Physical Exercise Training to Enhance Executive and Social Functions

May 17th, 2021

Background

Executive function and social functioning

Executive functions (EF) refer to goal-directed cognitive processes consisting of three major components including cognitive flexibility (mental flexibility), inhibition (inhibitory control) and working memory (Diamond, 2013). These components interact with each other and play a crucial role in a range of life outcomes including mental and physical health (Barch, 2005; Miller, Barnes, & Beaver, 2011), school and job success (Bailey, 2007; Duncan et al., 2007) and marital harmony (Eakin et al., 2004). In addition, higher EF is associated with better problem solving, reasoning and planning skills (Diamond, 2013) as well as social functions.

Relationship between executive and social function and autism spectrum disorder

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterised by social communication and interaction impairments, as well as restricted and repetitive patterns of behavior (American Psychiatric Association, 2013). Individuals with ASD have EF impairments which are linked to the restricted and repetitive behaviors that characterise this condition (Robinson et al., 2009). The prevalence of ASD is increasing with as many as 1 in 68 individuals (CDC, 2018), which further augments the burden to the ASD individuals, their families and society (Baron-Cohen et al., 2009; World Health Organization, 2005a). Hence, it is essential to investigate the underlying mechanism of ASD and design a cost-effective training that can be widely adopted in the community to reduce impairments arising from ASD symptoms.

Importantly, ASD traits occur on a continuum, and increasingly there is recognition of a broader autism phenotype (BAP) (e.g., see Dawson et al., 2002) in those that show sub-clinical symptoms. Similarly, these individuals also show impairments in executive function (e.g., Hill, 2004) and social functions, making this group an important target for the development and implementation of interventions. As such, we can deliver appropriate training at an earlier stage to prevent associated impairments in those with ASD traits. Therefore, instead of ASD, the present study examines the individuals with BAP.

The role of physical exercise on executive and social function in autistic individuals

Given EF impairments along with social function deficits are found in the sub-clinical individuals with BAP (Hill, 2004), is the training pertaining to ASD applicable to these individuals? In prior literature, physical exercise (PE) has been proved to enhance EF (Best, 2010) and social functions (Sowa & Meulenbroek, 2012). For instance, regular PE can enhance cerebral blood flow and increase the formation of new blood vessels in a number of brain regions that are involved in EF and social functions (e.g., Colcombe & Kramer, 2003). More specifically, PE is shown to enhance the performance of EF in healthy children and pre-adolescents (Best, 2010) and those with ASD (Lang et al., 2010). For example, Lang et al. (2010) and Lochbaum and Crews (2003) found that PE including jogging significantly decreased the repetitive and off-task behaviors and the level of aggression in individuals with ASD. Nevertheless, although PE is shown to be beneficial to reduce the symptoms and EF as well as social impairments in ASD, whether it produces the same positive outcomes on enhancing EF and social functions in the non-clinical population remains to be answered.

To address the research questions listed above, this proposed study aims to investigate whether PE training enhances the EF and social functions in the adolescents with BAP.

Research plan and methodology

Participants

To detect possible differences between the means of the primary measure with a power of 80%, eighty adolescents from secondary schools in Hong Kong and Australia will be recruited in this study (Hopkins et al., 2009). Written informed consent will be obtained from all participants. For participants who are below 18 years old, the consent from their parents or guardians will be obtained. Based on their self-reported autistic traits measured by Autism- Spectrum Quotient- Adolescent Version (details listed below), they will be categorized into two groups: 1) typically developing group (low ASD traits) and 2) BAP group (high ASD traits). To be included in the study, they must meet the following criteria: a) age ranges from 7 to 20; b) studying at one of the primary and secondary schools in Hong Kong; c) have never been diagnosed with ASD or any other disorder listed in the Fifth Edition of *Diagnostic and Statistical Manual* of Mental Disorders (DSM-V); and d) are not currently under any psychiatric medications or therapies.

Randomization. This study consists of a double-blind, and randomized controlled trial (RCT). After obtaining the informed consent, participants will be randomized into two conditions (1. physical exercise (PE) training group or 2. control group) using urn randomization, a covariate adaptive randomization method. A trained research assistant or a fitness trainer will be responsible to monitor and ensure the safety of the training process.

Physical exercise training. The PE training will adapt the exercise training employed by Lochbaum & Crews (2003) and Nicholson et al. (2011) since they targeted adolescents with ASD and the protocol of training can easily be replicated. The entire PE training lasts for six weeks and participants need to participate in a total of 12 sessions. In each session, every participant will be trained to run for 30 minutes on a treadmill. According to Exercise and Sports Science Australia (ESSA) exercise intensity guidelines, the intensity of running is suggested to be moderate and vigorous (alternating between the two) in this proposed study.

Control group. Participating adolescents in the control group will not receive any treatments. They are considered as waitlist controls.

Measures

The following self-reported measures will be administered at the baseline, post-training and 1-year follow-up.

Demographics. A simple demographic questionnaire will be used to gather participants personal information, including age, gender, current medication or therapy, and medical history of the participant and his/her family members. Besides, the blood pressure and heart rate of the participants will be assessed by electrocardiogram.

Autistic traits. The Autism-Spectrum Quotient-Adolescent Version (AQ-Adolescent; Baron-Cohen et al., 2006) and related self-report scales will be used to measure ASD traits. The AQ- adolescent is a self-report questionnaire comprising of 50 items assessing five areas, namely social, attention switching, attention to detail, communication and imagination. Participants will be asked to rate each item on a four-point Likert scale. The AQ-Adolescent received an excellent test-retest reliability (r = .92; Baron-Cohen et al., 2006) and a good internal consistency (α = .88, Sonié et al., 2013).

Executive functions and social functions. EF and social functions will be measured using the Cambridge Neuropsychological Test Automated Battery (CANTAB).The CANTAB is a computerized test battery targeting multiple neuropsychological functions that has been validated in different cultures (De Luca et al., 2003). This battery includes Reaction Time, Paired Associates Learning, Spatial Working Memory, One Touch Stockings of Cambridge, Multitasking Test, and Emotion Recognition Task. Besides

the CANTAB, participant's psychological well-being including resilience and mental health will be measured.

Implications

Although the benefits of physical exercise have been studied in the ASD, BAP is under studied in prior literature. This proposed study will extend from the current literature to investigate the non-clinical group who have autistic traits with a longitudinal and randomized controlled trial design (RCT). The findings of this proposed study have multiple levels of significance and implications. For instance, if the hypotheses are supported, the PE training which is more cost-effective than psychotherapy in treating EF and social functioning deficits and associated impairments can be promoted to school settings. Ultimately, it can be incorporated to the curriculum of the primary and secondary schools to reduce BAP and associated impairments in the adolescents. Secondly, by examining those with sub- clinical symptoms, this research will contribute to early trainings approaches for the condition. Lastly, this proposed study can also help promote physical activities among adolescents which can further decrease mental and health issues in Hong Kong (MacDonald et al. 2011).

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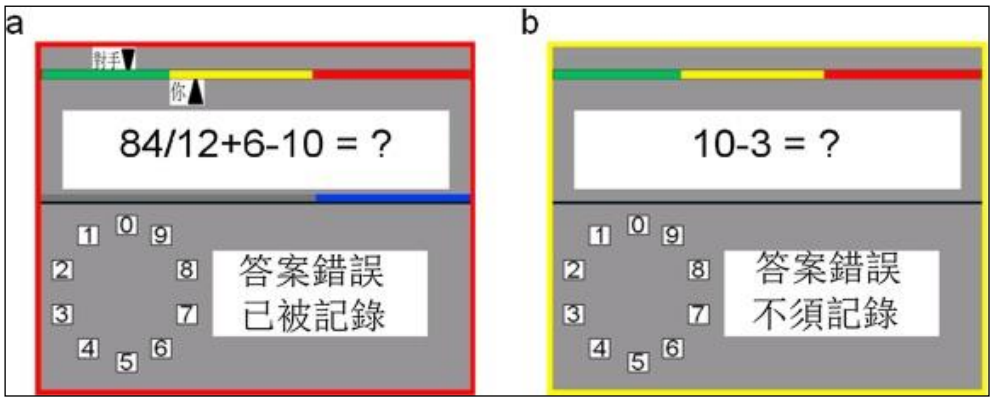
Appendix 1

‘Reading the Mind in the Eyes’’ Task

In the ‘‘Reading the Mind in the Eyes’’ task, the participants will first see a word labeling either a mental/emotional state (e.g., embarrassed) or a gender (e.g., female). The word is then replaced with a fixation cross, and then a picture of eyes. Participants will determine whether the eyes depicted the emotion or gender labeled by the word choices by pressing corresponding key.

Appendix 2

Montreal Imaging Stress Task (MIST)



The Montreal Imaging Stress Task (MIST) is a neuroimaging-adapted psychosocial stress task that uses mental arithmetic to combine the key situational components for eliciting stress response, including presence of social evaluative threat, atmosphere of high achievement, and low controllability.