Does Sport Addiction Enhance Frontal Executive Function? The Case of Badminton

Minji Kwon, Yujin Kim, Hyunji Kim, Jingu Kim

ABSTRACT

The present study aimed to investigate the frontal executive functions of a badminton addiction group (BAG), moderate badminton group (MBG), and avoidance group (AG). The Korean Exercise Addiction Scale was used to evaluate each participant's addiction status. An oddball paradigm was adopted using Go/NoGo tasks with auditory stimulation. The dependent variables were N200 and P300 amplitudes and latencies. The results revealed that the MBG exhibited a larger P300 amplitude than did the BAG and AG, whereas P300 latency was found to be shorter in the BAG than in the MBG and AG. The N200 amplitude was observed to be smaller in the MBG than the BAG and AD, while N200 latency was found to be shorter in the BAG and the AG than in the MBG. These results highlight that badminton addiction is positively correlated with cognitive functions, which contrasts with results of previous studies that indicated negative psychological consequences.

Key Words: Exercise Addiction, P300, N200, Executive Function, Badminton

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Introduction

Psychologically, exercise addiction refers to the phenomenon of becoming anxious, depressed, or nervous when a person is deprived of exercise and is unable to suppress a desire for exercise (Cumella, 2005; Ryu *et al.,* 2016, Sachs, 1981). Exercise addiction is accompanied by dependency and withdrawal symptoms (Landolfi, 2013). Especially when deprived of exercise, physical and psychological symptoms such as nervousness, anxiety, discomfort, restlessness, idleness, loss of appetite, demotivation, headaches, and eating disorders are reported to appear (Lichtenstein *et al.,* 2014; Conboy, 1994; Krivoschekov & Lushnikov, 2011; Pierce, 1994). Exercise withdrawal may also lead to cognitive problems such as diminished concentration and judgment (Lee, Hong, & Kim, 2009). In previous studies, the concept of exercise addiction has been discussed widely under various different terms such as "excessive exercise" (Davis & Fox, 1993), "negative exercise" (Furst & Germone, 1993), "obsessive exercise" (Thornton & Scott, 1995), "exercise dependence" (Adams & Kirkby, 1997, 1998), "obligatory exercise" (Brehm & Steffen, 1998), and "habitual runners" (Powers, Shocken, & Boyd, 1998).

Although many previous studies have investigated the effects of exercise addiction on affect and psychological functioning, only few have examined its effects on cognitive function. An example of the latter is a recent study by Ryu *et al.,* (2016), which investigated frontal executive functions in exercise addicts in comparison with those in exercise avoiders and moderate exercisers; this study revealed superior task switching abilities, larger P3 amplitudes, and smaller N2 amplitudes with shorter P3 and N2 latencies in exercise addicts than in other participants. These results suggest that unlike other types of addiction such as gambling addiction (Goudriaan, Oosterlaan, De Beurs &

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Van Den Brink, 2006; Ledgerwood *et al.,* 2012), alcohol addiction (Goudriaan *et al.,* 2006; Lubman, Yücel & Pantelis, 2004), and Internet addiction (Dong, Zhou & Zhao, 2011; Zhou, Yuan & Yao, 2012), exercise addiction does not have negative effects on cognitive functions, but may rather improve neural efficiency.

Notably, unlike other behavioural addictions, exercise addiction does not negatively affect cognitive function. In the cases of addiction to alcohol, the Internet, and gambling, addicts have exhibited delayed reaction times and smaller N200 and P300 amplitudes with longer latencies (Dong *et al.,* 2011; Morie, De Sanctis, Garavan & Foxe, 2014), reflecting their weaknesses in stimulus recognition, cognitive processing (N200), and decision making (P300).

However, Ryu *et al.,* (2016) proposed that exercise addiction has positive effects on cognitive control. A plethora of studies on the relationship between exercise and cognitive function, although not focusing in particular on exercise addiction, have reported a positive effect of exercise on cognitive functions, such as executive function (Chang, Laban, Gapin, & Etnier, 2012; Guiney & Machado, 2013; Smith *et al*., 2010). Davis *et al*., (2011) also argued that aerobic exercise improved cognitive performance by increasing frontal cortical activity and reducing posterior parietal activity. In addition, it is accepted that regular exercise (Hillman, Kramer, Belopolsky, & Smith, 2006; Kamijo & Takeda, 2010), high intensity exercise (Baker *et al*., 2010; Brown *et al*., 2012), and daily physical activity (Eggermont *et al*., 2009) also have beneficial effects on cognitive control and function.

To date, studies examining the relationship between exercise and cognition have found little evidence that exercise has a negative effect on cognitive function. However, in some studies examining exercise addiction from a psychological perspective, such excessive exercise is reported to have a negative influence on mental health (Berczik *et al*., 2012), psychological functioning (Broman-Fulks, Kelso, & Zawilinski, 2015), and emotion (Gapin, Etnier, & Tucker, 2009). The question is why exercise addiction has a negative impact on mental health but a positive impact on cognitive function. As there has only been a single study investigating cognitive function in exercise addicts, there appeared to be the need for a follow-up study elucidating whether Ryu *et al.'s* (2016) conclusion that exercise addiction has a positive effect on executive function can be generalised.

Therefore, this study aimed to examine the frontal executive function in subjects addicted to badminton neurophysiologically using a Go/Nogo task. Based on the findings by Ryu *et al.,* (2016), it was expected that the badminton addiction group would exhibit larger P300 amplitudes with shorter latencies and smaller N200 amplitudes with shorter latencies compared to moderate player group and avoidance group.

Methods

Participants

A total of 125 questionnaires were collected from various badminton clubs in Daegu, and 45 respondents (30 men and 15 women) were selected as the study participants. The participants were aged 20-29 years (mean = 22.06), had badminton experience of 1-3 years, and played badminton for 7-10 hours per week. The Korean Exercise Addiction Scale (KEAS) (Kang, 2009) was used to evaluate each participant's addiction status. Based on the KEAS scores, the top 20% was defined as the badminton addiction group (BAG) (n = 15), the middle 50% as the moderate badminton group (MBG) (n = 15), and the bottom 20% as the badminton avoidance group (AG) (n = 15). No participants had previous experience with similar experiments and all were free of neurological impairments. The study was conducted after receiving written informed consent from all participants and approval from the Kyungpook National University research ethics committee.

Materials

The KEAS consists of 18 questions covering five aspects of exercise addiction: withdrawal symptoms, conflict, affection, tolerance, and obsession. A score of more than 63 qualifies a person as an exercise addict. A score of less than 30 indicates exercise avoidance, and scores between 40 and 45 were classified as normal. The test-retest reliability of KEAS ranges from .70 to .87, and the reliability of all sub-factors is very high.

Task and experimental paradigm

In order to examine the frontal executive functions, an oddball paradigm using Go/NoGo tasks with auditory stimulation was adopted. The Go and NoGo stimuli were beep sounds of 2000 and 1000 Hz, respectively. A total of 300 stimuli

(20% Go and 80% NoGo) were presented in a randomised order. Each stimulus was presented for 500 ms with an inter-stimulus interval of 1500 ms. Participants were asked to press the button as quickly as possible on Go stimuli and not to respond to NoGo stimuli. The experimental task design is presented in Figure 1.

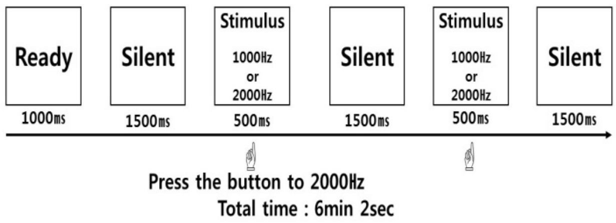

Figure 1. Go/NoGo task

Procedure

Upon arriving at the laboratory, participants were informed about the purpose, procedure, and task of the experiment. After signing an informed consent form, each participant was seated in a comfortable chair and all metal objects that could interfere with data collection were removed from his/her body. Impurities were removed from the skin by wiping with alcohol cotton pads, and head circumference was measured so that an electrode cap could be fitted according to the International 10-20 electrode arrangement method (Jasper, 1958). Ag/AgCl gel was injected into the scalp at the electrode sites of Fp1, Fp2, F3, Fz, F4, F7, F8, Cz, Pz and Fpz serving as a ground. Continuous EEG data were referenced online to the right earlobe (A2), while the signal from the left earlobe (A1) was used for an averaged ear reference to reduce lateral bias. For all channels, impedance levels were maintained at less than 5 kΩ. The participants were instructed to avoid any unnecessary body movements, including blinking or swallowing, during the experiment. Participants were also informed that they were free to withdraw from the study at any time. The stimulus was presented using a screen and speaker positioned at a 60-cm distance from the participant's eye.

Data collection and analysis

EEG data were obtained using QEEG-8 (LXE5208, LAXTHA Inc., Daejeon, South Korea) and analysed using the TeleScan (version 3.2.3) software. The collected raw data were processed through ensemble averaging with a Telescan Analysis tool. All raw data including EEG activity and response times were converted into a text file, and the peak amplitudes and latencies of N200 and P300 were analysed using the Signal Analysis application.

Statistical analysis

To examine the effects of badminton addiction on the ERP measures, 3 (group) × 2 (task) × 8 (site) three-way analysis of variance (ANOVA) was conducted. The dependent variables were the N200 and P300 amplitudes and latencies. Tukey's honestly significant difference test was used for post-hoc tests. One-way ANOVAs were performed to verify group differences in reaction time and response accuracy. The statistical significance threshold was set to $\alpha = .05$.

Results

Reaction time

In the analysis of reaction time, a main effect of group [$F(2, 42) = 3.072$, $P < .001$, $\eta p^2 = .982$] was revealed. In the post hoc tests, the BAG (M = 0.54, SD = 0.09) showed faster reaction times relative to the MBG (M = 0.55, SD = 0.05) and AG (M = 0.60, SD = 0.09).

Response accuracy

In the analysis of response accuracy, the AG showed higher accuracy than the MBG and BAG; this effect, however, did not reach statistical significance [$F(2, 42) = 2.938$, $P > .05$, $\eta p^2 = .123$).

P300 amplitude

In the analysis of P300 amplitude, significant main effects of group [$F(2, 672) = 35.286$, $P < .001$, $\eta p^2 = .095$], task [$F(1, 672) = 25.423$, $P < .001$, $\eta p^2 = .036$], and site [$F(7, 672) = 2.806$, $P < .01$, $\eta p^2 = .028$] were found. A Group × Task interaction effect [$F(14, 672) = 13.464$, $P < .001$, $\eta p^2 = .039$] was also significant. In the post *hoc* test for the group main effect, the MBG exhibited a larger P300 amplitude compared to the BAG and AG. A post *hoc* comparison between tasks showed that the P300 amplitude for the target stimulus was larger than for the standard stimulus. Post *hoc* testing also revealed that the Cz site exhibited a smaller P300 amplitude relative to the Fp1, Fp2, F3, and F4 sites, while Fp1 and Fp2 showed a greater amplitude than F7 and F8(Figure 3). Post *hoc* tests for Group × Task interaction showed a greater P300 amplitude in the BAG than in the MBG and AG for target stimuli, whereas the MBG showed greater P300 amplitudes for the standard stimuli (Figure 2. a.). Interaction effects for Group × Site [$F(2, 672) = .631$, $P > .05$, $\eta p^2 = .013$], Task ×

Site [$F(7, 672) = 1.512$, $P > .05$, $\eta p^2 = .016$], Group × Task × Site [$F(14, 672) = .167$, $P > .05$, $\eta p^2 = .003$] were not observed.

P300 latency

In the analysis of P300 latency, significant main effects emerged for group [$F(2, 672) = 183.215$, $P < .001$, $\eta p^2 = .353$], task [$F(1, 672) = 167.812$, $P < .001$, $\eta p^2 = .200$], and site [$F(7, 672) = 2.702$, $P < .01$, $\eta p^2 = .027$], with an interaction effect of Group × Task [$F(2, 672) = 179.351$, $P < .001$, $\eta p^2 = .348$]. Post *hoc* tests revealed that the P300 latency was longer for the MBG than the BAG and the AG, while it was shorter for the target stimulus than for the standard stimulus (Figure 2. b.). In addition, post hoc tests found that P300 latency was shorter at Cz compared to other regions (Figure 3). Post *hoc* comparisons for interaction effects revealed no significant difference between the groups for the target stimulus; however, the MBG showed a shorter P300 latency than the AG and BAG for the standard stimulus. Significant interaction effects did not emerge for Group × Site [$F(14, 672) = 1.056$, $P > .05$, $\eta p^2 = .022$], Task × Site [$F(7, 672) = 1.667$, $P > .05$, $\eta p^2 = .017$], and Group × Task × Site [$F(14, 672) = .944$, $P > .05$, $\eta p^2 = .019$].

N200 amplitude

In the analysis of N200 amplitude, significant main effects of group [$F(2, 672) = 7.650$ $P < .01$, $\eta p^2 = .022$], task [$F(1, 672) = 18.686$, $P < .001$, $\eta p^2 = .027$], and site [$F(7, 672) = 4.256$, $P < .001$, $\eta p^2 = .042$] were found. Post *hoc* tests revealed that the N200 amplitude was larger in the AG relative to the BAG and the MBG, with no significant difference between the BAG and MBG (Figure 2. c.). N200 amplitude was larger for the target stimulus compared to the standard stimulus. In addition, N200 amplitude was smaller at Fp1 and Fp2 compared to F4, Fz, and Cz, while Cz showed a larger amplitude than all other sites (Figure 3). Interaction effects were not significant for Group × Task [$F(2, 672) = 2.001$, $P > .05$, $\eta p^2 = .006$], Group × Site [$F(14, 672) = .299> .05$, $\eta p^2 = .006$], Task × [$F(7, 672) = .453$ $P > .05$, $\eta p^2 = .005$], and Group × Task × Site [$F(14, 672) = .112$, $P > .05$, $\eta p^2 = .002$].

N200 latency

In the analysis of N200 latency, a significant main effect of group [$F(2, 672) = 7.079$, $P < .01$, $\eta p^2 = .021$] emerged. Post *hoc* tests revealed a longer N200 latency in the MBG than in the AG and BAG (Figure 2. d.). Neither the main effects of task [$F(1, 672) = .002$, $P > .05$, $\eta p^2 = .000$] and site [$F(7, 672) = .324$, $P > .05$, $\eta p^2 = .003$] nor the interaction effects of Group × Task [$F(2, 672) = 1.603$, $P > .05$, $\eta p^2 = .005$], Group × Site [$F(14, 672) = .149$, $P > .05$, $\eta p^2 = .003$], Task × Site [$F(7, 672) = .670$ $P > .05$, $\eta p^2 = .007$], and Group × Task × Site [$F(14, 672) = .610$, $P > .05$, $\eta p^2 = .013$] reached statistical significance.

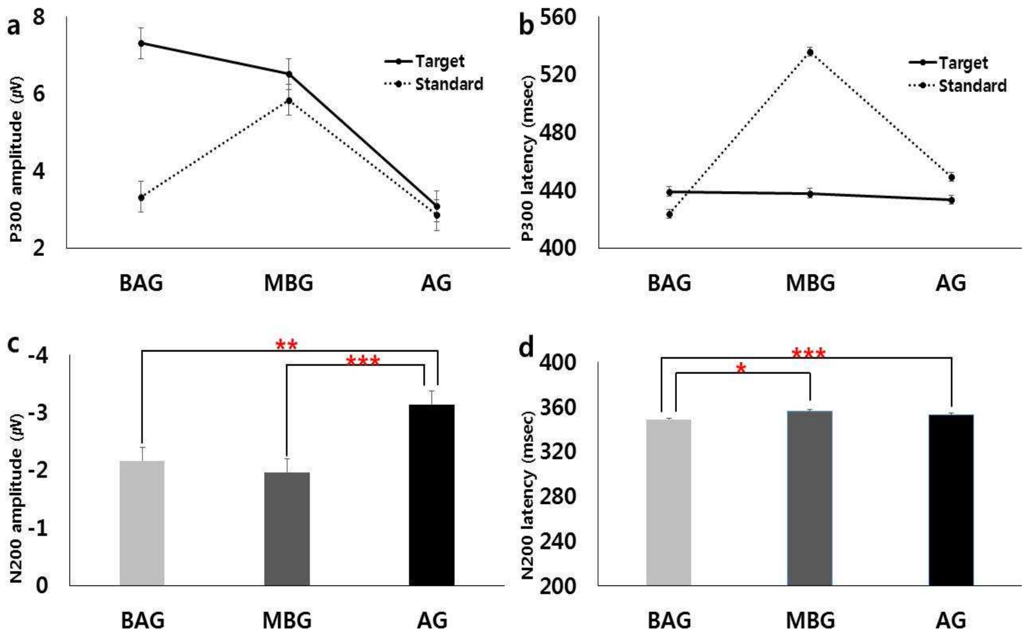

Figure 2. a. P300 amplitude as a function of group and task b. P300 latency as a function of group and task c. N200 amplitude by group d. N200 latency by group

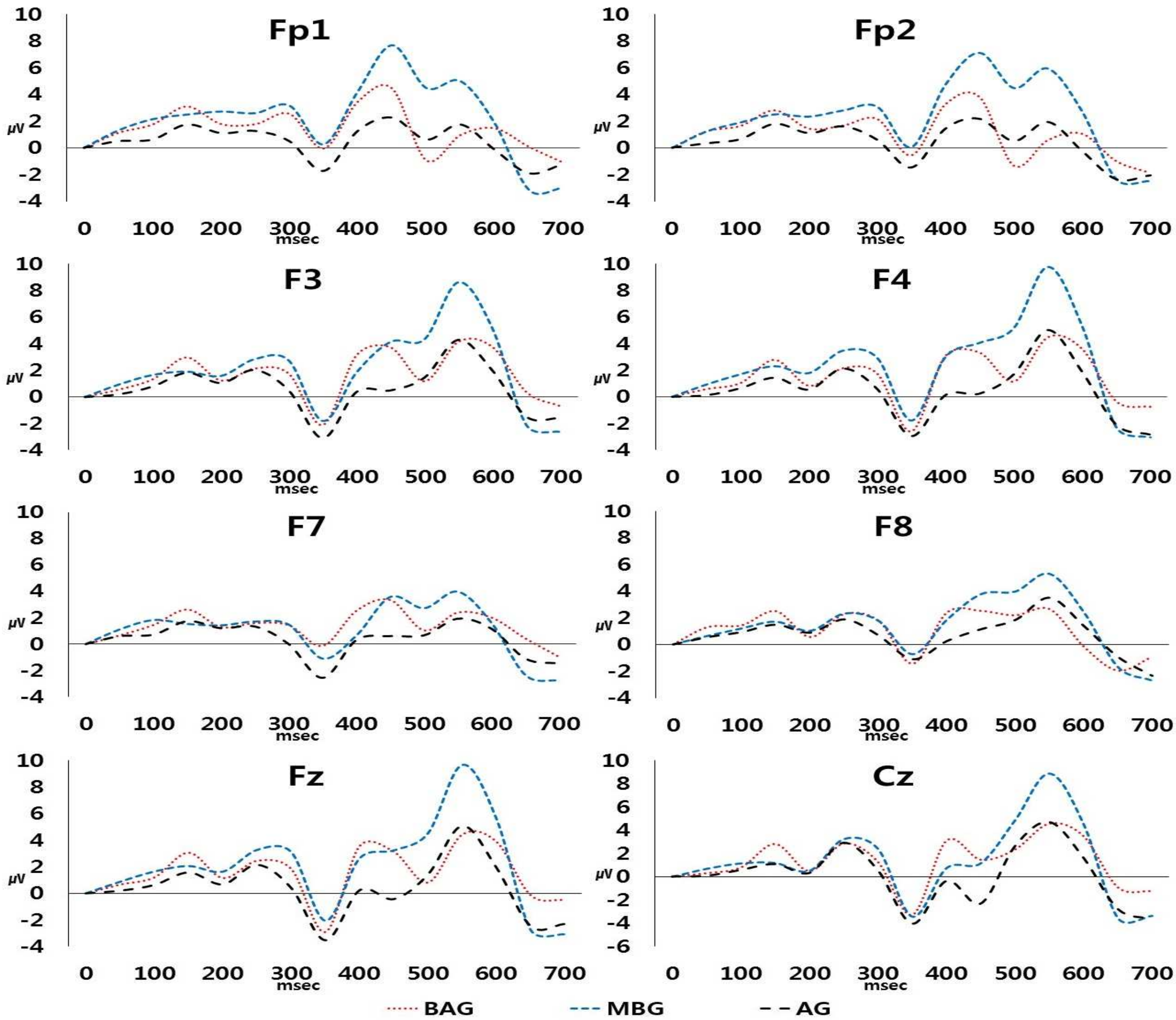

Figure 3. Average waveforms by group and site

Discussion

The present study aimed to investigate the frontal executive functions of a badminton addiction group (BAG), moderate badminton group (MBG), and avoidance group (AG). We found that the BAG exhibited shorter reaction times compared to the MBG and AG, and it seems plausible to attribute these to extensive badminton practice over a long period of time. This claim is supported by Dube, Mungal, and Kulkarni (2015) who revealed that the visual response time of badminton players was shorter than that of a control group. The finding of shorter reaction times of the BAG in the present study suggests that badminton addiction differs from other behaviour or substance addictions such as Internet, alcohol, drug, or cocaine addiction (Dong *et al.,* 2011; Morie *et al.,* 2014; Ryu *et al.,* 2016) in terms of its effect on cognitive functioning.

The results show larger P300 amplitudes in the MBG than in the BAG and AG. P300 amplitude is closely related to attention and decision making regarding a given stimulus (Johnson, 1988). Higher P300 amplitude indicates greater confidence in decision making (Hillyard, Squires, Bauer, & Lindsay, 1971). In this study, the BAG was found to show a lower P300 amplitude than the MBG. Our suggested reason for this finding is that badminton is a high-intensity sport that activates a broad range of muscle groups and consumes a lot of energy compared to other forms of exercise (Sarshin, Mohammadi, Shahrabad, & Sedighi, 2011; Raman & Nageswaran, 2013); thus, it could be hypothesised that fatigue with a decreased capacity for attention and concentration due to continued high intensity exercise might have affected a delay in cognitive processing in the BAG participants. Many studies support this interpretation by reporting that high intensity exercise reduces cognitive function more than low or moderate intensity exercise does (Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007;

Kamijo *et al.,* 2009; McMorris & Hale, 2012). In addition, Dietrich (2003) and Dietrich and Audiffren (2011) reported that moderate exercise using the reticular-activating hypofrontality (RAH) model improved performance by increasing attention and arousal, while excessive exercise led to increased activation in the premotor and supplementary motor cortex with reduced activation in the frontal area, resulting in a decline in cognitive abilities. The higher P300 of the MBG is also consistent with previous studies (Kamijo *et al.,* 2007; Kamijo *et al.,* 2009; McMorris & Hale, 2012) which argued that moderate exercise is helpful in activating cognitive function. In addition, McMorris & Hale (2012) and McMorris, Sproule, Turner and Hale (2011) support the findings of the present study by arguing that moderate exercise can increase neurotransmitters and the level of arousal, which facilitates cognitive performance.

P300 latency reflects the speed of information processing during decision making (Patel & Azzam, 2005), and in this study, was found to be shorter in the BAG than in the MBG and AG. These results indicate that the speed of information processing was higher in the BAG than in the MBG and the AG during the experiment. The reason for this appears to be the group difference in reaction time as a function of the amount of exercise affecting information processing speed; BAG participants exercised longer and more often than the MBG participants and thus trained for shorter reaction times. According to existing studies, physical activity promotes the production of brain-derived neurotrophic factor (BDNF) and shortens reaction times (Chang, Huang, Chen, & Hung 2013; Ebersbach *et al.,* 2014). In particular, it is known that with boosted BDNF levels cognitive processing improves and information processing speed increases (Ferris, Williams, & Shen, 2007; Tang, Chu, Hui, Helmeste, & Law, 2008). Lee *et al.,* (2014) also suggested that physical activity shortens reaction times and increases BDNF concentration. Hillman *et al.,* (2006) argued that physical activity shortens P300 latency and increases information processing speed. Although these previous studies have not investigated specifically subjects addicted to exercise, it is accepted that exercise improves cognitive functioning as the present study suggests. The present study found that unlike e.g. gambling (Goudriaan *et al.,* 2006; Ledgerwood *et al.,* 2012) and drug addiction (Lundqvist, 2005; Morie *et al.,* 2014), exercise addiction has a positive effect on cognitive processing speed, as Ryu *et al.,* (2016) suggested.

N200 amplitude was observed to be smaller in the MBG than in the BAG and AD. This ERP represents the intensity of cognitive processing associated with recognition and distinction of a given stimulus (Woods, 1990) and cognitive information processing related to response suppression (Mattler, van der Lugt, & Münte; (Donkers & Van Boxtel, 2004). The smaller the N200 amplitude, the easier it is to recognise the stimulus (Donkers & Van Boxtel, 2004). The larger N200 amplitude in the BAG and AG may indicate that these two groups found it more difficult to distinguish between the stimuli or inhibit responses to a given stimulus. In general, when dealing with a task with difficult-to-distinguish stimuli, the activity of the anterior cingulate cortex increases, which is known to boost the N200 amplitude (Patel & Azzam, 2005; Yeung, Botvinick, & Cohen, 2004). On the other hand, the lower N200 amplitude observed in the MBG seems to reflect improved cognitive function because of moderate exercise. The lower N200 amplitude of the MBG found in this study supports findings from previous studies which argued that moderate and low intensity exercise has a more positive effect on cognitive function than high intensity exercise (Kamijo *et al.,* 2007; Kamijo *et al.,* 2009; McMorris & Hale, 2012). The difference in N200 amplitude observed in the present study suggests that one's ability to process information and suppress responses may weaken with either continued excessive exercise or no exercise.

N200 latency was found to be shorter in the BAG and AG than the MBG. N200 latency is known to reflect response conflict (Nieuwenhuis, Yeung, Van Den Wildenberg & Ridderinkhof, 2003) and cognitive and behavioural processing time associated with response inhibition (Falkenstein, Hoormann, & Hohnsbein, 1999; Mattler *et al.,* 2006). Therefore, the shorter latency in the BAG may imply that regular and intensive exercise improves behavioural and cognitive processing functions. This study supports the results of a previous study (Yagi, Coburn, Estes, & Arruda, 1999) showing that regular exercise reduces the latency of the N2, and is consistent with the study of Ryu *et al.*, (2016) which reported shorter N200 latency in both subjects addicted to exercise and exercise avoiders compared to moderate exercisers. Our results suggest that exercise addiction has no negative effect on cognitive functioning; rather, exercise addiction has the potential to improve executive function.

However, surprisingly, the AG also showed shorter N200 latencies than did the MBG. A possible explanation of this observation is that the subjects in the AG may have pressed the arrow button more quickly because they were paying less attention to following the task instructions, rather than because their stimulus discrimination process or cognitive control were superior to those of BAG and MBG participants. In brief, AG participants were fast (short N200 latency), but often pressed the wrong button (showing a lower response accuracy, however with the difference not reaching statistical significance). Sedentary individuals tend to be passive, which may account for their poor attention to a given task. On the other hand, N200 latency in drug and gambling addicts has been reported to be prolonged (Smith, Johnstone, & Barry, 2008).

In conclusion, the BAG exhibited faster reaction times than did the MBG and AG, and the N200 and P300 latencies were shortest in the MBG. The AG participants showed the largest N200 amplitudes on average, while their P300 amplitudes were the lowest. To examine executive functions in the BAG, MBG, and AG, the P300 and N200 results were analysed, which led to the following conclusion: addiction to sport, particularly badminton, enhances executive function, unlike other addictions, which deteriorate cognitive function. These results highlight that sport addiction is positively correlated with cognitive function, which is in contrast to previous studies indicating negative psychological consequences. Further studies are required to examine cognitive function in relation to addiction in various different sports.

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