral prefrontal cortex activity and mitigating the increase in perceived exertion.

Byun et al. [6] determined that the Stroop task-measured IC improvement induced by aerobic exercise was related to enhance cerebral neural activity and increased arousal level, indicating that cerebral neural activation may be linked to the arousal system. Moreover, Sander et al. [24] reported that enhanced cerebral neural activation during exercise corresponded with increased cardiovascular responses, such as heart rate (HR) and blood pressure. Additionally, increases in cardiovascular responses may relate to exercise-induced improvements in executive function [25], suggesting that changes in cardiovascular responses may play an important role in improving executive function. Furthermore, glucose and lactate are known to be important energy sources in the human brain [26]. Although the brain mainly relies on glucose at rest, glucose uptake in the brain decreases during physical exercise, which is accompanied by increasing blood lactate levels [27]. Rasmussen et al. [28] reported that acceleration of lactate metabolism in the brain is induced by blood lactate levels > 2 mM. Blood lactate levels during moderate-intensity exercise (i.e., 60% $VO_{2\ peak}$) have been shown to reach levels of > 2 mM [11,13], suggesting that lactate is likely utilized in the brain during exercise. Considering the above factors, in addition to perceived exertion, it is likely that changes in arousal level and physiological parameters (i.e., cardiovascular response and blood metabolites) are required to improve post-exercise IC. In particular, previous studies have reported that music during aerobic exercise could mitigate the increases in blood lactate levels [22,23]. Therefore, we hypothesized that music during aerobic exercise may interfere with post-exercise improvements in IC, potentially by mitigating increases in perceived exertion and blood lactate levels. To test this hypothesis, we examined the effect of music on the Stroop task-measured IC improvements that were induced by moderate-intensity exercise.

## 2. Methods

### 2.1. Subjects

Before executing this study, we performed a power analysis to estimate the required sample size. Based on the results of our previous study regarding the difference of the two conditions on post-exercise IC [11], we calculated the required sample size utilizing an effect size (0.30), an α-level of 0.05, and a β-level of 0.2 (80% power). As a result, the calculated necessary number of subjects was 15; therefore, we recruited 15 subjects. Fifteen healthy, young men (age: 22.9 ± 0.5 years, height: 173.0 ± 1.1 cm, weight: 67.5 ± 1.6 kg, $VO_{2\ peak}$: 45.2 ± 1.9 ml/min/kg) participated in this study. The subjects were recreationally active. Subjects participated in physical exercise (e.g., aerobic exercise) for 2–4 h per week. The subjects were informed of the experimental procedures and potential risks and provided written consent to participate in the study. Because the Stroop task was performed using the subject's right hand, all subjects were considered right-hand dominant, which was ascertained by asking each subject which hand they preferred to use for writing. All subjects were also free of any known neurological, cardiovascular, and pulmonary disorders, as well as free from color-blindness and abnormal vision. All procedures were approved by the Ethics Committee of Ritsumeikan University (BKC-IRB-2014-028). Subjects were instructed to avoid strenuous physical activity in the 24 h prior to each experimental session. Each subject also abstained from food (overnight fasting), caffeine, and alcohol for 12 h prior to each experiment, and was not taking any medications that would affect cognitive performance.

### 2.2. Ramp-incremental test

During the first visit, all subjects performed a ramp-incremental exercise test on a cycle ergometer to determine $VO_{2\ peak}$ as previously described [10–13]. In brief, subjects performed 3 min of baseline cycling at 30 watt, after which the workload was increased at a rate of 30 watt/min until the limit of tolerance. The subjects were asked to maintain a cadence of 60 rpm. During the incremental test, breath-by-breath pulmonary gas exchange data were collected using a gas analyzer (AE-310S; Minato Medical Science, Osaka, Japan) and averaged every 10 s. $VO_{2\ peak}$ was determined by the highest 30-s mean value attained prior to exhaustion. HR was measured continuously via telemetry (RS400; Polar Electro Japan, Tokyo, Japan). The criteria for exhaustion have been described previously [10–13].

### 2.3. Experimental conditions

All subjects completed moderate-intensity cycle ergometer exercise based on either exercise conditions with music or non-music in a randomized and counterbalanced order. Exercise protocol in both conditions was performed following a warm-up at 50 watt for 5 min, and subjects were instructed to maintain a cadence of 60 rpm throughout the exercise session, which was carefully monitored by the examiners. The exercise intensity in the exercise protocol was set at 60% of $VO_{2\ peak}$. Both conditions were started immediately after the completion of a warm-up. The music condition was performed while listening to music songs through headphones connected to a portable music player. The songs were self-selected because non-preferred music may negatively alter the effects of music on psychological responses during aerobic exercise [29]. Prior to music condition, each subject made a playlist with at least 8 songs (4–6 min per song). Song choices were only Japanese pop. Additionally, only songs under 120 bpm were provided, because a faster tempo can influence several physiological responses, such as the cardiovascular response [30], which may relate to exercise-induced improvement in executive function [24,25]. Music volume was set at approximately 80 dB [31], which was checked using a sound level meter before the start of exercise. During music condition, subjects