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Acute Exercise and Cognitive Functions: International History and Research Development in Taiwan

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Acute exercise and cognitive function have become significantly related attentional topics in the international academic society. Taiwan's research team was not only connected to, but also directly involved in research within its own society on this topic. The purpose of this literature is to review studies about acute exercise and cognitive function and further to introduce the international history and studies established by Taiwan team. Specifically, the present review discussed classical reviews and a meta-analysis conducted by international and our teams and these results demonstrated positive and causal relationship between acute exercise and cognition. Afterward, we began to focus on moderators related to acute exercise and cognition and different individual backgrounds for conducting follow-up studies and further explore the brain mechanisms related to acute exercise and cognition. Finally, we here provide future directions and summarized findings of past studies. It is hoped that readers will have more reference to connect international academic society in the future.

Keywords: *physical activity, executive function, neuroscience, exercise prescription*

Extended Abstract

The relationship between exercise and cognitive functions has become a significant focus of international research attention. According to the PubMed database, research into the relationship between exercise and cognitive functions started in 1984 and has continued to expand since then (*Figure 1*). Taiwan's research team has been not only connected to, but also directly involved in research on this topic within its own society. Exercise paradigms can be divided into two types: acute (a single bout of exercise) and chronic (repeated bouts of exercise within a period of time). The present review focuses on issues related to acute exercise and cognitive functions. The review first introduces the topic's international history, and then discusses the studies established by our research team exploring moderators (cognition and exercise variables, individual background variables) and mechanisms using different brain assessment approaches (i.e., event-related potentials [ERP], functional magnetic resonance imaging [fMRI], biological indices) (*Figure 2*). Finally, the review provides current conclusions and future directions for follow-up research.

Historical development: review of classic studies

To examine the historical development of research on the relationship between acute exercise and cognitive functions, the present review discusses several classical reviews and meta-analyses conducted by international groups and our own team. The first review was initiated

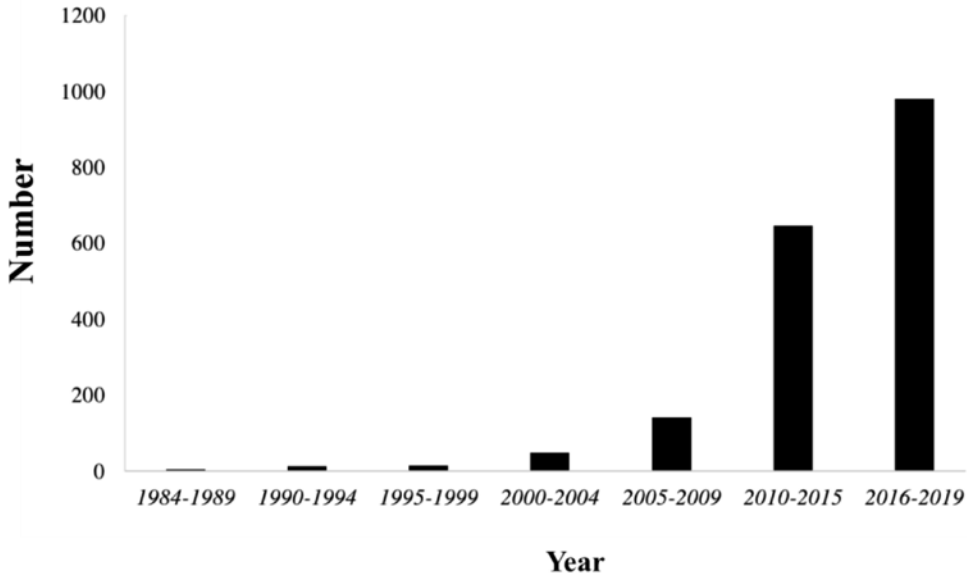

Figure 1. Quantitative examples of studies on exercise and cognitive function in the PubMed database.

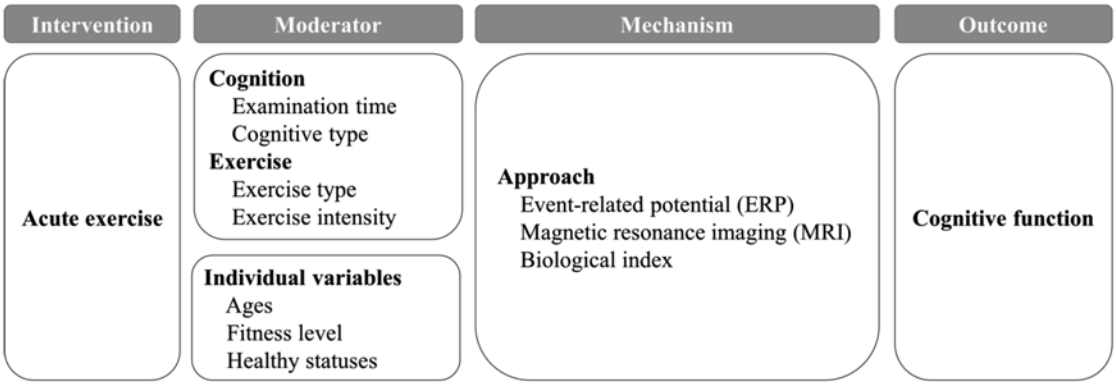

Figure 2. The moderators and mechanism of the relationship between acute exercise and cognitive function.

by Tomporowski and Ellis (1986), and early meta-analyses were conducted by Etnier et al. (1997) and Sibley and Etnier (2003), with the results suggesting that acute exercise has positive impacts on cognitive functions. Building on these findings, Chang et al. (2012) conducted a comprehensive meta-analysis and further supported a positive causal relationship between acute exercise and cognitive functions. These finding also attracted and encouraged more international and domestic research teams to further explore the effects of acute exercise on cognition.

Moderators of the relationship between acute exercise and cognitive function

Our review of the present literature ascertained the following important points for understanding the effects of acute exercise on cognitive functions, while considering the moderators of these effects. 1) Previous studies and our own findings suggest that acute exercise significantly improves executive functions more than other types of cognitive functions (e.g., reaction time) (Chang & Etnier, 2009; Pesce, Cereatti, Casella, Baldari, & Capranica,

2007). 2) We further explored the effects of acute exercise on executive functions measured at different times, and found that acute exercise can benefit executive functions measured immediately after acute exercise (Chang, Tsai, et al., 2011), and the beneficial effects were sustained up to 80 minutes after the intervention (Hung, Tsai, Chen, Wang, & Chang, 2013). When measured during exercise, we found that acute exercise performed at high intensity worsened executive function performance compared with low or moderate intensity exercise (Wang, Chu, Chu, Chan, & Chang, 2013), which supports the transient hypofrontality theory (i.e., individual faced high demand to temporarily decrease efficiency of prefrontal cortex) (Dietrich, 2003). 3) In addition to aerobic exercise, resistance exercise has a positive impact on executive function, and our findings provide evidence for a causal relationship (Chang, Chu, Chen, & Wang, 2011; Chang & Etnier, 2009; Chang, Tsai, Huang, Wang, & Chu, 2014; Hsieh, Chang, Fang, & Hung, 2016; Hsieh, Chang, Hung, & Fang, 2016). 4) We examined the dose-response relationship between acute exercise and executive function and found a U-shaped relationship with regard to acute exercise intensity and session time. Specifically, we concluded that acute exercise at a moderate intensity (i.e., 65-70% heart rate reserve) and a moderate session time (i.e., 30 minutes) provides the optimum benefits for executive function (Chang, Chu, et al., 2015; Chen et al., 2018).

Individual variables

As the effects of acute exercise on cognitive functions may differ depending on individual-level variables, we explored relevant variables such as age, fitness level, and special populations. In terms of age, Chu et al. (2017) compared different age groups (preadolescents vs. young adults) and found that acute exercise significantly improved cognitive functions in younger adults more than in preadolescents. Notably, ERP showed different results, which indicated that acute exercise significantly increased the P300 amplitude in both age groups, suggesting that the allocation of attentional resources was enhanced after an acute exercise intervention. For individual fitness levels, Chang, Chi, et al. (2014) showed that the effects of acute exercise on cognitive functions did not differ significantly among young adults with different fitness levels. Chang et al. (2015), in contrast, found that older adults' fitness levels were moderated by the effects of acute exercise on their cognitive functions, suggesting individual wit higher fitness exhibited better cognitive performance than those with lower fitness. With regards to special populations, our research team targeted three diverse populations: children with attention deficit hyperactivity disorder (ADHD), children born preterm, and people addicted to methamphetamine. From our findings, we conclude that acute exercise can improve cognitive functioning in these populations. However, due to a few studies targeting on special population, further studies are needed in this area to ensure that the findings relating to the effects of acute exercise on cognition in these populations are accurate and valid.

The mechanism of the effects of acute exercise on cognitive functions

In our previous studies, we also investigated the relationship between acute exercise and its effects on brain mechanisms (i.e., brain activation and biological indicators). We used ERP to examine the cognitive operations that contribute to improved executive function following acute exercise. Our recent results showed that acute exercise increased the amplitude of the P300 component (Chang, Pesce, Chiang, Kuo, & Fong, 2015). In addition to the ERP approach, Li et al. (2014) used fMRI to understand the blood oxygen level-dependent response following acute exercise. After acute exercise while performing cognitive function tasks, activation of cognition related brain regions (i.e., the right middle prefrontal gyrus, right lingual gyrus, left fusiform gyrus) was enhanced and activation of other brain regions (i.e., the anterior cingulate cortex, left inferior gyrus, and right paracentral lobule) was reduced compared with those that did not engage in the exercise intervention (the control condition). These findings evidenced that acute exercise facilitated brain activation after acute exercise intervention. In terms of biological indices, Chang et al. (2017) found that acute exercise did not increase levels of

brain-derived neurotrophic factor, which is inconsistent with the findings from other research teams (Etnier et al., 2016; C. L. Hung, Tseng, Chao, Hung, & Wang, 2018). Importantly, studies on the impact of biological indices related to cognitive functions are still in their infancy, so more research is needed to confirm the relational mechanisms by which acute exercise affects cognition in the future.

Conclusion

This paper reviews the international literature on acute exercise and cognitive functions and introduces studies from our own research team. Previous reviews and meta-analyses have verified the positive relationship between acute exercise and cognitive functions and have even established causal relationships between these psycho-physical dimensions. Our research team further conducted a comprehensive meta-analysis and the results supported the positive relationship between acute exercise and cognition. We then considered moderators and individual-level variables to examine their influence on the relationship between acute exercise and cognitive functions, and further explored the brain mechanisms by which acute exercise exerts its effects on cognitive functions using several approaches (i.e., ERP, fMRI, biological indices), while seeking to establish a foundation and provide a reference for follow-up studies on this topic. Overall, Taiwan research teams continue to integrate their related research on acute exercise and its effects on cognitive functions with that of the international community, and will continue to develop this research area in the future.