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Original Research

The Effect of Neuropriming and Focus of Attention on Amateur Standing Long Jump Performance

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ABSTRACT

International Journal of Exercise Science 15(1): 1472-1480, 2022. Non-invasive brain stimulation has been prominent in recent neurophysiology research. The use of brain stimulation has not been examined in combination with the focus of attention paradigm, an established motor control tool. Therefore, the purpose of this study was to examine the effects of both brain stimulation and focus of attention on the outcome performance, peak force, lower extremity joint kinematics, and projection angle of a standing long jump. Forty-one participants were assigned to either the brain stimulation group or placebo group via a counterbalance design based on leg length and jump distance. Participants were only accepted if they had not previously trained in the standing long jump. On a second day, participants performed a standing long jump under control, external, and internal attentional foci after having undergone either a single session of brain stimulation or a placebo warm-up. Five total jumps were performed: one baseline jump followed by two for each attentional focus condition. The results indicated that an external focus of attention and control conditions created a reduced projection angle compared to an internal focus of attention and that brain stimulation did not have any effects on the performance of a standing long jump after a single session. There were no changes evident between hip, knee, and ankle joint angles, force production, or jump distance between any of the conditions or groups.

KEY WORDS: Attentional focus, motor control, brain stimulation, motor learning, verbal instructions

INTRODUCTION

Focus of attention has been widely studied within the field of motor control and learning for the last two decades. Focus of attention (FOA) refers to where one directs their attentional resources before, during, and after a motor action and is typically generated through verbal instructions (15). This area of research was sparked by Wulf and Weigelt's study, where they found that two different attentional focus strategies prompted vastly different motor performance outcomes (24). Since, the use of attentional focus and how it affects the performance of motor skills has been widely researched in a variety of motor tasks that include jumping, juggling, soccer, golf, volleyball, track and field, and ballet (5, 15, 16, 19, 21, 27). The standing long jump was used in this study due to the previous number of studies utilizing this exercise to show the difference between an internal and external FOA (4, 15, 16, 19, 21).

A majority of these studies have demonstrated that an external FOA elicits better performance outcomes and movement production measures, such as increased accuracy and efficiency of movement, when compared to an internal FOA (4, 7, 15, 16, 19, 21). An external FOA is characterized by an individual focusing on the effect of their movement in relation to the environment (21). For example, in this context, the participants focused on jumping a great distance toward a chair in front of them. An internal FOA is characterized by an individual focusing on a specific movement or body part within themselves (21). For example, the participants in this study focused on extending their knees as quickly as possible to achieve the wanted outcome. While most of the studies on this subject attribute the effect of FOA to the constrained action hypothesis, few have directly tested the hypothesis. According to Wulf and Weigelt, the constrained action hypothesis describes how an external FOA fosters the automatic cognitive processing that is naturally generated within the nervous system to execute a motor action (24). The constrained action hypothesis also proposes that an internal FOA prevents automatic processing and causes the motor system to constrain its degrees of freedom (movement options) resulting in inefficient movement patterns (7, 16, 21, 23). In a study by Vidal et al., the authors provided support of the constrained action hypothesis demonstrating greater joint coordination when participants adopted an external focus of attention, whereas, the internal focus condition demonstrated a strategy in which they constrained their degrees of freedom (19).

Along with focus of attention, brain stimulation and its relation to movement has been a recurring topic in the field of motor control. One type of brain stimulation, known as neuropriming, consists of applying direct electrical stimulation to the motor cortex. Research surrounding this practice in regards to single-dose sessions often suggests an increase in force production and endurance looking at elbow flexors or lower extremities (3, 13, 18, 20, 26). When neuropriming has been applied throughout multiple sessions, there have been increases in areas such as training efficiency, muscle strength, and motor unit recruitment strategies (11, 26). An important point of consideration is the strength of the stimulation current and the duration of the application. The magnitude of the current and duration of the application are inversely related, as would be expected. Magnitudes of 1-2 mA for a duration of 10-20 minutes have been shown to be effective (8, 11) in eliciting a response mechanism.

There have been few studies looking at established motor control paradigms in combination with the use of neuropriming, and whether it has an effect on kinetics or outcome performance in a single session. This has yet to be examined in simple tasks such as a standing long jump. This experimental study was designed to observe whether neuropriming would enhance the effects seen in internal and external focus conditions, or if the benefits of an external focus of attention are cancelled out when neuropriming is performed before a standing long jump. Therefore, the purpose of this present research is to combine the two prominent topics of brain stimulation and focus of attention to test their effects on a standing long jump activity. It was hypothesized that neuropriming would outperform non-neuropriming and external focus of attention would outperform internal focus of attention by increasing peak flexion angles in the hip, knee, and ankle along with increasing jump distance while decreasing the force needed to achieve the increased jump distance. It was further hypothesized that this would be achieved by producing a more efficient jump (projection) angle.

METHODS

Participants

The participants recruited for this study were healthy young adults (18-30) who were able to perform, but were not formally trained in a standing long jump. Forty-one participants participated in the study. Forty-two participants completed a medical history questionnaire and informed consent to establish that they were both willing and physically able to participate in the study (one participant was dropped from the study due to a discovery of ineligibility during the consent process). Exclusion criteria included anyone who had formal training in a standing long jump or any injury within the last 6 months that hindered lower extremity movement or exercise. Assignment to the brain stimulation (BS) or placebo (P) conditions, and order of attentional focus cues (external or internal) was counterbalanced for all participants. This was accomplished by conducting a preliminary trial where participants performed three standing long jumps and had their leg length measured. Leg length was designated as the distance from the greater trochanter to the lateral malleolus of the participant's dominant leg. Jump distances were recorded manually by an experimenter taking the distance from a labeled starting line to the heel of the participants' back foot after the completion of the jump with a measuring tape. The BS and P groups were then counterbalanced based upon leg length and gender. When the same leg lengths were measured, the order for counterbalancing was based upon jump distance. All participants provided written informed consent prior to participation and the Institutional Review Board at California State University, Long Beach approved the forms and protocol. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (12).

Table 1. Participant demographic data (Mean ± STD)

	Brain Stimulation Group (BS)	Placebo Group (P)
Height (m)	1.68 ± 0.09	1.69 ± 0.11
Mass (kg)	70.0 ± 16.9	68.8 ± 14.4
Gender (male/female)	10/10	11/10

Protocol

Study participants were broken up into two groups, brain stimulation (BS) or placebo (P), based on a single blind design. Both groups wore the brain stimulation device for twenty minutes (8). The BS group's device was activated sending mild, low grade electrical current stimulating the motor cortex with the potential to feel a mild tingling sensation. All participants were informed that there may or may not be a mild tingling sensation to help keep the single blind design. The P group wore the device while it was not activated. While wearing the brain stimulation device, participants participated in a five-minute warm-up on a stationary bike at a self-selected pace (15, 21). Upon completion of the warm-up, experimenters placed all markers on the participants on sites listed previously. After completion of a static trial, all single markers were taken off, leaving only the four tracking clusters. Participants were then asked to perform a baseline standing long jump and were instructed to jump as far as they could. Following the baseline jump, a total of four jumps were completed – two jumps for each focus of attention condition. Each jump was followed by a two-minute rest period. For the internal focus condition, participants were told to jump as far as they could and to think about extending their knees as fast as possible. For the external focus condition, participants were instructed to jump as far as they could and think about jumping as close to the chair as they could (which was placed 12 feet in front of them). Each jump was preceded by an attentional focus cue read to them from a script. To ensure that the subject thought internally/externally, they were asked to verbalize what they were supposed to focus on just prior to the jump.

Two Bertec force platforms sampling at 1200 Hz (Bertec Corp., Columbus, OH) were used to obtain ground reaction force data. A fifteen-camera motion analysis system (240 Hz, Qualisys OQUS, Gothenburg, Sweden) was used to obtain raw marker data during testing. Anatomical retroreflective markers were placed bilaterally on iliac crests and greater trochanters and unilaterally on the medial and lateral femoral epicondyles, medial and lateral malleoli, and 1st and 5th metatarsal heads of the dominant leg. Clusters of four retroreflective tracking markers were placed on the lateral aspect of the shank and thigh of the dominant leg and the sacrum. A cluster of three retroreflective markers was placed on the lateral curve of the heel of the dominant leg. Single retroreflective markers were kept on using a strong double-sided tape, clusters were kept on using Velcro straps and a thermoplastic base which markers were screwed into for clusters. If experimenters noticed movement in any clusters or if single markers fell off, that trial was redone, and a new static was made for the new marker placement. An experimenter recorded jump distance using the same protocol used in the preliminary trial.

The Halo Sport device was used for brain stimulation and placebo. The three sets of primers on the device were set on each participant's head, experimenters insured good contact between the skin and electrodes. Electrodes were placed directly over their motor cortex. The device released a mild, low grade electrical current (max voltage of 36V; FDA approved) when activated. The device has been used in a recent study for stimulation of the motor cortex for the purposes of enhancing movement performance (6).

Statistical Analysis

Raw marker data and ground reaction force data were imported into Visual3D biomechanical software (version 6.0, C-motion Inc., Germantown MD). Ground reaction force data were filtered using a fourth order low pass Butterworth filter at 50 Hz. Marker data imported from Qualisys were filtered using fourth order low pass Butterworth filter at 6 Hz. Variables of interest were peak hip flexion, peak knee flexion, peak ankle dorsiflexion, and tibial projection angle at time of toe off. Joint angles were computed using Visual 3D, calculated in the proximal reference frame using a cardan rotational sequence (X-Y-Z) and were polarized using the righthand rule. The tibial projection angle at the time of take-off was calculated as the segmental angle of the tibia relative to the lab coordinate system. Other variables of interest included peak vertical ground reaction force and jump distance. Statistical analysis of the data was completed using 2 x 3 (stimulation x focus) factorial ANOVA for each variable, with repeated measures on the focus factor and post hoc LSD with an alpha level of 0.05.

RESULTS

Mean values of the six dependent variables split by treatment (BS and P groups) and focus of attention (control, internal, and external FOA) are presented in Table 1. There was no significant interaction between treatment and focus of attention ($F(12,26) = 1.022$, $p = 0.459$) nor was there a main effect for treatment ($F(6,32) = 1.709$, $p = 0.151$). However, there was a significant main effect for focus of attention ($F(12,26) = 3.844$, $p = 0.002$, observed power = 0.984) on the combined dependent variables. Post-hoc analysis revealed a single difference in the tibial inclination angle ($F = 19.165$, $p < 0.001$, observed power = 0.999). The control condition (40.6 ± 1.0 °) and the external focus of attention condition (39.8 ± 0.8°) showed significantly smaller tibial inclination angles (Figure 1) compared to the internal focus of attention condition (44.3 ± 1.0°, $p < 0.001$ for both comparisons). No other differences were evident amongst the variables within the ANOVA.

Table 2. Peak joint angles, jump distance, and vertical ground reaction force during a standing long jump (Mean ±STD)

	Neuropriming			Control		
	Control FOA	External FOA	Internal FOA	Control FOA	External FOA	Internal FOA
Distance (cm)	198.80 ± 10.17	213.55 ± 10.03	201.71 ± 10.02	204.59 ± 9.91	204.13 ± 9.78	206.06 ± 9.77
Force (BW)	1.07 ± 0.04	1.05 ± 0.03	1.09 ± 0.04	1.17 ± 0.04	1.18 ± 0.03	1.17 ± 0.03
Hip Angle (°)	83.4 ± 3.2	83.6 ± 3.3	84.3 ± 3.5	78.9 ± 3.1	80.7 ± 3.2	78.0 ± 3.4
Knee Angle (°)	81.5 ± 2.3	82.5 ± 2.4	83.7 ± 3.2	83.7 ± 2.2	85.0 ± 2.4	83.1 ± 3.1
Ankle Angle (°)	29.6 ± 1.9	29.5 ± 1.9	28.8 ± 1.9	29.4 ± 1.9	29.3 ± 1.9	28.7 ± 1.9
Tibia Angle (°)	39.0 ± 1.4	39.0 ± 1.1	43.7 ± 1.4*	42.1 ± 1.4	40.5 ± 1.0	44.9 ± 1.4*

*Significant focus of attention main effect. Internal focus of attention (FOA) significantly increased compared to control and external FOA.

DISCUSSION

The purpose of this study was to investigate the effects of single dose brain stimulation and focus of attention strategies on the kinetics, kinematics, and outcome performance measures of a standing long jump. It was hypothesized that the results would replicate previous findings that an external FOA promotes greater jump distance, joint flexion, and a more efficient projection angle and force production. In addition, it was hypothesized that the brain stimulation group would outperform the placebo group in jump distance, force production, hip flexion, knee flexion, and ankle dorsiflexion.

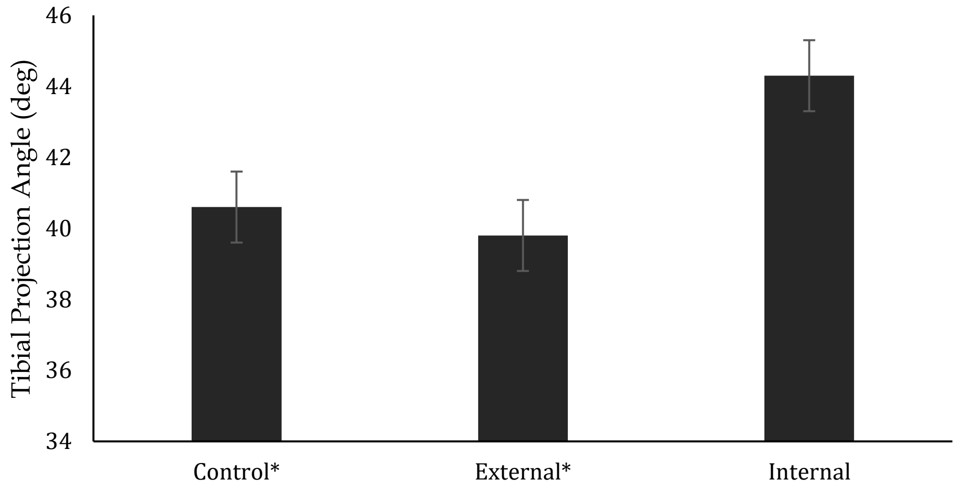

Figure 1. Tibial projection angles at moment of takeoff for three different focus of attention conditions. *Significantly different from internal focus of attention condition ($p < 0.05$).

The results of this research partially supported the hypotheses. The current study replicated past research in that more efficient projection angles were observed of an external FOA compared to an internal FOA which was consistent with previous literature (4, 21). However, the control condition produced a similar projection angle to the external FOA. The majority of results of the attentional focus conditions of the study failed to demonstrate a robust effect of the external focus condition, which is inconsistent with previous studies (4, 7, 15, 16, 19, 21). The use of brain stimulation was found to have no effects on any of the dependent variables measured, which contributes to the mixed body of literature surrounding this topic. In contrast to previous studies (10, 14, 17, 18, 26), the results of the present study did not reveal significant differences in the brain stimulation condition for a single session use. However, other studies are consistent with the present study's findings in that single dose brain stimulation had no effect (2, 9, 25). According to De Xivry et al., a potential cause for not seeing a single-dose effect is that the use of brain stimulation encourages micro-rewiring to create new connections which weakens existing inhibitory connections (25). They used the example of GABA concentration in the primary motor cortex (M1) decreasing during motor learning which is part of the micro-rewiring process. The authors also state that GABA agonists result in performance impairments suggesting GABA to be a key neurotransmitter in M1 short-term plasticity. Kan et al. describes that the ceiling effect can explain why there were no observed differences for the brain stimulation condition (9). Specifically, brain stimulation may have no effect on maximal voluntary isometric contractions because they are already at a maximum; thus a "ceiling" is hit (9).

The lack of change in kinetics could also be explained by previous studies of FOA using the standing long jump. In previous studies, observed changes in kinetics were not found with the standing long jump (19, 21). Instead, the primary variable of change was kinematic -- the projection angle of the jump. Average projection angles of 45.7° for external and 49.5° for internal FOA were found by Ducharme et al. (4). The results of this study followed a similar trend as the external FOA condition produced an average projection angle of 39.7˚ while the internal FOA condition demonstrated an average projection angle of 44.5˚, similar trend but reduced magnitudes of angle. In addition, past studies examining direct brain stimulation generally used novel motor coordination tasks. Even though participants were excluded from this study if they had any previous formal training in the standing long jump, it is possible that participants had performed the task before. Since the task was not completely novel, it is conceivable that there was not much room for improvement in kinetics to be made when provided brain stimulation.

To expand upon this study in the future, it is encouraged that multiple sessions of brain stimulation be examined to determine whether it has any effects on motor learning, rather than motor control which was observed in the present study with a single session of brain stimulation. This study demonstrates how the incorporation of established motor control paradigms with new developments in direct brain stimulation techniques should be examined more closely in the future.

Conclusion: While the study replicated previous findings of the attentional focus effect, there were no observed differences in kinetics, kinematics, or outcome measures of a standing long jump for the brain stimulation condition. This opposes previous research performed using single session direct brain stimulation (3, 13, 18, 20, 26). The present study partly agrees with previous research regarding the differences of an external FOA versus an internal FOA in the projection angle during a standing long jump (4, 21). This study also opposed previous studies by not showing significance in jump distance between extrinsic and intrinsic FOA (15, 16, 19, 21). Further research on this subject should examine other kinetic and kinematic measures such as time to peak force since they are key aspects of overall performance. The influence of the use of a brain stimulation device over multiple sessions should also be tested with a variety of motor skills and not only a standing long jump. It is vital that new research bridge the gap between behavioral motor control paradigms and direct brain stimulation in order to expand the knowledge of within the motor control and learning domains. It may be that the amateur jumping training is more appropriately influenced by focus of attention strategies rather than neuropriming as a mechanism for enhancing jump performance. The neuropriming tool may not be adequate for a skill that has not yet been refined to a higher level of achievement.

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