“The EEG Biofeedback training effect on the number of repetitions performed to failure during the bench press in the aspect of alpha band asymmetry and external load”

This study analyzed the impact of EEG biofeedback training on the number of repetitions performed to failure in the bench press exercise. The subject of consideration was the role of motivation in shaping athletic performance. Motivation, defined as a process that organizes and directs actions, influences an athlete's activity by determining their focus and perseverance. Strength sports, which require a high level of technique and concentration, pose particular challenges for athletes in terms of attention control and motivation. An increase in motivation may positively affect attentional efficiency, enabling athletes to focus on stimuli that are crucial for achieving their goals.

Additionally, the study discussed the potential use of electroencephalography (EEG) as a method of monitoring brain activity and EEG biofeedback as a technique for modifying that activity in real time. EEG biofeedback allows for conscious regulation of motivational and attentional states by providing real-time feedback on brainwave activity. The study was based on the concept of frontal alpha asymmetry (8–13 Hz), which refers to differences in alpha band activity between the brain's hemispheres and reflects the motivational and emotional state. Lower alpha power in a given cortical area reflects higher neuronal activity. In the context of motivation, increased left frontal activation is associated with approach-related emotions (proactive motivation), whereas increased right frontal activation is linked to withdrawal-related emotions (aversive motivation).

The aim of the study was to assess the effect of EEG biofeedback training on the number of repetitions performed to failure in the bench press exercise and to evaluate changes in frontal alpha asymmetry in relation to increasing external load, measured immediately before the effort. Additionally, changes in frontal alpha activity following the EEG biofeedback protocol were analyzed.

The study involved a group of 20 male judo athletes with International or Master Class level qualifications, meeting specific criteria such as at least six years of training experience, no neurological or psychiatric disorders, right-handedness, and age between 18 and 23. All participants were in good health and actively trained at least five times per week. The group was randomly divided into two parts: an experimental group that underwent 14 sessions of EEG biofeedback training, and a control group that received simulated EEG biofeedback.

The experiment consisted of three stages. In the first and third stages, participants performed bench press tests at 30% and 50% of their one-repetition maximum (1RM),

carried out to failure with a one-day break between trials. The 1RM values were established one week before the start of the main study. Each testing stage was preceded by the recording of resting brain activity using EEG. The measurements enabled calculation of two variables: alpha L (from the left frontal lobe, F3) and alpha P (from the right frontal lobe, F4), which were then analyzed to examine interhemispheric differences. Based on these values, the Frontal Alpha Asymmetry Index (FAI) was calculated as the difference in mean alpha amplitude between the right and left frontal areas. In this context, an increase in the FAI indicated an increase in left frontal cortical activity.

During the second stage of the study, the experimental group completed EEG biofeedback sessions every other day for five weeks (14 sessions in total). Prior to each session, participants were screened for compliance with training and dietary recommendations and eligibility for the session. Each EEG biofeedback session consisted of six 2-minute training blocks with 1-minute breaks between them. EEG data were recorded in real time and presented to participants in the form of animations and auditory signals. Each session was preceded by a 2-minute resting EEG recording to determine the baseline alpha amplitude at F3 (left frontal area), which served as the training threshold. Participants were instructed to maintain their alpha amplitude below this threshold for as long as possible. Correct execution of the task was reinforced by visual and auditory feedback.

In the control group, the second stage involved simulated EEG biofeedback consisting of replayed neurofeedback sessions from the experimental group, with full connection to the equipment. These sessions included identical visual and auditory feedback. Each session was also preceded by a 2-minute resting EEG recording. Participants were instructed to maintain the alpha amplitude at F3 below the established threshold for as long as possible.

This study was among the first to apply EEG biofeedback training to increase relative left frontal cortical activity in the context of improving performance in a strength endurance task, specifically the number of repetitions performed to failure in the bench press.

The first research hypothesis assumed that the magnitude of external load in the bench press would significantly differentiate the values of frontal alpha asymmetry measured prior to exertion. The results showed no statistically significant differences in the FAI index for loads of 30% and 50% 1RM, in either the experimental or control group. Therefore, this hypothesis was not confirmed.

The second hypothesis posited that EEG biofeedback training would significantly affect frontal alpha asymmetry. Participants were divided into two groups: the experimental group, which received alpha suppression training targeting the left frontal cortex, and a control group

receiving placebo intervention. Between-group analyses revealed that significant FAI changes occurred only in the experimental group, while the control group did not show comparable changes.

The third hypothesis concerned the relationship between frontal alpha asymmetry and strength endurance, measured by the number of repetitions performed to failure. In the experimental group, a significant increase in repetitions was observed following the EEG biofeedback intervention at both load levels: from an average of 26 to 30 reps at 30% 1RM, and from 18 to 22 reps at 50% 1RM. In the control group, the number of repetitions remained virtually unchanged. These findings suggest that enhancing frontal alpha asymmetry through EEG biofeedback may improve physical performance.

One limitation of the study was the absence of internal load monitoring during exertion, which could have provided greater insight into mechanisms responsible for the observed improvements in strength endurance. Furthermore, the small sample size (N = 20), despite being composed of elite judo athletes, limits the generalizability of the results to broader populations. The choice of test exercise—bench press—was guided by the need to minimize EEG artifacts, though it does not fully reflect the specific movement demands of judo. The use of 30% and 50% 1RM loads allowed for the execution of sets to failure but limited the ability to assess performance at higher intensities. Nonetheless, the findings offer novel evidence supporting EEG biofeedback as a tool for enhancing athletic performance.