Sport Training and Neural Function Based on EEG Analysis of Athlete's Performance

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Abstract

It is the purpose of the study to discover any performance when engaging behaviorally and/or neurologically where athletes are compared with non-athletes. A literature review was carried out to locate 16 studies that compared athletic behavior or brain activity against novices or non-athletes. Principle EEG bands that were recorded included theta, alpha, and beta rhythms. Athletes who were the subject of this literature review exhibited significant changes in brain function and behavioral performance. The effect size for sports tasks showed the highest average and general tasks presented the lowest average effect size. Experts explained behavior efficiency in athletes by their higher efficiency for tasks' sub-attributes associated with sports activities. Fewer neural connections procuring higher cortical asymmetry, enhanced explosiveness, cognitive flexibility, and greater precision of cortical activation were the brain elements associated with athletes. Introduction It has been shown through the use of EEG technology that players' talent identification and performance improvement in sports have been encouraging in young players.

Keywords: Athletes, Sports, Performance, Neuroscience, Brain Function

Introduction

Sport is both a physical and mental activity that goes beyond simple competition. This is an extension of the strength and conditioning training that includes the endurance and speed components and the appropriate information and its access; anticipating and structuring thoughts; and competition decision-making are other important factors for athletic performance [1]-[3].

The attractiveness of the hidden cognitive complexity of athletes and athletes has been of interest to sports psychology researchers. By analyzing a series of studies about the cognitive abilities among athletes, it has been established that athletes have better cognitive abilities than amateurs or nonathletic implying that cognitive abilities are mediated by experiences of being an athlete. People have been aware that a range of complex brain mechanisms play a major role in cognition [4][5]. Both on-field and off-the-field behavior depends on brain activity and can influence whether a certain team wins or loses. Recent developments in neuroimaging methods have enabled researchers to view brain activity during the observation of the performance.

Transcranial magnetic stimulation (TMS), electroencephalography (EEG), functional near-infrared spectroscopy (FNIRS), and functional magnetic resonance imaging (fMRI) are some of the neuro-imaging techniques [6][7]. EEG is particularly useful in the new and emerging sports science because it is portable non-invasive and has a temporal resolution of a fraction of a second millisecond and researchers utilizing EEG could then study the brain processes associated with athletes [8][9]. Athletes are in a better position than non-athletes in terms of neurological function due to the display of superior behavioral performance as training studies have also been conducted based on EEG task performance to determine the impact that sports engagement has on the brain [10][11].

Brain changes specifically related to sport can be distinguished between athletes and non-athletes through variability in EEG patterns and the brain state changes associated with performance gains suggest that there are neural level benefits, and how that actually plays out in the brain is where the patterns come in [12]-[14].

Elite sports are also a good inspiration for understanding how the nervous system responds to training intensity and duration; they also lead to a better understanding of neural changes and better control of them for optimal sports performance; Finally, the brain-behavior relationship takes center stage in neuroscience research on athletes [15][16].

There are two pieces of work in the domain of sports science that are used as justification materials while arguing why the current review research is necessary. Now there are two narrative reviews regarding athletic EEG profiles and there has been no established method or process that is used for searching and analyzing the literature [17]-[19].

The current study employs the scoping review and the meta-analysis of the quantitative and qualitative guidelines for conducting a comprehensive review of the current research on the topic. Perhaps another explanation is that the growing interest in suitable connections between brain function and athletic performance is pretty fast.

The impetus for the writing of this review article stems from the fact that the recent review article was published over five years ago and thus an update is needed given the expanding research on the association between athletic performance and neuroscience [20]. The research presented in the current review is thus warranted for the reasons stated above.

The meta-analysis focuses on and determines the gap in the brain and behavioral profiles between athletes and those who are non-athletes, while the scoping review simply aims to collate or collect all these differences [21].

The results from the meta-analysis can be generalized to answer questions such as Do athletes outperform non-athletes in behavioral tasks and do athletes have a significant edge in brain processes compared to non-athletes? Qualitative analysis of the meta-analysis results encouraged very active and time-consuming discussions about the meaning of the results of the meta-analysis and about the problems of the previous research which still required special attention [22][23].

Methods and Materials

The scoping review process followed the guidance provided by the Extended Preferred Reporting Items for Systematic Reviews and Meta-Analysis Statement for Scoping Reviews.

The search method focused on three subject-related constructs: Brain function, Brain scanning, and Neuroscience imaging.

The study must have originalities, have been published in peer-reviewed English-language journals, be an experimental design that included an athlete group and a corresponding non-athlete control group, and must have utilized an EEG to quantify brain activity in order to be considered for inclusion.

In cases when a study failed to meet at least one of the mentioned criteria (for example, when no comparisons between athletes and controls were demonstrated or when either athletes or controls were recovering from concussions or any other sports-related injuries etc., or the study did not report any EEG data). The process of identifying the studies of interest was the independent work of two authors that resolved any discrepancies through discussion.

The following items were developed and used to extract key information from the evaluated research: Participants: Information that pertains to the physical and mental characteristics of the participants in the research.

Tasks: Information that relates to the tasks that were assigned to the participants in the research.

Behavioral performance: Information that stands for the attitude of the participants in the research with respect to behavior.

EEG Measures: Information that stands for the brain activity that was read by the Mean: the subjects item collected data on the sample size used and the average age of the controls and athletes in relation to the sport; the task description included specific aspects of the tasks.

Behavioral performance and EEG responses have evidential task-related effects in the same way. The meta-analytic effect size was calculated as the total number of effects from the same study squared and divided by the number of effects in the study multiplied by 1/3 with Hedges'g as an estimate for impact size for small sample sizes. Heterogeneity was adjusted for in the meta-analysis using a random model.

EEG Measures Included In The Research

The frontal cortical areas are responsible for generating the theta rhythms which indicate a high level of attention focus. Athletes have developed sufficient abilities and knowledge to devote more attentional resources to promote performance in complex tasks and research shows that greater frontal theta power is significantly related to higher levels of task complexity.

The spontaneous activity of the human brain manifests itself mainly in the alpha rhythm with its focal inhibition. In terms of ERD, lower values indicate low cortical activity; therefore in athletes, the lower found value of ERD may explain the lower cortical activity for task performance. This lower ERD is believed to show higher cognitive function of the brain.

Changes in beta power imply higher facilitation of the motor cortex neurons. Beta oscillations refer to a frequency band that denotes motor tasks. This is generally associated with faster motor responses in basic self-paced movement tasks and increased mental engagement in the task of processing motor-related information. The researchers also found that significantly higher beta ERD in athletes than the controls.

It also has positive effects on behavioral performance like increasing the accuracy of golfers' putting performance and shooting performance at cognitive tests, and improving certain aspects of brain functioning.

After all, by undertaking such a comprehensive insight into the nature of such oscillations, athletes can make better decisions regarding the allocation of attentional resources and raise their performance in tasks that are difficult to control.

Brain Function and the EEG

A meta-analysis of brain function studies comparing the brain functions of athletes and controls was conducted. The results showed that athletes had a modest effect size, which favored them over controls. This result supported the notable neurological advantage enjoyed by athletes.

Athletes' brain functioning significantly outperformed controls in physical and cognitive tasks. Key characteristics of their neural advantages include neural efficiency, improved cortical asymmetry, increased cognitive flexibility, and precise timing of cortical activation.

Neural efficiency suggests lower energy consumption during task performance, with higher IQs showing less brain activity during cognitive tasks.

Athletes used less brain power when performing tasks specific to their sport better than novices or non-athletes, but still performed comparably well on general tasks. In a study with novices and expert rifle shooters, experts demonstrated considerable hemisphere asymmetry during the practice phase, while novices showed similar activation between the two hemispheres. This hemisphere asymmetry is linked to optimal brain reorganizations brought about by long-term training to promote high-level performance.

Enhanced neural flexibility and accurate timing of cortical activation in athletes are attributed to better neural functioning. Before the exercise, athletes' cortical activation was initially lower than in novices', suggesting more relaxation in the early stages of preparation.

However, the pattern was reversed in the final two seconds before the movement because athletes' alpha power significantly decreased, indicating higher brain activation before the putting movement began. In contrast to novices or non-athletes, athletes' precise control over the timing of cortex activation demonstrated a clear advantage in their brain function.

Discussion and Limitation

The recent meta-analysis of 16 studies that investigated the cortical activations of athletes and controls during demeanor tasks revealed the superiority of the athletes over the controls in overall behavior. It is due to caused by a number of advantages in sports that are gained through extensive training over a long period of time that athletes obtain favorable performance. Electroencephalography recordings measured the cortical activities in terms of frequency bands including the following: theta, alpha, and beta. EEG findings of the studies were summarized to answer the question of brain functionality and a meta-analysis was performed.

Athletes reported overwhelming results in neural levels such as neural efficiency, greater cortical asymmetry, increased cognitive flexibility, and enhanced timing of activation on the cortex. This was an empirical study that sought to prove the notion that training for sports results in enhanced brain function as well as improved behavior. Both the higher performance and the better functional integrity of athletes compared with their non-athlete peers suggest the beneficial effects of sports experience on brain organization and behavioral output.

Comparison groups included fencing athletes and non-athletes in cognitive tasks revealed that the degree of benefit from cognitive training linked to performance improvement in athletes was attributed to the training-related promotion of inhibitory control and task switching. Longitudinal training positions itself in the role of affordances to facilitate the development of motor and cognitive skills in addition to providing a neurogenesis effect on the athletes' brains in the process of information processing.

This trend indicated that some changes in behavior are experienced due to sports experience. In addition, great performance on tasks unique to sports enhances the potential implications concerning the neural mechanisms that contribute to the enhancement of expertise by means of sustained training. The following main themes emerged from the current review: There are potential implications and implementations of EEG into practice. EEG-based sports performance research is considered a valuable pursuit because it lays down a foundation of knowledge for the development of optimal training strategies. Brain regulations serve the purpose of allowing athletes to bring their minds to certain patterns to prepare themselves before a significant event. Neurofeedback training is a technique whereby athletes train to control parameters like the EEG parameters: theta & alpha waves.

Conclusion

If athletes and non-athletes participate in activities involving behavior and/or brain function in the study, one can identify any performance variations. Sixteen research that analyzed the functional state of the brain or athlete behavior compared to the brain of a normal person or non-athlete after analysis of the literature were selected. Three primary EEG bands were recorded: Theta, Alpha, and Beta Waves. The athletes studied in this literature review were found to have made significant adaptations in their brain activity and behavior. Sports came out as having the highest average effect size followed by chores while tasks that were related to general duties had the lowest effect size. Researchers argued the reason the athletes behaved efficiently for tasks associated with sub-attributes that related to sporting activities was because of efficiency. Higher levels of cortical asymmetry, information-processing speed, and greater increases in speed, coordination, and agility in response to increased movement demands; greater brain activation to physical exercise and less neural connectivity were the brain traits associated with athletes. Background Current research demonstrates that the identification of talent and increasing the number of athletes in young athletes can be done using EEG technology.

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