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EDITORIAL

Optimizing Athletic Performance Through Brain Endurance Training

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Combined physical and cognitive training, or brain endurance training (BET), is an innovative training methodology that integrates both physical and cognitive components within a single training session. This approach can be further refined based on the timing of cognitive training, categorized as before (pre-BET), during (intermixed-BET), or after (post-BET) physical training. BET is typically implemented over multiple sessions per week for an extended period of time (starting from 4 wk). The rationale behind BET is that it leverages the combined effects of physical and cognitive training on brain function and structure, potentially producing synergistic benefits that enhance both general brain health and general performance capacity. Therefore, it should not come as a surprise that studies have applied pre-BET, intermixed-BET, or post-BET to combat physical and cognitive decline in older adults and patients.

In an elaborate study, Bogataj et al[1,2] developed a protocol in which patients with chronic kidney disease underwent consecutive physical and cognitive training during each dialysis session (3/wk). After 12 weeks, the patients' scores on tests such as spontaneous gait speed, timed up and go (physical component), trail making task, and test of attentional performance (cognitive component), as well as their frailty and quality of life, improved significantly. Given the vast amount of research in specific populations, it is remarkable how little can be found on BET in an athletic population, the population of interest for the readers of the *International Journal of Sports Physiology and Performance (IJSPP)*.

The rationale to apply BET in an athletic population derives from the known negative impact of mental fatigue on physical performance and technical skills.[3] By increasing the cognitive load of physical training, athletes become more resilient to mental fatigue and can potentially improve their endurance performance. A recent study by Staiano et al[4] published in *IJSPP* explored the impact of post-BET in professional football players. They found that BET significantly improved cognitive, physical, and multitasking performance compared with physical training alone. Specifically, BET decreased reaction times, reduced errors in agility tasks, boosted the ability to sustain attention, and maintained endurance performance. However, no significant effects were observed in blood lactate concentration and heart rate. A few other studies have similarly demonstrated that BET can improve endurance capacity and cognitive function in athletes.

From a mechanistic perspective, BET is hypothesized to stimulate regions of the brain such as the anterior cingulate cortex and the prefrontal cortex (PFC), which are heavily implicated in the onset of mental fatigue, in cognitive control, and in endurance performance. By continuously engaging these brain regions during training, BET could enhance their efficiency and capacity, leading to improved mental and physical endurance during competition. This effect might be visualized through advanced neuroimaging techniques, such as functional near-infrared spectroscopy (fNIRS), functional magnetic resonance imaging, or electroencephalography. In regard to BET, fNIRS, which measures changes in brain oxygenation and blood flow, has recently been employed. Dallaway et al[5] investigated the effects of pre-BET on exercise performance. Participants who engaged in 20 minutes of cognitive tasks before physical training showed a 24% improvement in endurance performance compared with a 12% improvement with physical training alone. This enhancement was associated with higher PFC oxygenation during exercise tasks (determined by fNIRS), suggesting that BET may improve endurance performance by enhancing brain function. Xiang et al[6] supported this finding by showing that BET significantly increased PFC oxygenated hemoglobin levels during cognitive tasks compared with cognitive training alone. This outcome indicates that BET leads to greater neural activation, particularly in the PFC, thus potentially providing a more efficient brain function during tasks requiring executive control.

Despite these promising findings, the research on BET in athletic populations is still in its infancy. The number of studies is limited, and the subject groups are relatively small, often comprising athletes from specific sports and levels. In addition, methodologies differ widely between studies, particularly regarding the timing (before, during, or after physical training) and duration (20–60 min) of cognitive training, making it challenging to draw more general conclusions about the most effective BET protocols. Moreover, there is a notable lack of neurophysiological measurements in these studies, which are crucial for understanding the precise mechanisms through which BET exerts its effects. For instance, functional magnetic resonance imaging, electroencephalography, and fNIRS could provide insights into how BET influences brain regions and networks associated with cognitive and physical endurance, such as the anterior cingulate cortex and the PFC.

To advance the field, future research should focus on several key areas. First, there is a need for larger scale studies that include diverse athletic populations and apply standardized BET protocols. This approach would establish the generalizability of BET's potential benefits across different training regimens and in distinct sports. Second, incorporating advanced neurophysiological measurements will be essential to elucidate the brain mechanisms underlying BET and to optimize its implementation. Finally, the potential of BET to be implemented into rehabilitation programs or for athletes prone to overuse injuries has to be explored.

In conclusion, BET represents a promising approach to enhance athletic performance by making athletes more resilient to mental fatigue. Although initial studies indicate significant

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benefits, particularly in improving endurance capacity and cognitive function, further research is needed to standardize protocols, expand subject groups, and incorporate neurophysiological insights. By addressing these gaps, BET could become a critical component of training programs, helping athletes achieve peak performance while mitigating the risks of mental fatigue and injuries. *IJSPP* provides an excellent platform for dissemination of research findings on this concept for the broad field of sport.

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