The effects of karate training and moderate aerobic exercise on college students' self-control

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C Statistical Analysis
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Abstract

Background and Study Aim: Karate is one of martial arts that requires a lot of "control". However, the research about benefits of self-control from karate is scant. The aim of present study is knowledge about the effects of karate training and moderate aerobic exercise on college students' self-control.

Material and Methods: Participants were assigned to either karate training group (n = 13) or cycling group (n = 13) for 4-week intervention, or no additional exercise group as the control group (n = 17). The participants' self-control, including their cognitive control as measured by a Go/NoGo task, their self-control in learning behavior as measured by eye behaviors when watching video courses, and their trait self-control as measured by the Self-Control Scale for College Students, was tested before and after the intervention.

Results: After 4 weeks of intervention, in the cognitive self-control test the improvement of the karate group was significantly greater than that of the control group, while the improvement in the cycling group was marginally greater than that of the control group. In the learning behavior test, the improvements in the karate group and the cycling group were similar, both greater than the control group. In the measurement of trait self-control, the three groups did not differ.

Conclusions: Karate training can improve college students' self-control, resulting in a more stable effect than aerobic exercise; the effect can be generalized to the students' learning behavior but not their trait self-control.

Keywords: cognition • kumite • martial arts • physical education • skills

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INTRODUCTION

The concept of self-control

Self-control is the capability to exert control over oneself to follow rules or inhibit immediate impulses [1, 2]. Self-control involves overriding competing urges and behaviors, resisting temptations, and keeping one's action to be more in line with long-term goals [2-4]; it enables the individual not only to refrain from potentially harmful behaviors but also to form good habits and positive lifestyles. Therefore, self-control is critical for various daily activities and is a key to success in almost all life aspects [3, 5, 6]. There is growing evidence that self-control is positively correlated with health, well-being, social and educational outcomes across lifespan [7, 8]. Higher scores on self-control scales are associated with better adjustment, better school readiness, and a higher-grade point average [8, 9], and higher self-control scores remain beneficial for success throughout life in careers and marriage [5, 10]. Conversely, poor self-control has been linked to adverse outcomes, such as binge eating, substance dependence, lack of persistence, school underachievement, unemployment, and crime [3, 7, 8].

In research, the concepts of self-control, self-regulation, and executive function are closely related, and the terms are used interchangeably in many cases. When making distinctions between the terms, self-regulation can be considered a broader term, while self-control is the deliberate, conscious, and effortful subset of self-regulation [3]. Executive function often refers to the cognitive processes contributing to self-regulation [6, 8], similar to the cognitive control in self-control. Cognitive control has been intensively investigated, usually by using various computerized cognitive tasks, such as the Go/NoGo task, the Stroop task, and the flanker task. For instance, the Go/NoGo task requires the participants to respond as quickly and accurately as possible when seeing the Go signal and to inhibit the impulse to respond when seeing the NoGo signal. This resembles people's real-life self-control behaviors to react when following rules and to inhibit impulses for irrelevant behaviors and urges.

Self-control training

Evidence suggests that self-control can be improved through training [6] just as muscles can grow stronger through exercise training [11, 12]. The training of self-control can exert potentially enormous impacts on individuals and society. Trainings that achieve even small improvements for individuals could shift the entire distribution and yield large improvements in health and wealth for the society [5, 7].

Diverse training activities, such as aerobic exercise, martial arts, yoga, mindfulness, school curricula and family-focused interventions, etc., can be used to improve self-control [5, 8, 11]. It is not yet clear which type of activities are more effective and whether the effectiveness varies in different population groups [8]. A recent meta-analysis found that consistent improvement in self-control was reported in 33 of 50 interventions, including 16 of 21 curriculum-based interventions, 5 of 9 family-based programs, 4 of 6 social and personal skills interventions, 4 of 8 mindfulness and yoga interventions, and 4 of 6 exercise-based programs [8]. The present study focused on aerobic exercise and martial arts. To date, research results on the effect of aerobic exercise on self-control are mixed, and research on the effect of martial arts on self-control is rare and has not been compared with other types of exercise.

The effect of aerobic exercise on self-control

A number of studies found significant effects of aerobic exercise on self-control [13-15]. In many studies, a single bout of acute aerobic exercise was conducted with children, and the children's self-control before and after the acute exercise was compared. For instance, Hillman et al. [16] found that a single bout of acute treadmill walking impacted preadolescent children's cognitive control of attention. Similarly, Chen et al. [17] adopted the acute exercise of jogging in groups at a moderate intensity for 30 mins on a playing field and found that the exercise benefited preadolescent children's cognitive control. In recent years, there have been increasing numbers of studies on the effect of chronic exercise on adults' self-control. For instance, Zou et al.'s [18] study found that 30-min running for a period of 5 weeks increased female undergraduate students' self-control. Wang et al.'s [19] study found that 12 weeks of moderate aerobic exercise with three 30-min sessions per week increased the self-control of adults with methamphetamine dependencies.

In contrast to the promising positive effects found in these studies, there is also evidence suggesting that aerobic exercise produces little or no self-control benefit [6]. Some studies have suggested that acute aerobic exercise may not be effective for adults' cognitive control. Vincent and

Self-control – *noun* the capability to exert control over oneself to follow rules or inhibit immediate impulses [1, 2], which is positively correlated with health, well-being, social and educational outcomes across lifespan [7, 8].

Academic learning behavior – *noun* one of the most significant features for college students in their study career. In the present study, a video coursing task was designed to reflect students' ability to focus on the course video without being distracted by the distracting video. Greater performance on the task indicates higher self-control during learning.

Eye movement – *noun* any shift of position of the eye in its orbit. Eye movements determine what information reaches our retina, visual cortex, and most important, higher cortical centers. Hence, eye movements are critically important for vision, attention, and memory; they determine what we see, attend to, and remember about our surroundings [41].

IPAQ – *noun* the International Physical Activity Questionnaire (IPAQ) and its short version were developed to measure health-related physical activity (PA) in populations. Data measured with IPAQ are often used to predict health-related behaviors or characteristics, or to monitor changes in physical activity in addition to the intervention during exercise interventions

Open skills – *noun* sports such as netball, football, and hockey involve open skills. The environment is continually changing, and so movements have to be continually adapted. Skills are predominantly perceptual and externally paced, for example, a pass in football.

Closed skills – *noun* take place in a stable, predictable environment, and the performer knows what to do and when. Skills are not affected by the environment and movements follow set patterns and have a clear beginning and end. The skills tend to be self-paced, for example, a free throw in basketball and serving in squash or tennis.

Kumite – is a semi-contact karate competitive concurrence, where two athletes perform various

Hall's [20] study examined the effect of a 30-min bout of acute moderate-intensity aerobic exercise in overweight and obese adults living with type 2 diabetes, and the results revealed no reliable benefit as measured by the Stroop task and the Go/NoGo performance. Similarly, Stroth et al.'s [21] study found that 20 mins of stationary bicycling at moderate intensity did not improve adolescents' (age 13-15 years) self-control as measured by their performance on a modified Go/NoGo version of the flanker task. Moreover, some studies have suggested that even chronic aerobic exercise may not be effective if there is no cognitive component involved in the exercise. For instance, Costigan et al. [22] delivered 8 weeks of aerobic exercise sessions to students in grades 9 and 10, yet they found small and non-significant improvements in their cognitive control. Schmidt et al. [23] assigned children aged between 10 and 12 years to 6-week physical education programs of aerobic exercise, team games, or a control condition. Improvement in cognitive control was found only in the children in the team games group but not the aerobic exercise group. Similarly, there are also studies showed that in older adults' aerobic exercise exerts little impact on self-control [24, 25]. In sum, the research results of the effect of aerobic exercise on self-control are mixed, probably because the effect is relatively small and unstable and depends on the characteristics of the exercise and the exerciser.

The effect of martial arts on self-control

Martial arts are potentially more efficacious interventions for self-control, considering that martial arts typically include various forms of training on mind in addition to training on body [5]. Research has shown that taekwondo is beneficial for children's self-control. Lakes and Hoyt [26] assigned classes of children in kindergarten through grade 5 to either a taekwondo group or a standard physical education group for a 3-month intervention. After the intervention, the taekwondo group demonstrated greater improvements in self-control, and the effect generalized to their classroom conduct. In addition to taekwondo, there are still other martial arts that may greatly benefit people's self-control, yet their effects have rarely been investigated.

One promising martial art intervention is karate. Karate was developed in East Asia under the influence of kung fu. In movies and other mass media, karate is frequently depicted as a mysterious way of fighting that is capable of causing death or injury with a single blow. However, in fact, "Karate may be considered as the conflict within oneself or as a life-long marathon which can be won only through self-discipline, hard training and one's own creative efforts" [27]. As a traditional martial art, it particularly emphasizes character development, discipline, and control [28]. The control aspect aims to control the opponent and, more importantly, to control oneself. Kumite training in karate requires practitioners to have good control in strength, speed, and mind to make their actions accurate, stable, and harmonious. Moreover, a critical practice in kumite fighting is sun-dome (寸止), meaning that the punches, strikes, and kicks used in attacking must be controlled, stopping at a single sun (寸, approximately 3 cm) before the intended target instead of making actual physical contact. That is, regardless of the speed and ferocity of their attacking techniques, the practitioners must bring themselves to an immediate halt just before reaching the target, which requires great control. Recent studies on karate have shown that karate can improve older adults' subjective mental health and cognitive processing speed [29], and reduce communication deficits in children with autism spectrum disorder (ASD) [30]. However, there has been no empirical research on the effects of karate on self-control.

Issues in the current research on the effects of exercise on self-control

In sum, whereas it is generally acknowledged that exercise can benefit self-control, there are a number of critical issues requiring further investigation. First, more studies on the effect of chronic exercise and the effect in adults are needed. Although some studies found that acute exercise can benefit self-control, the effect may be elusive and transient [5]. Chronic exercise may be a more reliable intervention for obtaining robust beneficial effects. Prior studies were conducted mostly in children, and it is generally assumed that children's self-control may benefit more from training. However, the improvement of self-control in adults also has an enormous impact on individuals and society, and adults may possibly obtain the beneficial effects from exercises that involve training on mind more readily.

Second, more studies on the beneficial effects of martial arts are needed. It has been debated whether "mindless" aerobic exercises that do not

kicking, punching and blocking techniques towards each other with maximum control in order to gain points and win the match. Destruction is fictive.

Skill – ***noun*** an ability to do perform an action well, acquired by training [42].

engage cognitive components can effectively improve self-control. In contrast, martial arts usually stress both the mind and the body, which may make them better interventions than aerobic exercises.

Third, more studies are needed for the transferability or generalizability of the training effects on self-control. The merit of self-control training is that the gains in one domain are supposedly transferable to other domains of the individual's life [11, 12].

However, current research on this issue is insufficient and controversial. Recent studies have revealed that the training effect of moderate aerobic exercise on self-control is transferable to the participants' dietary behavior, such that individuals who participate in moderate aerobic exercise consume more healthy foods and less appetitive calorie dense snack foods [31, 32]. The transfer or generalization to other domains awaits more research; whether the trainings can help students have better self-control during learning remains unclear. Fourth, more studies are needed for different aspects of self-control. Self-control includes the state self-control, which is the momentarily available self-control strength, and the trait self-control, which is the interindividual dispositional differences in self-control [9, 33]. It is not yet known whether exercise affects state self-control only or whether it can also alter one's trait self-control.

The aim of present study is knowledge about the effects of karate training and moderate aerobic exercise on college students' self-control.

Specifically, the present study addressed the following questions: (1) Can karate training and chronic moderate aerobic exercise improve college students' self-control? (2) Does karate training improve college students' self-control to a larger degree than aerobic exercise? (3) Can the training effects be generalized to the students' learning behavior, such as video course learning? (4) Can karate training, which contains character development and training on the mind, alter the students' trait self-control?

MATERIAL AND METHODS

Participants

Forty-three college students were recruited (20 males, 23 females), all with normal or corrected-to-normal visual acuity and normal color vision. None of them had any experience with karate training or other martial arts training prior to the experiment. The students volunteered to participate in the experiment and provided informed consent. The participants were each assigned to one of three groups: 13 were assigned to the karate training group (6 males, 7 females), 13 were assigned to the cycling group (6 males, 7 females), and 17 were assigned to the no additional exercise group as the control group (8 males, 9 females).

The three groups were similar in age (M, SD_{karate} = 22.9 ±4.0, $M, SD_{cycling}$ = 20.5 ±2.4, $M, SD_{no\ additional}$ = 22.2 ±3.4, p = .156), BMI (M, SD_{karate} = 21.5±1.8, $M, SD_{cycling}$ = 20.6 ±2.3, $M, SD_{no\ additional}$ = 21.2 ±1.8, p = 0.526), and weekly physical activity as measured by the brief version of Bauman et al.'s [34] International Physical Activity Questionnaire (IPAQ) (M, SD_{karate} = 889.1±320.5, $M, SD_{cycling}$ = 914.2 ±330.5, $M, SD_{no\ additional}$ = 861.7 ±330.6, p = 0.915).

Physical activity was continually monitored during the 4 weeks of the intervention period by using the IPAQ, ensuring that the three groups were matched in physical activity except the intervention.

Experimental design and procedure

We adopted a 2 (testing time: pretest, posttest) ×3 (group: karate training group, cycling group, no additional exercise group) mixed design. The testing time was the within-participants variable, and the group was the between-participants variable. The independent variables were the performances in the self-control tasks, which are described in detail in the sections below.

The intervention lasted for 4 weeks. During this period, the karate training group was trained by a karate coach with a black belt and three years of coaching experiences. The training was conducted twice a week. Each training session lasted 90 mins, including stages of warming up, teaching, practicing, and cooling down. After the 4-week training, a final examination was conducted, testing whether the participants mastered the trained karate skills. During the same period, the cycling group participated in moderate cycling exercises on stationary bicycles twice a week for 4 weeks. Each cycling session lasted 40 mins, so that the cycling group matches with the karate group in the load of physical activity.

The no additional exercise group maintained their ordinary physical activity without any additional activity. The results of the IPAQ showed that the three groups did not differ in physical activity during the 4 weeks except the intervention (M, SD_{karate} = 889.42 ±296.65, $M, SD_{cycling}$ = 920.46 ±305.85, $M, SD_{no\ additional}$ = 858.71 ±353.31, p = 0.847). The participants' self-control was tested before and after the intervention, including cognitive control as measured by the Go/NoGo task, self-control in academic learning behaviors as measured by the eye behavior when watching video courses, and trait self-control as measured by the Self-Control Scale for College Students [9, 35]. Each participant was tested separately. The three sessions of self-control testing lasted approximately 40 mins in total, including short breaks between the sessions.

The Go/NoGo task for testing cognitive control

When performing the Go/NoGo task, the participant was seated approximately 57 cm from the monitor. In each trial, a fixation point was presented for 500 ms, after which the Go or NoGo stimulus was presented for 100 ms, followed by an 800 ms blank screen for the participant to respond (or to refrain from responding). The stimuli were presented on the center of a gray background. For half of the participants, the Go stimulus was the letter N and the NoGo stimulus was M, while for the other half of the participants, the stimuli were reversed. Participants were required to press the key "1" as quickly and accurately as possible when seeing the Go stimulus and to refrain from pressing any keys when seeing the NoGo stimulus.

Participants were first familiarized with the task and then conducted a practice block of 10 trials (a random mix of 5 Go trials and 5 NoGo trials) before starting the experimental block of 300 trials. In the experimental block, the ratio of Go and NoGo trials was 4:1 (i.e., 240 trials vs. 60 trials) to induce the participants' strong key-press impulse. Participants took a break of approximately 2 mins after 150 trials.

We calculated the d value of the Go/NoGo task performance for each participant as the measure for cognitive control. The d value is the difference between the Z score of the correct reaction time in the Go condition and the Z score of the error rate in the NoGo condition (i.e., $d = Z_{Go\ correct\ reaction\ time} - Z_{NoGo\ error\ rate}$). This measure takes into account both the reaction time and the accuracy in the Go/NoGo task [36]. A higher d value indicated that the participant was better at controlling him/herself according to the task requirement, reacting quickly when seeing the Go signal and inhibiting the impulse to react when seeing the NoGo signal.

We conducted a 2 (testing time: pretest, posttest) × 3 (group: karate training group, cycling group, no additional exercise group) repeated-measure ANOVA on the d value (i.e., $Z_{Go\ correct\ reaction\ time} - Z_{NoGo\ error\ rate}$) in the Go/NoGo task, with the testing time as the within-participants variable and the group as the between-participants variable.

To examine the interaction, we compared the three groups' improvements in d from pretest to posttest.

The video course task for testing the generalizability to learning behavior

In the video course task, we used clips of a Chinese language lesson from a video course as the materials for testing the learning behavior. The lesson is a basic lesson for college students in all majors. We used clips from a fashion show (i.e., Victoria's Secret) as the distracting video, considering it is of great interest to both male and female students. We first selected three video clips of each type. Each clip was 9 mins in duration. We had the six clips rated by 120 college students (half males and half females, mean age = 20.7 ±2.7) on a 7-point Likert scale according to their degree of interest in each video (1 = very uninterested, 7 = very interested). Then, we chose two video clips of each type, which were used separately for the pretest and the posttest. ANOVA analyses showed that the degrees of interest were significantly higher for the clips from the fashion show than for the Chinese language lesson (6.12 vs. 1.93, $F(1, 116) = 752.793$, $p<0.001$, $\eta_p^2 = 0.866$; 6.13 vs. 1.87, $F(1, 116) = 1062.944$, $p<0.001$, $\eta_p^2 = 0.902$, respectively, for the video clips used in the pretest and posttest); the ratings of the male and the female students did not differ (4.02 vs. 4.03, $F(1, 116) = 0.012$, $p = 0.913$, $\eta_p^2 <0.001$; 4.03 vs. 3.97, $F(1, 116) = 0.260$, $p = 0.611$, $\eta_p^2 = 0.002$, respectively, for pretest and posttest); and there was no interaction between the video type and the gender of the rater ($F(1, 116) = 1.446$, $p = 0.232$, $\eta_p^2 = 0.012$; $F(1, 116) = 0.260$, $p = 0.611$, $\eta_p^2 = 0.002$, respectively, for pretest and posttest).

When performing the video course task, participants were seated 65 cm away from the monitor. Head position was stabilized using a chin-rest. The video course and the fashion show video were presented side by side on the same screen at the same time, simulating a situation in which the students were watching video courses with potential distraction around. The video course was played with audio while the fashion show video was played in silence. The participants were required to concentrate on watching the video course and ignore the distraction of the fashion show video. To encourage the participants to maintain concentration on the video course, we masked one sentence on each slide and required the participants to verbally rehearse the sentence immediately after the teacher read it.

Participants' eye behavior when watching the video course was monitored by a Tobii S1200 eye tracker (Tobii, Stockholm, Sweden). We computed the percentage of fixation number on the video course relative to the total number of fixations and the percentage of gaze duration on the video course relative to the total gaze duration. Greater percentages of fixation number and gaze duration on the video course indicates higher self-control during learning, showing that the student was able to concentrate on the main task of the video course and inhibit the impulse to watch the distracting stimuli.

The eye movement data of 33 participants (11 in the karate training group, 10 in the cycling group, and 12 in the no additional exercise group) were entered into the data analyses for the video course task, while the other ten participants' data were excluded due to the participants' eye conditions or excessive tracking loss. We performed 2 (testing time) × 3 (group) repeated measures ANOVAs on the participants' percentage of fixation number and percentage of gaze duration on the video course, with the testing time as the within-participants variable and the group as the between-participants variable.

The Self-Control Scale for testing trait self-control

We measured the participants' trait self-control by the Self-Control Scale for College Students. The scale was developed by Tangney et al. [9], and translated into Chinese and revised by Tan and Guo [35]. It is a 5-point Likert scale of 19 items, including five dimensions of self-control: impulse control, healthy habits, resisting temptation, concentration on work, and abstemiousness. A higher score indicates higher self-control.

Statistical analysis

The estimation of the results is based on the following indicators: mean (*M*); mean difference (*MD*); standard deviation (SD or ±); average absolute deviation (*d*); distribution, F-Snedecor statistics, result of the analysis of variance (*F*); significance level, probability (*p*); partial eta squared (ηp2) is calculated from the variance associated with an effect divided by the variance associated with the effect plus its associated error variance [SS effect / (SS effect + SS error)]; test *Z*.

RESULTS

The Go/NoGo task for testing cognitive control

The results yielded a significant main effect of testing time, $F(1, 40) = 69.552$, $p<0.001$, $\eta_p^2 = 0.635$, with a higher *d* in the posttest than in the pretest. The main effect of group was not significant, $F(2, 40) = 2.100$, $p = 0.136$, $\eta_p^2 = 0.095$. More importantly, the interaction between testing time and group was significant, $F(2, 40) = 7.852$, $p = 0.001$, $\eta_p^2 = 0.282$ (Figure 1). The improvement of interaction was significantly greater in the karate group than in the no additional exercise group ($MD = 0.933$, $p<0.001$), while the improvement in the cycling group was marginally higher than that in the no additional exercise group ($MD = 0.451$, $p = 0.063$) and marginally lower than that in the karate group ($MD = -0.482$, $p = 0.062$).

The video course task for testing generalizability to learning behavior

The ANOVA results for both the percentage of fixation number and the percentage of gaze (Figure 2) duration showed significant main effects of testing time ($F(1, 30) = 8.103$, $p = 0.008$, $\eta_p^2 = 0.213$; $F(1, 30) = 5.932$, $p = 0.021$, $\eta_p^2 = 0.165$) and significant time × group interactions ($F(2, 30) = 3.580$, $p = 0.040$, $\eta_p^2 = 0.193$; $F(2, 30) = 3.686$, $p = 0.037$, $\eta_p^2 = 0.197$), along with nonsignificant main effects of group ($F(2, 30) = 1.407$, $p = 0.261$, $\eta_p^2 = 0.086$; $F(2, 30) = 0.843$, $p = 0.440$, $\eta_p^2 = 0.053$). We conducted further analyses on the testing time × group interactions by comparing the improvement from pretest to posttest in the three groups. The improvement in the percentage of fixation number on the video course was significantly greater in the

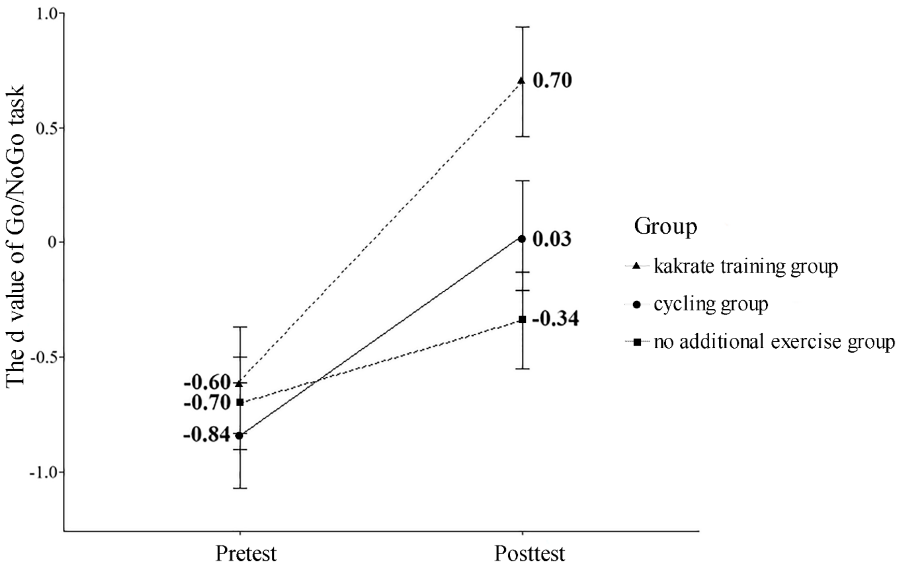

Figure 1. The results of the Go/NoGo task.

karate group than in the no additional exercise group (*MD* = 5.778, *p* = 0.019), and significantly greater in the cycling group than in the no additional exercise group (*MD* = 4.920, *p* = 0.049), while there was no significant difference between the karate group and cycling group (*MD* = 0.858, *p* = 0.728). The improvement in the percentage of gaze duration on the video course was significantly greater in the karate group than in the no additional exercise group (*MD* = 6.313, *p* = 0.013), and marginally greater in the cycling group than in the no additional exercise group (*MD* = 4.393, *p* = 0.083), while there was no significant difference between the karate group and cycling group (*MD* = 1.920, *p* = 0.449).

The Self-Control Scale for testing trait self-control

There was no significant main effect of testing time, no significant main effect of group, and no significant time × group interaction for any of the scores (*ps*>0.11) (Table 1).

DISCUSSION

The present study showed that after 4 weeks of intervention, in the cognitive control test (i.e., the Go/NoGo task), the karate training group's improvement was significantly greater than that of the no additional exercise group, and marginally

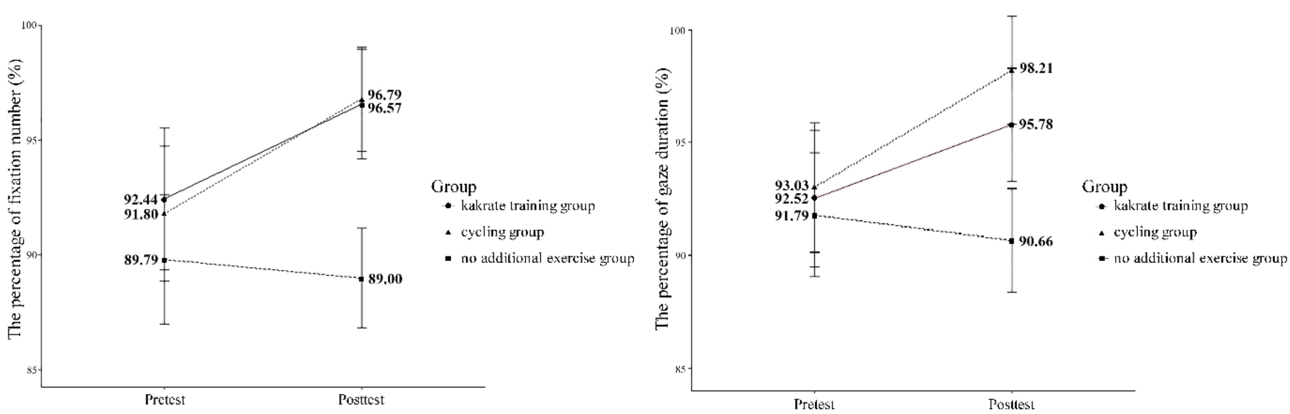

Figure 2. The results of the percentage of fixation number and the percentage of gaze (11 the karate training group, 10 the cycling group, 12 the no additional exercise group).

Table 1. The Three Groups' Scores on Each Dimension and the Total Scores of the Self-Control Scale.

Variable	Karate group (n = 13)		Cycling group (n = 13)		No additional exercise group (n = 17)	
	Pretest (M, SD)	Posttest (M, SD)	Pretest (M, SD)	Posttest (M, SD)	Pretest (M, SD)	Posttest (M, SD)
Impulse control	3.40 ±0.74	3.50 ±0.68	3.51 ±0.48	3.37 ±0.52	3.51 ±0.84	3.30 ±0.78
Healthy habit	3.05 ±0.74	3.13 ±0.66	3.15 ±0.80	3.26 ±0.63	2.98 ±0.89	2.96 ±0.96
Resisting temptation	2.96 ±0.44	3.17 ±0.48	3.00 ±0.68	2.94 ±0.70	2.99 ±0.63	2.93 ±0.71
Concentration on work	2.92 ±0.75	3.13 ±0.66	3.08 ±0.77	3.10 ±0.58	3.22 ±0.59	3.20 ±0.72
Abstemiousness	2.92 ±0.78	3.08 ±0.58	3..21 ±0.81	3.46 ±0.98	3.14 ±1.06	3.16 ±0.93
Total average	3.10 ±0.46	3.25 ±0.39	3.23 ±0.57	3.23 ±0.48	3.21 ±0.67	3.13 ±0.61
Total score	58.92 ±8.77	61.69 ±7.48	61.38 ±10.92	61.46 ±9.13	61.00 ±12.64	59.47 ±11.57

greater than that of the cycling group, while the improvement in the cycling group was marginally greater than that of the no additional exercise group. In the learning behavior test (i.e., the video course task), the karate group's improvements in the percentage of fixation number and the percentage of gaze duration on the video course were similar to the cycling group's improvement. They were all significantly greater than the improvements of the no additional exercise group, except that the cycling group's improvement in percentage of gaze duration was marginally greater than that of the no additional exercise group. In the test for trait self-control (i.e., the Self-Control Scale for College Students), the three groups' scores did not differ, either in the total score or in the score of any of the five dimensions. In short, the results were as follows: cognitive control: karate > cycling > no additional exercise; learning behavior: karate = cycling > no additional exercise; trait self-control: karate = cycling = no additional exercise.

These results suggest that (1) both karate training and chronic moderate aerobic exercise can improve college students' self-control, and particularly, the improvement of karate training may be marginally greater than that of aerobic exercise; (2) the training effects can be generalized to students' learning behavior in watching video courses; and (3) 4 weeks of karate training or aerobic exercise does not alter students' trait self-control. In the following sections, we discuss these issues in detail.

The effect of chronic moderate aerobic exercise on adults' self-control

These results suggest that chronic moderate aerobic exercise can improve college students' self-control even if the exercise involves little cognitive component besides physical activity. These results support the notion that physical activity can impact not only the lower-level perceptual or automatic cognitive processes but also the higher-order, complex cognitive processes that enable humans to behave in an adaptive and goal-directed fashion [14]. Physical activity not only benefits children and adolescents who are not yet mature in their self-control but also benefits young adults such as college students. Both cognitive control in lab experiments, such as the Go/NoGo task, and self-control in behaviors in video course learning were improved.

Nevertheless, it is noteworthy that the effect of aerobic exercise on self-control appeared to be not very robust. In the present study, the difference between the cycling group and the no additional exercise group was marginally significant on the Go/NoGo performance and on the percentage of the gaze duration in video course learning. Such marginally significant improvement was frequently found in previous studies on the effects of aerobic exercise on self-control as well. For example, Dunsky et al. [37] found that improvement in cognitive control among adults (approximately 50 years old) was marginally higher after a 25-min moderate-intensity walk on a treadmill than among those seated while watching a video. Thus, the debate on the effects of aerobic exercise is probably because the effects are relatively small and unstable.

The effects of karate vs. cycling on self-control

Karate training may improve adults' self-control to a larger degree than aerobic exercise. In prior research, the effects of martial arts on self-control have rarely been studied and have not been compared with aerobic exercise. Considering that physical activity of any kind may provide some benefit to the participants' mind, it is necessary to examine whether karate and other martial arts bring additional benefits to self-control. In the present study, the results showed that the improvement of cognitive control in the karate group was marginally higher than that of the cycling group, which may be due to that karate involves more cognitive components and training on open skills; additionally, karate uniquely emphasize control.

Previous research has suggested that the degree to which an exercise requires complex, controlled, and adaptive cognition and movement may determine its impact on cognitive control [14]. For example, Hillman et al. [38] found that a 9-month afterschool physical activity program that included both aerobic exercise and games centered on skill themes resulted in significantly greater improvements in cognitive control compared with the control condition.

In addition, it has been suggested that open skill sports and close skill sports may impact cognitive control differently. Open skill sports refer to sports in which players need to react in a dynamically changing, unpredictable and externally paced environment, while closed skill sports refer to sports in which the sporting environment is consistent, predictable, and self-paced for the athletes [39]. Wang et al. [40] found that tennis players (i.e., open sports players) exhibited stronger cognitive control compared with swimmers (i.e., closed sports players) and sedentary controls, whereas there was no difference between the swimmers and the sedentary controls. These results indicate that open skill sports may be more beneficial for cognitive control than closed skill sports. Similarly, in the present study, karate is an open skill sport that requires the players to control and adjust themselves according to the environment; therefore, it may more impact self-control more strongly compared with cycling on a stationary bike.

Moreover, karate uniquely emphasizes "control". The kumite training in karate requires athletes to have good control in strength, speed, and mind; and the sun-dome practice in the kumite training particularly requires the athletes to bring their actions to an immediate halt just before reaching the target, regardless of the speed and ferocity of their attacking techniques. The present results suggest that repeated trainings on such practices, which require extraordinary control, not only improve participants' control during karate but also their self-control in general.

The generalizability of the training effect to learning behavior

The training effects of karate and cycling can be generalized to the students' learning behavior, enabling them to be more capable of concentrating on watching video courses accompanied by surrounding distraction. The generalizability or transferability is a major issue in research on the training of self-control. In particular, computerized training programs used in previous research have been criticized for lacking transferability or having only narrow transferability [6]. In contrast, the generalizability or transferability of martial arts and other exercises appears more promising. For instance, a previous study showed that a taekwondo intervention led to greater improvement in academic achievement compared with the control condition [26]. The present study also showed robust generalizability of the karate training effect to college students' self-control in learning behavior. The generalizability of the cycling training effect was also revealed, though it was not as robust as that of the karate training. In this sense, karate training and aerobic exercises are suitable interventions in schools, as they bring benefits to students' physical health as well as exert generalizable effects on their mind.

The effect of exercises on trait self-control

In contrast to the positive effects of physical activities on cognitive control and learning behavior, the training in the present study did not lead to significant improvement in the students' trait self-control. There may be two possible reasons underlying these null effects. First, the 4-week training might have been too short to alter the participants' trait self-control, although it did lead to improvements in their state self-control in a number of tasks. Second, the measurement of trait self-control by the questionnaire may not be sensitive enough. People may not be consciously aware of the subtle changes that occurred gradually across an extended period, and they may tend to maintain a consistent view about themselves even if they do notice some small changes. Considering that karate emphasizes character development during training, it may potentially alter the trainee's trait self-control gradually. In future studies, longer training and more effective measurements can be adopted for detecting such changes.

CONCLUSIONS

Both chronic moderate aerobic exercise and karate training can improve college students' self-control in cognitive tasks, and the training effects are generalizable to the students' learning behavior. The effects of karate training are more robust than those of aerobic exercise. Yet neither training leads to substantial improvements in the students' trait self-control after 4 weeks of intervention.

HIGHLIGHTS

- Four-week karate training and chronic moderate aerobic exercise both had direct effects on college students' cognitive self-control, while the improvement of karate training may be marginally greater than that of aerobic exercise.
- The training effects can be generalized to students' learning behavior in watching video courses.
- Four weeks of karate training or aerobic exercise does not alter students' trait self-control.

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