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Differences in motivation during the bench press movement with progressive loads using EEG analysis

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ABSTRACT: Considering our preliminary research with EEG analysis of the bench press in experienced powerlifters, we hypothesized that there would be significant differences in motivation between novice and elite powerlifters. Therefore the main objective of this study was to identify patterns of frontal alpha asymmetry (FAA) of the prime movers by alpha frequency band analysis (named as alpha motivation values) for each 35–100% one-repetition maximum (1RM) during the flat bench press. Ten novice powerlifters with no more than 2.5 years of resistance training experience and ten elite powerlifters with at least 7.5 years of training experience participated in the study. All participants were required to squat, bench press, and deadlift 100, 125, and 150% of their body mass, respectively. The athletes constituted a homogeneous group with respect to age (mean 22.3 ± 0.5 years). The EEG recordings were conducted using automatic headcups with 19 electrodes that were placed according to the International 10-20 Electrode Placement System. Signals from 8–12 Hz considering points F3 and F4 were analyzed. Furthermore, electromyographic (EMG) signals from the trapezius muscle were recorded. Before testing, moods and emotions of subjects were assessed to eliminate subjects with intense emotions. The results showed brain activity before, during and after cognitive and motor performance using electroencephalography (EEG). However, considering the still existing problems of movement artefacts during EEG measurements, eligible sports and exercises are limited to those that are relatively motionless during execution. Further studies are needed to confirm these preliminary results.

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INTRODUCTION

According to the approach/withdrawal model of frontal EEG alpha asymmetry, motivation, and emotion, patterns of frontal brain activity correspond to motivational propensities to approach versus withdraw [1,2]. Greater left frontal activity corresponds to an increased tendency to approach or respond more intensely to affective positive stimuli, whereas greater right frontal activity corresponds to an increased tendency to withdraw or respond more intensely to affective negative stimuli [3,4,5,6]. These trait-like relationships are mirrored by a correspondence between changes in frontal EEG asymmetry and state changes in emotion and motivational tendency [1,7,8,9].

Neurophysiological aspects of skilled performance in sports and exercise sciences have become more important during the past years. Especially the brain as the centre of movement planning and control is currently a research subject with increasing interest to bridge the gap between behaviour-related models in sports science and neuroscientific models of basic mechanisms that support sports performance [2,9,10]. Electroencephalography (EEG) represents a methodological tool to display brain activity before, during and after cognitive and motor performance, with excellent temporal resolution and the advantages of wireless hardware as well as equipment portability [2,3,6,9].

At present, FAA registered with EEG seems the only objective means of assessing motivation at specific moments. Other available methods present several weaknesses that should be considered. Firstly, they are subjective as they are based on self-report questionnaires.

Secondly, given that questionnaires are composed of several items, duration of the entire process of responding to questions may negatively influence the level of concentration of respondents.

The aspect of motivation is particularly important for powerlifters' performance when attempting loads near personal records. The bench press (BP) is a complex upper body exercise in which substantial external loads can be lifted, demanding high neuromuscular activity. The potential of the BP for strength development and the popularity of BP competitions have made it a unique phenomenon as a popular exercise for training, testing or research purposes [11]. Previous studies have examined the kinematics of the bench press movement [12], the effect of different chest press exercises [13,14], unstable surfaces [15], the impact of fatigue [16], as well as motivation [6,17] and different approaches in the bench press. These have included comparisons of concentric-only bench press to those performed with a counter movement [4], as well as the motivation analysis of the BP and chest press exercises with maximal and submaximal loads [17,18,19].

The central nervous system (CNS) is responsible for processing information received from the environment (through the sensory cortex) and commanding a response from the rest of the body. Neural pathways that are well used and developed are retained and promoted, whereas those that are less needed in the present situation will be pruned or shut down to enable the release of brain capacity. The neuromuscular system uses two strategies to regulate the amount of force generated while performing a certain task. One of them is motor unit recruitment (i.e., calling into play more motor units and muscle fibres), and the other one is rate coding motivation for rapid electrical impulses, or action potentials, that are fired down the motor neuron to the muscle fibre it innervates [20,21,22].

In strength athletes at the elite level, excessive training loads cause numerous injuries which require changes in neuromuscular patterns during resistance exercises. In symmetrical exercises such as the bench press or the barbell squat, these changes may occur between the left and right limb, making evaluation from one side of the body incomplete, leading to erroneous conclusions.

Considering our preliminary research with EEG analysis of the bench press in experienced powerlifters, we hypothesized that there would be significant differences in motivation between novice and elite powerlifters. Therefore the main objective of this study was to identify the patterns of motivation activity of the prime movers by alpha frequency band analysis (named as alpha motivation values) for each 35-100% 1RM during the flat bench press. The study aimed to identify differences in brain activity between novice and expert weightlifters with different workloads.

MATERIALS AND METHODS

The applied methodology is described in the previous paragraph. Considering that there is no objective means of assessing motivation, we decided to focus on frontal alpha asymmetry (FAA), which is in agreement with Davidson [1].

Participants

Ten novice powerlifters with no more than 2.5 years of resistance training experience and ten elite powerlifters with at least 7.5 years of training experience participated in the study (Table 1). All participants were required to squat, bench press, and deadlift 100, 125, and 150% of their body mass, respectively. The athletes constituted a homogeneous group with regard to age (average age of 22.3 ± 0.5 years), somatic characteristics, and anaerobic performance. All participants were right-handed and scored over 35 on the 39-point scale [23]. Due to missing data in resting EEG files, 4 participants were excluded from further analyses, resulting in a final sample of 16 participants. The subjects (n=16) were divided into two groups: the novice group (NG; n=8), and the elite group (EG; n=8). All subjects had valid medical examinations and showed no contraindications to participate in the study. The participants were informed verbally and in writing of the experimental protocol and the possibility to withdraw at any stage of the experiment, and gave their written consent for participation. The measurements were carried out at the Strength and Power Laboratory of the Academy of Physical Education in Katowice, using a wireless EEG. The study was approved by the Research Ethics Committee of the Academy of Physical Education in Katowice, Poland (7/2016 for NRSA 4 040 54).

Procedures

The influence of other known factors on the asymmetry of the leading alpha was excluded. The laterality test was performed for all subjects. Handedness was determined using Chapman's scale [23]. All were right-handed. In parallel with the EEG recording, muscular activity was monitored to exclude moments that could contain artefacts. The measure for moods and emotions was made using the Russkam set of emoticons expressing 29 moods and emotions on three levels of intensity [24]. The results of the Russkam set allowed the exclusion of 4 competitors from further studies (2 with novice group and 2 with elite group).

EEG measurements procedure

The EEG recordings of frequency power over left and right frontal regions were conducted according to the International Federation of Electrophysiological Societies [25] and American EEG Society [26]. EEGs were recorded with Ag/AgCl scalp electrodes, placed according to the International 10–20 system [27]. Impedance was maintained <5 kΩ to avoid polarization effects. Signals were recorded from 24 active channels (Deymed Truscan 24 ch. system, soft. version 6.34.1761, Czech Republic). The sampling frequency was 1024 Hz. A 50 Hz main filter, as well as high and low pass filters (1 and 40 Hz respectively), were used. The reference electrode was placed on the ear. To limit the muscle artefacts on the bench the roller was placed under the neck of the subjects.

Before every bench press, the subject had 15 seconds during which his task was to motivate himself and prepare to lift the weight. Then, these 15-second fragments from F3 and F4 locations were divided into 1-second epochs. The epochs containing the artefacts were excluded from further analysis. Spectral analyses with fast Fourier transform (FTT) were done for artefact-free 1-second epochs allowing for calculation of the mean and standard deviation for each channel for absolute band power, relative band power, median-power frequency and peak-power frequency. Spectral analyses were conducted for the alpha frequency band 8-12 Hz.

Each EEG recording was assessed by a neurologist certified by the Polish Society of Clinical Neurophysiology, who was blinded for the subjects. Recordings were first analyzed to exclude signals indicating epilepsy. Afterwards, 1-second artefact-free epochs were searched.

The Frontal Asymmetry Index (FAI) was calculated for each concentration period before the barbell lift according to the formula proposed by Coan and Allen [7]. Engagement in this case is expressed as the logarithm difference between frequency power over the left and right frontal regions (FAI). Many studies use the (8-12 Hz) alpha frequency band, which was used in this research too [7,22]. Due to the inverse relationship between (8-12 Hz) alpha power and cortical activity (meaning that the less alpha range activity that there is, the more brain activity there is), decreased alpha power reflects increased engagement. In short: more brain activity means less alpha power, while less brain activity means more alpha power.

First, the recording with eyes closed was analyzed, to find possible elements of epileptiform discharges or other abnormalities, whose presence would exclude the participant. After their exclusion, the rest of the record and the entire analysis below were carried out with the eyes open.

Bench press sessions

The measurements were performed in the Laboratory of Muscular Strength and Power at the Academy of Physical Education in Katowice (Poland). There were two sessions of the experiment (initial and main session). Sessions consisted of performing one repetition of the flat bench press with loads from 35% 1RM to 100% 1RM. The rest periods between sets were 5 minutes to avoid potential effects of fatigue. A standardized warm-up protocol was used for each session, including a general warm-up (5 min), using a hand cycle ergometer (heart rate of around 130 bpm) and performing several lower and upper body resistance exercises.

The determination of 1RM was performed according to the protocol by van den Tillaar and Saeterbakken [16]. The percentage of the 1RM load was calculated based on the values self-reported by the participants. The self-reported 1RM was set according to the information given by the participant on maximal lifts performed in the previous three months. When the self-reported 1RM was successful, a trial with an additional load of 2.5-5 kg was performed. When the initial trial was unsuccessful, the weight was decreased by 2.5-5 kg. A total of 2-3 trials were performed by the study participant. Two experienced spotters assisted the athlete in the preload phases.

Statistical analysis

The Shapiro-Wilk, Levene and Mauchly's tests were used in order to verify the normality, homogeneity and sphericity of the sample's data variances, respectively. Average alpha power values at each site were then log transformed using the natural log. A measure of EEG hemispheric asymmetry (right hemisphere compared to left hemisphere) was then derived (ln[right] - ln[left]) for each of the regions of interest. Because cortical alpha power is inversely related to cortical activity [1], lower scores on this metric indicate relatively low left frontal activity. The differences between NG and EG for analyzed values of motivation were verified using one-way ANOVA. Effect sizes (Cohen's d) were reported where appropriate. Parametric effect sizes (d) were defined as large for > 0.8, as moderate between 0.8 and 0.5, and as small for < 0.5 [5,28,29]. Statistical significance was set at $p<0.05$. All statistical analyses were performed using Statistica 9.1 and Microsoft Office, and were presented as means with standard deviations.

RESULTS

All participants completed the described testing protocol. The procedures were completed in identical environmental conditions with an air temperature of 19.2 °C and humidity of 58% (Carl Roth hydrometer, Germany).

The one-way ANOVA between the NG and EG for alpha motivation values before increasing loads of 35%-100% 1RM, revealed statistically significant results for thirteen variables (Table 2). Figure 1 presents graphical trends of mean alpha values of motivation in each phases of sessions.

Post-hoc tests revealed a statistically significant differences between groups for:
35% 1RM (0.22 Hz in NG to -0.13 Hz in EG with p=0.0016),
40% 1RM (0.04 Hz in NG to -0.098 Hz in EG with p=0.0044),
50% 1RM (0.16 Hz in NG to -0.051 Hz in EG with p=0.0018),
60% 1RM (-0.13 Hz in NG to 0.02 Hz in EG with p=0.0039),
65% 1RM (-0.10 Hz in NG to 0.15 Hz in EG with p=0.0013),
70% 1RM (-0.09 Hz in NG to 0.36 Hz in EG with p=0.0004),
75% 1RM (-0.20 Hz in NG to 0.09 Hz in EG with p=0.0011),
80% 1RM (-0.42 Hz in NG to 0.07 Hz in EG with p=0.0003),
85% 1RM (-0.61 Hz in NG to 0.09 Hz in EG with p=0.0001),
90% 1RM (0.14 Hz in NG to -0.12 Hz in EG with p=0.0011),
95% 1RM and 100% 1RM (0.06 Hz in NG to 0.19 Hz in EG with p=0.0044) variables for alpha values.

Post-hoc tests revealed a significant motivation increase in the NG for 35% 1RM, as well as in the EG for 40% 1RM. For the 50% 1RM variable an increase of motivation value was observed for both groups, but there was a statistically significant difference between the groups.

There was no statistically significant difference between the groups for the 55% 1RM variable.

Post-hoc tests revealed a statistically significant motivation decrease in the NG for 60% 1RM, 65% 1RM, 70% 1RM, 75% 1RM,

TABLE 1. Characteristics of study participants.

Variables	Elite Group (n=8)	Novice Group (n=8)
Age (yrs.)	22.7±3.2	22.4 ± 2.8
Height (cm)	181.2±2.1	178.3±4.9
Body mass (kg)	81.8±3.2	79.2 ±2.6
FM (%)	10.2±2.1	10.8±2.4
Wt - upper limbs (J/kg)	172.6 ± 21.3	112.5 ± 10.8
Pmax – upper limbs (W/kg)	8.9±1.1	8.7±0.4

TABLE 2. Statistically significant differences between the NG and EG groups for FAI values with increasing loads from 35% to 100%1RM.

Load [%]	D	p	F
35	0.861	0,0016	15202,81
40	0.780	0,0044	2264,88
50	0.799	0,0018	5566,23
55	0,231	0,1051	18,04
60	0.790	0,0039	2559,73
65	0,801	0,0013	7900,49
70	0.884	0,0004	24659,45
75	0.854	0,0011	11002,67
80	0.923	0,0003	30213,35
85	0.989	0,0001	63035,46
90	0,852	0,0011	8952,70
95	0,556	0,0015	655,67
100	0.773	0,0044	2259,98

Note: D - effect size; p - statistical significance; F – value of analysis of variance function

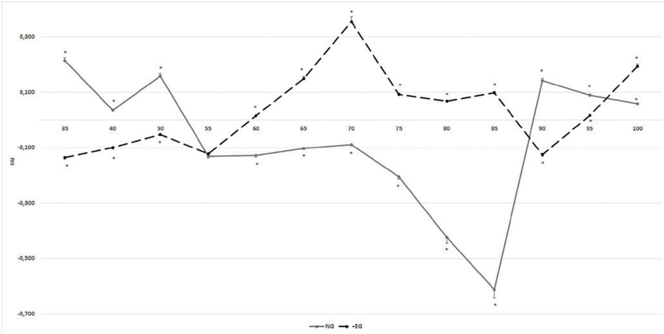

FIG 1. Differences between the trends of FAI values in each phase of the exercise protocol. * p<0.05.

80% 1RM and 85% 1RM with significant differences between the groups.

Similarly, post-hoc tests revealed a statistically significant motivation decrease in the EG for 75% 1RM, 80% 1RM, 85% 1RM and 90% 1RM with significant differences between the groups.

DISCUSSION

The main objective of this study was to identify the patterns of motivation evaluated by the alpha values during the flat bench press with progressive loads from 35 to 100% 1 RM.

There have been many attempts to assess the bioelectric activity of the brain in sport. However, only in sports disciplines where the athlete remains relatively motionless during their execution are recordings without artefacts possible [30-34]. Such research provides reliable data on cortical activation patterns during a complex sports-related motor task. However, all the studies have been conducted under laboratory conditions; thus they were well controlled and reproducible [35]. On the other hand, several sports and exercise studies indicate that laboratory based findings do not automatically hold under training and competition situations [35,36,37]. Considering these methodological conditions, our experiment was conducted in a professional strength training gym. To the best of our knowledge, there is only one study that has examined changes of EEG power spectra in the bench press [42]. Engchuan et al. [42] observed increases in beta and gamma frequency bands during the bench press exercise. However, caution is needed when interpreting their results. It should be noted that Engchuan et al. [42] used equipment that allowed for recordings from only one point (Fp1) that is sensible to muscular and ocular artefacts. Furthermore, gamma bands of 30.5–60 Hz may be influenced by the electrical activity of muscles (10-200 Hz).

The results clearly indicate that all participants from the NG applied significantly more motivation at initial loads to ensure success than participants from the EG. At minimum loads the NG (35-55% of 1RM) used more motivation than necessary for such a task. This can be directly related to relaxation and satisfaction after successive attempts. However, before each successive approach to overcoming greater loads (55-85% 1RM), the motivation decreased significantly. The motivation increased again at submaximal and maximal loads (90-100% 1RM). It can be concluded that the most effective motivation for the NG was observed for 35% 1RM, 50% 1RM and 90% 1RM with significant differences between groups. For 95% 1RM and 100% 1RM a significant decrease of alpha values was recorded for novice powerlifters (decreased motivation).

The EG varied their motivation to a much higher degree to optimize their performance in the final attempts with maximum loads. The athletes of this group started with a significantly lower level of motivation for lighter loads (35-55% 1RM). The level of motivation for EG gradually increased up to 70% 1RM. Then the temporary relaxation became visible. However, strong motivation was recorded again when the maximum load was attempted. We observed that motivation increased for the EG significantly for 70% 1RM, 95% 1RM and 100% 1RM with significant differences between groups. For the EG motivation increased significantly for 70% 1RM, 95% 1RM and 100% 1RM with significant differences between groups.

Some research has focused on measuring differences between elite and sub-elite athletes. Wilson et al. [38], using EEG equipment, investigated university volleyball players, who were deemed by their coaches to be better under the stress of critical game situations. They had lower resting frequencies at O1-T3 (cortical sites in the occipital and temporal regions, designated in the 10–20 international system) during baseline resting states than those who were not as competent under pressure [38]. An example of a more refined study was performed by Haufler et al. [31], who examined EEG differences between experts and novices in a shooting task. The expert marksmen showed increased alpha power across all regions, but particularly at T3, compared with novices. The authors suggested that the increased alpha may reflect a refinement in analytical or better self-talk strategies during the pre-shot time. A very simplified interpretation of their conclusions includes the following: The demands of the sport result in task-specific cortical resources being used in an efficient manner; that is, the same amount of work is accomplished but with less cortical activation or effort. Expert performance is associated with quieting of the left hemisphere and, in some cases, quieting of the right hemisphere; tasks are performed better if the person learns to become more "automatic" rather than engaging in "thinking".

Considering the aspect of motivation in relation to athletes, it can be concluded that the results obtained in this research are indirectly convergent with the research of other authors and confirm their observations referring to the dependence of sports performance on individual skills during the bench press movement [19]. In addition, the obtained results of this study verify to a certain extent the results obtained during the measurements of muscular tension of competitors during a bench press competition [19,39]. Researchers found that muscle tension was much higher in the initial trials at lower 1RM percentages. In later attempts the tension dropped until loads of 95% 1RM to 120% 1RM were reached [39,40]. It was observed that in professional powerlifters, the muscle tension increased in direct proportion to the load [19,39,40,41].

CONCLUSIONS

The present study should be treated as a pilot study and provides preliminary results for further original research. To the authors' knowledge this is the first study focused on groups of elite and novice athletes who were compared during the bench press performance using EEG to determine motivation before attempting different loads. These findings showed that the EEG methodology with analysis of FAI changes seems to be a reliable tool to observe brain activity under field conditions such as those taking place during the bench press exercise. Further studies with a greater sample size and including different exercises such as the leg press are needed to confirm these preliminary results.

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