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Fencing expertise and physical fitness enhance action inhibition

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ABSTRACT

Objective: This study investigated the effects of fencing expertise and physical fitness on the inhibitory control of fencers and non-fencers.

Design: This study used a 2 × 2 factorial design. Fencers and non-fencers both in low-fit and averagely-fit subgroups were compared in reaction times (RT) and accuracy in simple reaction time (SRT) and go/no-go reaction time (go/no-go RT) tasks.

Method: The participants were 30 fencers (aged 18–26) and 30 non-fencers (aged 19–25), each having a different fitness level. With a standard computer keyboard, each participant performed an SRT task by responding to all stimuli. In the go/no-go RT task, each participant responded only to the go signals while withholding their response to the no-go signals.

Results: There were no significant differences between the participants with different levels of fitness or fencing expertise in SRT, go/no-go RT, omission error and commission error. However, an interaction of fitness and fencing expertise on commission error was found ($p < .05$). Averagely-fit fencers committed a similar number of errors to the averagely-fit non-fencers, but the high-fit fencers committed significantly fewer errors compared to the high-fit non-fencers ($p < .05$).

Conclusions: Fencing experience and physical fitness facilitate a person's ability to withhold action when necessary. The interactive nature of aerobic fitness and sport expertise on action inhibition suggests that cognitive control benefits most from the combination of physical and mental training compared to when each is administered singly.

Physical activities and exercise benefit physical and cognitive well-being (Hassmén, Koivula, & Uutela, 2000; Lee, Hsieh, & Paffenbarger, 1995). Among a wide range of cognitive capabilities, executive functions supported by the frontal and the prefrontal areas of brain, receive particular and substantial benefits from physical exercise (Colcombe & Kramer, 2003; Kramer et al., 1999). Consistent with this view, habitual sport or exercise participants are presumably expected to show better cognitive capabilities than their non-exercising counterparts (Ozel, Larue, & Molinaro, 2004).

Improvements in cognitive functioning are associated with the length of sport participation (Brisswalter, Collardeau, & René, 2002). Improved signal detection and perceptual abilities were observed after a single session of aerobic exercise (Gliner, Matsen-Twisdale, Horvath, & Maron, 1979; Lybrand, Andrews, & Ross, 1954). Such enhancing effects from acute exercise are similar to the state-dependent transient alternations of cognition that return to the baseline level after a short period of time. In contrast, the enhancing effects of chronic exercise are more long-lasting than those of acute exercise. In addition to the effects of exercise duration, acute and chronic exercises produce different levels of improvement in cognitive functioning. Chronic exercise results in a greater cognitive enhancement (Etnier et al., 1997; Thomas, Landers, Salazar, & Etnier, 1994).

Cognitive abilities improve after chronic involvement in sports. For example, elite basketball, volleyball and water-polo players showed better performances in a series of perceptual-motor skills than did the novice players (*e.g.*, perceptual speed, attention, and estimation of object speed and direction) (Kioumourtzoglou, Kourtesses, Michalopolou, & Derri, 1998). Theories about cognitive changes after exercise or sports training have been proposed. It is plausible that long-term involvement in sports alters neural activities or brain structures and functions. In an imaging study, increased brain volume both in the white and the gray regions was observed among older adults after aerobic training (Colcombe et al., 2006). In addition, it has been speculated that aerobic

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exercises can influence neural functions and cognitive capabilities by altering the plasticity of a person's neural system (Kramer & Erickson, 2007).

In addition to the length of sport participation, cognitive abilities are enhanced as a result of the specific demands of certain sports. For example, action inhibition, a subset of executive control, is better in players of some sports than it is in those of other sports. This shows the relation between a given sport and specific cognitive abilities. Kida, Oda, and Matsumura (2005) indicated that the response inhibition was different between baseball batters of varying skill levels, but not among tennis players of various skill levels. Hence, a differential improvement of cognitive abilities in different sports was observed. Skilled baseball batters showed stronger response inhibition ability in conflicting conditions in a go/no-go task than the amateur and novice players. In addition to baseball players, professional fencers also showed stronger action inhibition than did the novices in another study (Di Russo, Taddei, Apnile, & Spinelli, 2006).

We assume that the improved action inhibition is the result of frequent and intense conflict control developed by fencers and baseball batters in the training and subsequent competitions. Specific sport-related demands play a critical role in enhancing cognitive abilities. Fencers are required to make as few errors as possible while judging accurately and acting swiftly. Fencers are challenged by their opponents' feints or fakes in training and competitions. Sport-specific experiences lead to better cognitive abilities. For instance, elite fencers can better adapt to conflicting situations and control actions in tasks which require a high degree of concentration or attention. Similarly, baseball batters hold back their movements unless the approaching balls go to the designated area for batting. However, faking is uncommon in tennis. Tennis players require action inhibition less frequently than fencers or baseball batters. Tennis players have to return the ball as accurately and as promptly as possible. The nature of this sport provides relatively fewer opportunities for tennis players to improve action inhibition. Thus, it is possible that frequent experience of certain cognitive demands improves those cognitive abilities.

Although previous research shows the differences in cognitive ability between athletes and non-athletes and claims that sport training is the cause, the effect of a potential confounding variable such as fitness level has not been examined. A recent ERP study reported that physical fitness could modulate the neural-electric activities for executive control after acute exercise, thus complicating the interpretation of previous results (Stroth et al., 2009). Specifically, professional athletes have higher fitness levels than non-athletes. It is likely that fitness rather than exercise *per se* leads to superior cognitive functioning. Previous studies suggested that fitness plays a role in modulating action-inhibitory control among elderly people (Bixby et al., 2007; Kamijo et al., 2009). Elderly people with a higher fitness level lose less brain tissue in the frontal, parietal and temporal cortices than their less fit counterparts. The results suggested that fitness serves as a protective function for people against neural degenerations (Raz, 2002). Thus, the different cognitive capabilities observed in athletes and non-athletes may be caused by various levels of physical fitness, sport experiences, or the interaction of both factors. This issue, however, has not been addressed in the literature. Without knowing the interactive effects of fitness levels and sports expertise on cognitive functioning, we cannot know whether the conclusions drawn from previous studies about cognitive enhancement from exercise or sport training are valid.

The purpose of this study is to shed light on the relation between physical fitness and sport experience and their collective effects on the enhancement of cognitive capability. Although independent effects of fitness and sport experience were found in previous research, the relationship between physical fitness and sport experience has not been investigated. Thus, we examined the effects of physical fitness and sport experience on the executive functioning of fencers and non-fencers. We specifically examined the action-inhibitory ability of fencers and non-fencers with high and normal fitness levels. To accomplish this goal, we used a go/no-go reaction time (RT) task to examine inhibitory control. We expected that participants with better inhibitory control would commit fewer errors in the task. In addition, we used a simple RT task as a control measure of motor speed. This test could provide evidence that the differences observed in the go/no-go RT task were not explained by the differences in motor abilities among participants. Moreover, we examined the effects of practice and fatigue on performance to exclude potential confounding impacts on our results.

We had three specific hypotheses. Firstly, although a positive relationship between fitness level and executive function has been found among the older adult population, such an effect has not been observed among young adults in behavioral studies (Chodzko-Zajko, 1991). We expected no significant difference between participants of different fitness levels in the measure of response accuracy in the go/no-go RT task. Secondly, we hypothesized that the fencers would commit fewer errors than the non-fencers. Fencers could better inhibit their actions than non-fencers (Di Russo et al., 2006). Finally, previous studies suggested that both fitness and sport training are related to the enhancement of executive control. We therefore hypothesized that there would be an interactive effect of fencing expertise and fitness level on inhibitory control.

Method

Participants

There were a total of 60 participants: 30 fencers (15 females and 15 males, with 5 years or more fencing experience, practiced 5–6 times a week, $M = 20.63$ years, $SD = 2.11$ years); and 30 college students (15 females and 15 males, no prior experience in fencing, $M = 20.63$ years, $SD = 2.11$ years). The gender ratio was the same both for the fencers and the non-fencers. All subjects had normal or corrected-to-normal vision and had no history of psychiatric and neurological disorders. Fencers and non-fencers were divided into two subgroups on the basis of a median split according to their questionnaire estimated VO_{2max}. The fencers' fitness level, indexed by the estimated VO_{2max}, was not significantly different from that of the non-fencers' ($p = .13$). The high-fit subjects had a significantly higher estimated VO_{2max} than the averagely-fit subjects ($p < .001$). Informed consent approved by the Research Ethical Committee of the Chinese University of Hong Kong was obtained from each subject. Each subject received HK$50 for participation. Table 1 shows the demographics of each group.

Stimuli

Fig. 1 shows the stimuli for both RT tasks. White visual stimuli (10 cm × 10 cm) were presented at the center of the screen against

Table 1
Demographic information of the participants in four experimental groups.

Group[a]	Age	Fitness scores
Averagely-fit non-fencers	20.87 (1.46)	43.24 (3.92)
High-fit non-fencers	20.07 (1.10)	51.51 (7.01)
Averagely-fit fencers	20.53 (2.85)	45.87 (4.23)
High-fit fencers	21.07 (2.58)	53.83 (2.96)

Note. Fitness level is indexed by the questionnaire estimated maximal oxygen uptake, VO_{2max} (mL kg^{-1} min^{-1}). SD is presented in parentheses.
[a] $N = 15$, comparable gender composition for each group.