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A Preliminary Study on How Combining Internal and External Focus of Attention in a Movement Language Can Improve Movement Patterns

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Abstract: *Background*: Movement feedback is used to promote anatomically correct movement patterns. Two primary forms of movement feedback exist: verbal cues and visual cues. There is ongoing debate regarding which type of feedback yields superior effects for learning desired movements. This study investigated how a combination of visual and verbal cues improved shoulder stability in four arm movements, Biceps Curls, Reverse Flys, Rowing, and Shoulder Extensions. *Methods*: Twelve participants were allocated to three different conditions and instructed to perform four different arm movements: Condition 1 (no specific instructions), Condition 2 (image only), and Condition 3 (verbal cues and image). Measurements of acromioclavicular (AC) joint displacement, and electromyography (EMG) peak and burst duration were taken for each arm movement within each condition. *Results*: Condition 3 exhibited a significant reduction in AC displacement and prolonged EMG burst duration. Variations in EMG peak and burst duration across different arm movements were attributed to anticipated muscle activation specific to each movement. *Conclusions*: The combination of visual and verbal cues through the "reConnect Your Dots" movement language was found to improve scapular stabilization and associated muscle activation. This approach to movement patterns practice holds promise for injury rehabilitation and risk mitigation for future occurrences.

Keywords: visual feedback; verbal feedback; scapular stabilization; motor imagery

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1. Introduction

Most coaches and movement instructors use cues and imagery as movement language to teach intended movements. However, misinterpretation or miscommunication of this language can result in inappropriate and undesired movement patterns, potentially leading to poor performance, and in some cases, musculoskeletal injuries, especially in repetitive activities [1]. While precise execution of repetitive movements is crucial in any context, athletes are particularly susceptible to injuries in sports requiring repetitive movements, such as pitching in baseball and serving in tennis, due to the high intensity (level of effort) of each performance as well as the high number of repetitions.

An important example seen frequently in repeated, high-intensity arm movements is the increased risk of shoulder and elbow injuries associated with shoulder hypermobility [2]. For example, baseball pitchers have been found to be 34% more likely to experience a shoulder injury than fielders [1]. The shoulder joint's relatively shallow joint structure makes it susceptible to destabilization when muscular forces act to move the arm at the shoulder, increasing the risk of dislocation or injury [2,3]. Stability of the shoulder joint is heavily dependent on the strength and stability of scapular muscles such as the serratus anterior, rotator cuff muscles, and lower trapezius, which promotes safe movement techniques and reduces injury risk [4,5]. Therefore, in teaching repetitive arm motions like baseball pitching, tennis serving, and vigorous exercise routines, it is essential to employ movement language that effectively conveys biomechanically sound movement patterns that include scapular stabilization (SS) [3].

Motor imagery (MI) is a significant form of movement language. It involves a cognitive process wherein an individual mentally rehearses or stimulates a specific motor action without actually physically performing it. This mental simulation engages similar neural networks and brain regions that are activated when the actual movement is performed [6]. Therefore, MI has been utilized for instructional coaching and has become a major contributor to the success of athletes [7].

One significant limitation encountered in MI is that the quality of the image(s), described by the instructor and/or imagined by the athlete, directly affects the quality of the movement learned [7,8]. This challenge may stem from inconsistencies or complexities in language used to build mental images [9]. For example, a basic squat movement can be described or instructed in numerous ways through the use of MI [10–13]. Some instructors describe the muscles needed for execution, some describe body position such as knees and hips in relation to the feet, and some simply describe an image such as sitting back on a chair [14–16].

Therefore, to maximize the effectiveness of hands-on feedback, coaches and movement instructors continue to explore optimal verbal instructions, MI, or a combination, to cultivate proper technique and produce structurally sound, anatomically correct movements [6,8,10]. Regarding the learner's internal or external focus of attention during hands-on feedback, MI serves to create an internal focus of attention (IFA), while verbal cues provide an external focus of attention (EFA). IFA entails directing attention inward toward body parts and body position [17–21]. Previous research indicates that this type of focus enhances proprioceptive awareness [21,22], thereby contributing to improved motor learning [23]. In contrast, EFA directs performers to focus attention on the outcome of the movement rather than its individual movement elements, such as body positioning and specific movement components.

The focus of this study was to test the impact of a movement language that combines IFA and EFA, known as "reConnect Your Dots", and to compare the effectiveness of using IFA solely versus the combination of IFA and EFA. This particular movement language, "reConnect Your Dots", uses the image of moving and stabilizing points or dots, representing joints, to describe the desired movement. It utilizes IFA by directing attention to a particular body part—"Imagine a dot on your elbow and a dot on your scapula", and EFA by focusing on the outcome of the movement—"Move the elbow dot toward the scapula dot". Although the image of points/dots has been used to direct modern dance movements [24–26], there are no previous studies that have suggested this type of MI is the combination of IFA and EFA. The objective of the movement language (feedback) in this study was to improve scapular stabilization (SS) in four standard exercise movements, Biceps Curls, Reverse Flys, Rowing, and Shoulder Extensions. We hypothesized that by providing both IFA and EFA in condition 3 (C3), SS would improve for all the exercise movements. Additionally, we hypothesized that the combination of IFA and EFA provided in C3 would show superior results for SS compared to IFA alone, condition 2 (C2), resulting in decreased muscle activation in the biceps brachii but increased muscle activation in the triceps brachii and lower trapezius.

2. Methods

2.1. Participants

Twelve healthy volunteer participants between the ages of 20 and 65 years (3 males and 9 females) participated in this study. This study included participants from two CrossFit gyms in Austin, TX, to ensure they were all familiar with the movements to be tested. All participants had at least one year of experience in CrossFit or similar exercise training and at least one previous shoulder injury, but were currently in no physical pain and were able to perform the arm movements without modifications. As movement technique is important for safe and effective movement, a previous shoulder injury could indicate there was room for improvement in arm movements; therefore, these participants were chosen under the assumption that they would be likely to have room for improved arm movement patterns through movement feedback.

All procedures were approved by the Institutional Review Board at the University of Texas at Austin (IRB#: 2019-01-0048) on 10 January 2018 and were in accordance with the Helsinki Declaration of 1975. All participants provided written informed consent prior to participating in the study.

2.2. Data Collection

Volunteer participants were told the location for the study (University of Texas at Austin Biomechanics Lab), what to wear for testing, time commitment involved (2 h), and procedures for the study. For each movement, there were three trials, five repetitions per trial for each movement, which were conducted under three different feedback conditions. Upon arrival, all participants were escorted to the laboratory, informed of test proceedings, and signed the consent forms.

2.2.1. Preparation for Data Collection

Kinematics: A 10-camera motion capture system (VICON Motion Systems Ltd., Oxford, UK) was used to record the upper-body kinematics. Participants were prepared for testing with nine small, spherical reflective motion capture markers placed along each arm and shoulder area based on the upper-body modeling (Vicon Nexus 2.12) with Plug-in-Gait (Vicon Motion System, Oxford Metrics Group Ltd., Oxford, UK): C7, right back over the scapula, sternum, both AC joints, both elbows (lateral epicondyle of the humerus), and medial surface of both wrists at the ulna (see Figure 1). Motion capture data were collected at 120 Hz.

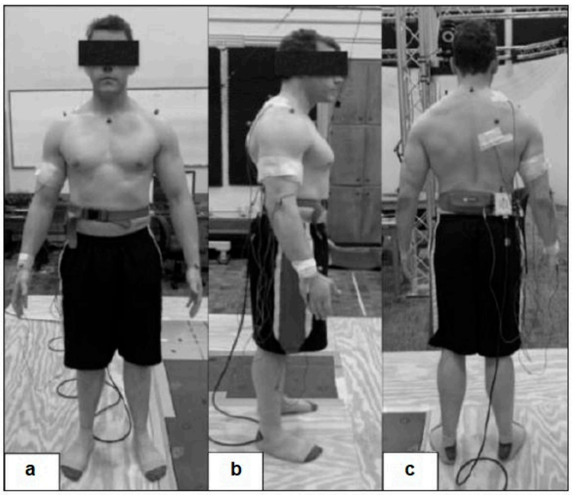

Figure 1. Experimental Setup for data collection: (**a**)—front view; (**b**)—side view; (**c**)—back view.

EMG: A Trigno Wireless EMG System (Delsys, Inc.) was used for acquisition of muscle activity at 1200 Hz. Adhesive pre-gelled Ag/AgCl surface EMG electrodes (inter-electrode distance: 10 mm, Delsys Inc., Boston, MA, USA) were placed on the muscles of the participant's dominant arm: biceps brachii (BB), triceps brachii (TB), lower trapezius (LT). The positioning of the electrodes was in accordance with SENIAM guidelines [27].

2.2.2. Movements Tested

The four movements tested were 1. Biceps Curls, 2. Reverse Flys, 3. Rowing, and 4. Shoulder Extensions (Figure 2). Participants were instructed to sit on a chair, ensuring that ischial tuberosities were close to the front edge, both feet were placed on the ground hip-distance apart, and shoulders were relaxed and down. All participants were familiar with the movements tested in this study.

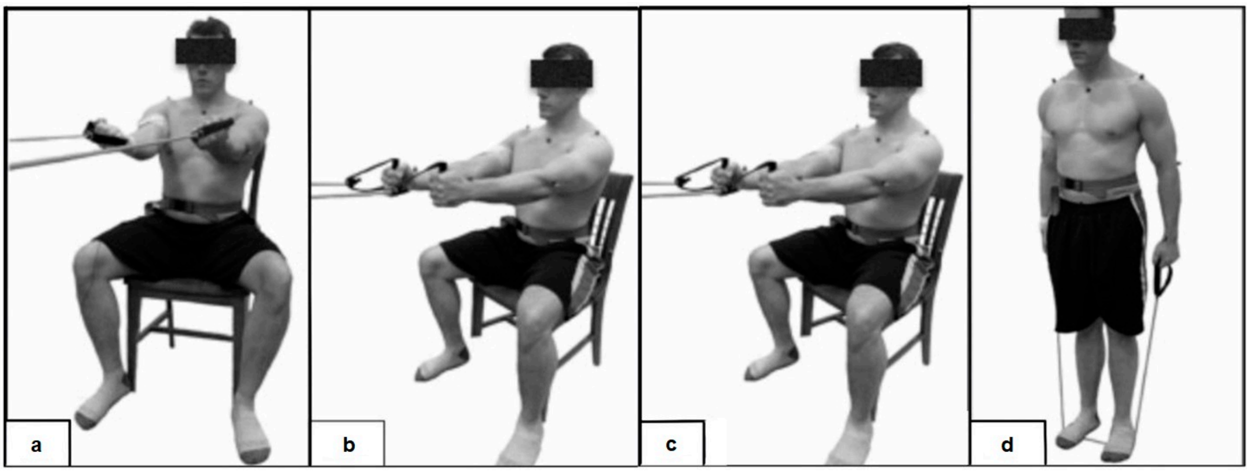

Figure 2. Initial position for the four exercises: (**a**)—Biceps Curls; (**b**)—Reverse Flys; (**c**)—Rowing; (**d**)—Shoulder Extensions.

For the fourth movement (Shoulder Extensions), participants were instructed to stand. A bungee cord was used to provide resistance during the movements. The cord was positioned at a distance that offered sufficient challenge without being overly difficult. Participants grasped the ends of the bungee cord with their hands.

2.2.3. Feedback Condition

There were three different feedback conditions while performing each test movement:

Condition 1—Without instructions about dots, images, or cues

For condition 1 (C1), no specific instructions were provided, as participants were chosen because of previous knowledge of the movements.

Condition 2—Dots image (visual feedback)

Condition 2 (C2) was designed to test whether scapular stability (SS) could be improved through imagery (visual feedback) without verbal cues. Participants were presented with a dot image (Figure 3) and given the following instructions: “Imagine there are dots on your body at your shoulder blades, shoulders, elbows, and wrists, and that the dots are connected by lines. When you move your shoulder blade dots, they will pull or push the shoulder dots, resulting in movement of your elbow and wrist dots”.

Condition 3—Dots image (visual feedback) and verbal instruction (verbal feedback)

For condition 3 (C3), participants were presented with the same image of the body with dots, and instructions for each movement were provided. The following information was given before repeating the four movements: “Some of the dots should move. We will call them movers. Some should not move. We will call them stabilizers”. The movement-specific cues were as follows:

1. Biceps Curls—“The shoulder, shoulder blade, and elbow dots should not move and the wrist dots should move toward the shoulder dots”.
2. Reverse Flys—“The shoulder and shoulder blade dots should not move. The wrist dots should move back toward the shoulder blade dots and the elbow dots should maintain their relationship to the shoulder and wrist dots (slightly bent line) throughout the move”.
3. Rowing—“The shoulder and shoulder blade dots should not move, the elbow dots should move back toward the shoulder blade dots, and the wrist dots should follow the elbow dots”.

4. Shoulder Extensions—"The shoulder and shoulder blade dots should not move. The wrist dots should move back toward the shoulder blade dots and the elbow dots should maintain their relationship to the shoulder and wrist dots (a slightly bent line) throughout the move".

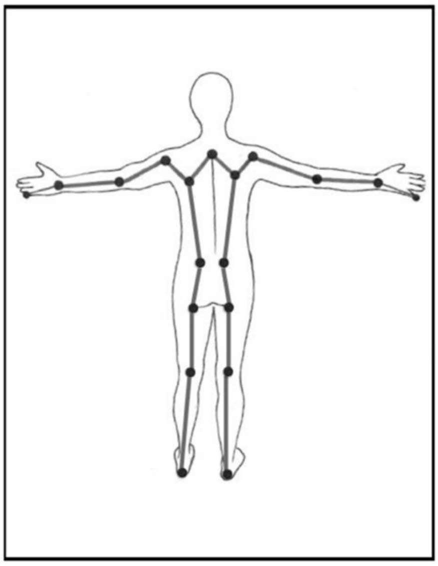

Figure 3. Dots image used for feedback conditions 2 and 3.

2.3. Data Acquisition and Analysis

All kinematic and EMG variables to evaluate scapular stability during the movement were computed using a custom-written algorithm in MATLAB (version 2023b, The Mathworks Inc., Natick, MA, USA).

Kinematics: Kinematic data (the acromioclavicular (AC) joint displacement) exported by Vicon Nexus 2.12 Software (Vicon, Oxford Metrics, Oxford, UK) were low-pass filtered through a fourth-order Butterworth filter with a cut-off frequency of 6 Hz [28].

EMG: The peak amplitude and burst duration of EMG in each muscle (biceps, triceps, and lower trapezius) were measured. The raw EMG data collected during the movement testing underwent the following processing steps:

(1) Pre-processing of sEMG signal: Any DC offset was first eliminated using the "detrend" function in MATLAB. Next, a median filter was applied to the signal to remove noise, followed by the application of a 20–450 Hz bandpass filter to extract the frequency range where muscular energy is concentrated [29–31].

(2) sEMG rectification and linear envelope: sEMG signal values below zero were converted to positive values of the same amplitude to create a full-wave rectified sEMG signal (see Figure 2). To obtain sEMG envelopes, a 2nd-order Butterworth low pass filter with a 20 Hz cutoff frequency was applied for digital smoothing [29–31].

(3) % EMG peak amplitude

EMG peak amplitude was normalized to the baseline EMG value, calculated as follows:

$$\%\ \text{EMG peak amplitude} = \frac{(\text{peak amplitude value} - \text{baseline EMG value})}{\text{baseline EMG value}} \times 100$$

(4) EMG Burst Duration

EMG onset time was determined as the moment when the EMG exceeded three standard deviations (SD) of the baseline EMG value. The EMG offset was identified as the time when the EMG activity decreased to a level below three SD of the baseline EMG value [32]. The interval between EMG on and off was defined as "EMG burst duration".

2.4. Statistical Analysis

Statistical software (IBM SPSS Statistics 25; Chicago, IL, USA) was used for all statistical analyses, with an established a priori alpha level of 0.05. For the justification of our sample size, an a priori power analysis was conducted using G*Power. Effect size (Cohen's d) was calculated based on previous studies [28,31,32]. Support for our sample size comes from several studies on external and internal focus of attention, with a similar number of subjects. Zachry et al. (n = 14) found that EFA resulted in more accuracy when free throw shooting, when compared to IFA. In this study, EMG was used to measure biceps brachii, triceps brachii, and deltoid muscle activity on the shooting arm. Even though more accuracy occurred in the free throw with EFA, less EMG activity resulted in the biceps and triceps [18]. Similarly, Kuhn et al. (n = 14) reported EFA produced better motor performance or greater control over the foot pedal compared to IFA; however, EMG results showed no significant differences [33].

In the current study, we detected an effect size of 0.78. Through power calculation, we determined that with 12 participants, there would be 80% power ($1-\beta$) at a 5% level of significance (α). Normality was assessed using the Shapiro–Wilk test.

A two-way repeated measures ANOVA was used to determine differences in (1) the acromioclavicular (AC) joint displacement in both vertical and horizontal directions, and (2) EMG peak amplitude and burst duration in each muscle (biceps, triceps, and lower trapezius). The first within-subject factor was "three different feedback conditions (C1, C2, and C3)", while the second within-subject factor was "four test movements (Biceps Curls, Reverse Flys, Rowing, and Shoulder Extensions)".

3. Results

No interaction was observed between exercise type and feedback condition on AC joint displacement and EMG activity.

3.1. AC Joint Displacement

Horizontal Displacement

There was a main effect of the exercise type on horizontal AC joint displacement ($p < 0.01$, effect size: $\eta 2 = 0.546$, observed power = 1.000). Reverse Flys and Rowing showed significantly greater horizontal AC joint displacement compared to Biceps Curls and Shoulder Extensions ($p < 0.01$, Figure 4A).

There was a main effect of the feedback conditions on horizontal AC joint displacement ($p < 0.01$, effect size: $\eta 2 = 0.878$, observed power = 1.000). C3 (Dots image (visual feedback) and verbal instruction (verbal feedback)) showed significantly less horizontal AC joint displacement compared to C2 (Dots image without verbal instruction, $p < 0.01$, Figure 4B) and C1 (without instructions, $p < 0.01$, Figure 4B).

Vertical Displacement

There was a main effect of the exercise type on vertical AC joint displacement ($p < 0.01$, effect size: $\eta 2 = 0.625$, observed power = 1.000). Biceps Curls showed significantly less vertical displacement compared to Reverse Files, Rowing, and Shoulder Extensions ($p < 0.01$, Figure 4C).

There was a main effect of the feedback conditions on vertical AC joint displacement ($p < 0.05$, effect size: $\eta 2 = 0.238$, observed power = 0.789). C3 showed significantly less vertical AC joint displacement compared to C2 (Dots image without verbal instruction, $p < 0.05$, Figure 4D) and C1 (without instructions, $p < 0.05$, Figure 4D).

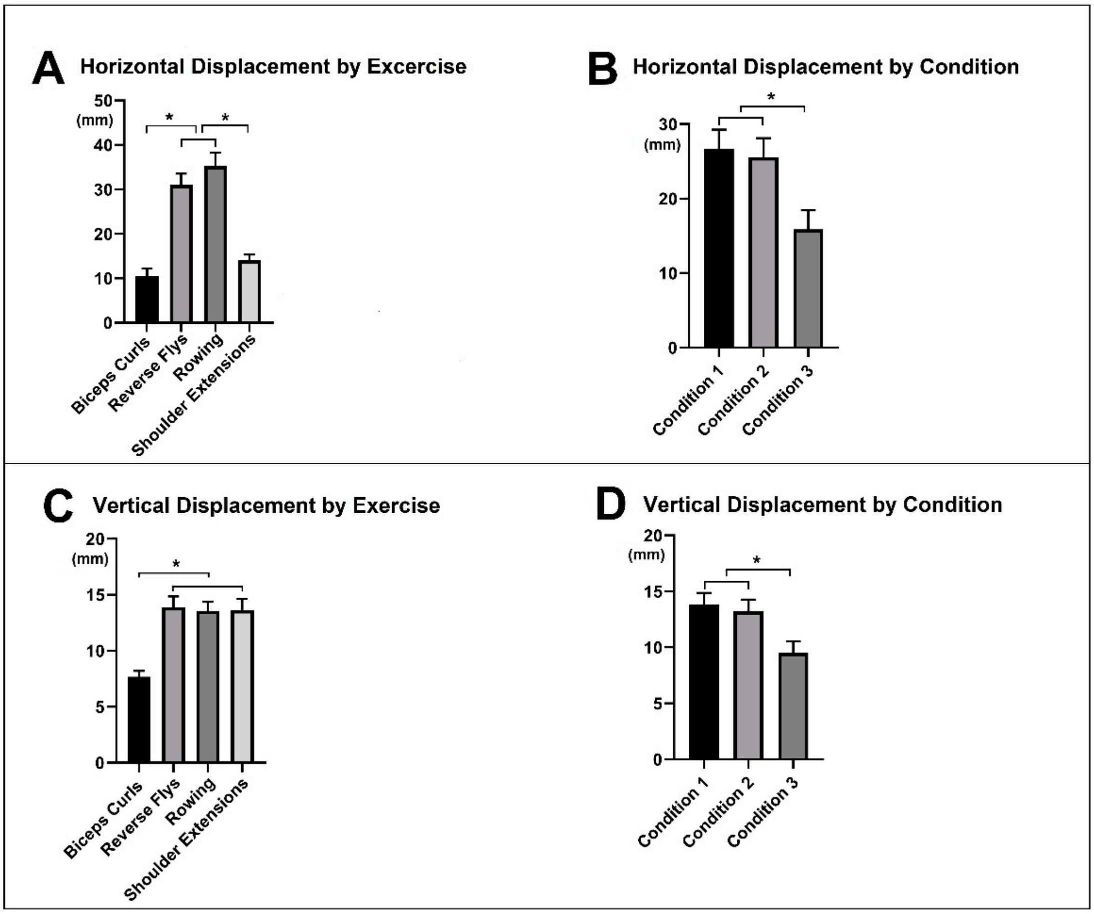

Figure 4. Differences in horizontal and vertical acromioclavicular (AC) joint displacement by Exercise (**A**,**C**) and by Feedback Condition (**B**,**D**): Condition 1: Without instructions about dots, images, or cues. Condition 2: Dots image (visual feedback). Condition 3: Dots image (visual feedback) and verbal instruction (verbal feedback). * represents statistical significance between exercises or feedback conditions ($p < 0.05$).

3.2. EMG Activity

3.2.1. Normalized %EMG Peak Amplitude

Biceps

There was a main effect of the exercise type on %EMG peak ($p < 0.01$, effect size: $\eta2 = 0.744$, observed power = 1.000). Biceps Curls showed greater %EMG peak compared to Reverse Flys, Rowing, and Shoulder Extensions ($p < 0.01$, Figure 5A). Additionally, Rowing showed greater %EMG peak compared to Reverse Flys ($p < 0.05$, Figure 5A).

There was no significant difference in %EMG peak among the three feedback conditions (Figure 5B).

Triceps

There was a main effect of the exercise type on %EMG peak ($p < 0.01$, effect size: $\eta2 = 0.751$, observed power = 1.000). Shoulder Extensions showed greater %EMG peak compared to Biceps Curls, Reverse Flys, and Rowing ($p < 0.01$, Figure 5C). Additionally, Reverse Flys showed greater EMG peak compared to Biceps Curls and Rowing ($p < 0.01$, Figure 5C).

There was no significant difference in %EMG peak among the three feedback conditions (Figure 5D).

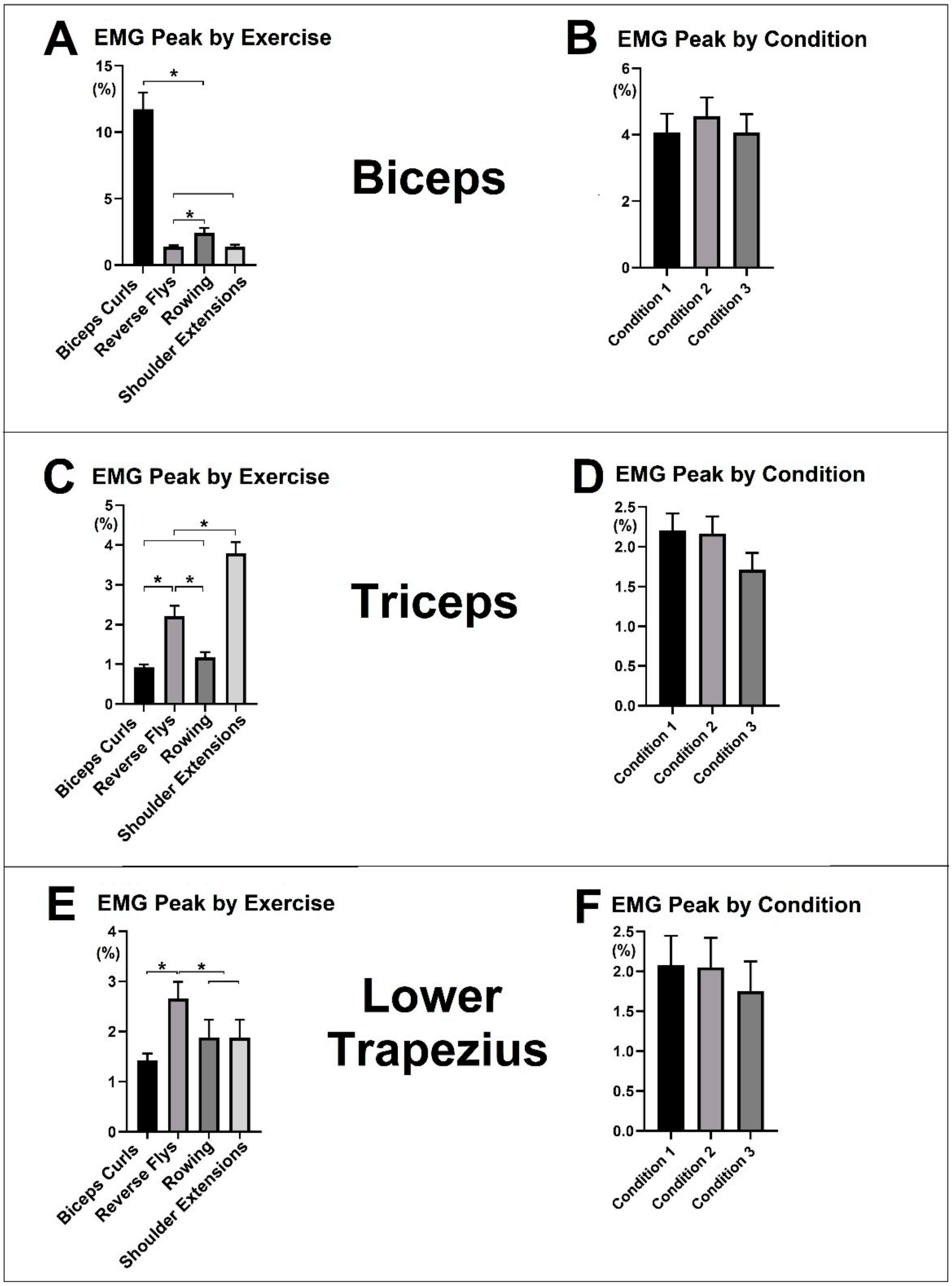

Figure 5. Differences in normalized EMG peak (%) of each muscle (biceps, triceps, and lower trapezius) by Exercise (**A**,**C**,**E**) and by Feedback Condition (**B**,**D**,**F**): Condition 1: Without instructions about dots, images, or cues. Condition 2: Dots image (visual feedback). Condition 3: Dots image (visual feedback) and verbal instruction (verbal feedback). * represents statistical significance between exercises or feedback conditions ($p < 0.05$).

Lower Trapezius

There was a main effect of the exercise type on %EMG peak ($p < 0.01$, effect size: $\eta2 = 0.109$, observed power = 0.828). Reverse Flys showed greater EMG peak compared to Biceps Curls ($p < 0.01$, Figure 5E), and Rowing and Shoulder Extensions ($p < 0.05$, Figure 5E).

There was no significant difference in %EMG peak among the three feedback conditions (Figure 5F).

Across all feedback conditions and in each exercise, there was no significant difference in %EMG Peak Amplitude (Figure 6).

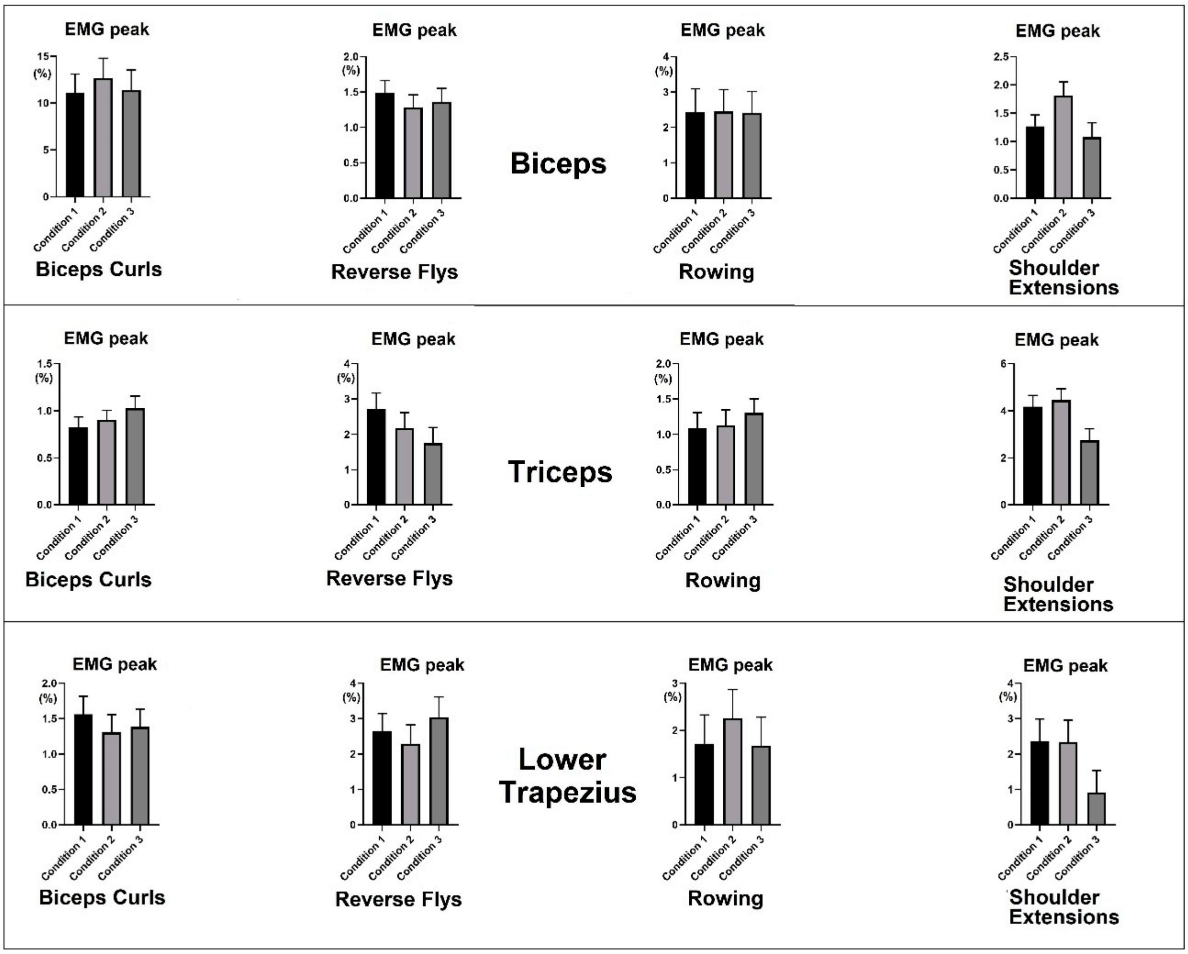

Figure 6. Differences in normalized EMG peak (%) of each muscle (biceps, triceps, and lower trapezius) by each Exercise and by Feedback Condition: Condition 1: Without instructions about dots, images, or cues. Condition 2: Dots image (visual feedback). Condition 3: Dots image (visual feedback) and verbal instruction (verbal feedback).

3.2.2. EMG Burst Duration

Biceps

There was a main effect of the exercise type on EMG burst duration ($p < 0.01$, effect size: $\eta2 = 0.398$, observed power = 0.95). Biceps Curls showed longer EMG burst duration compared to Rowing and Shoulder Extensions ($p < 0.01$, Figure 7A).

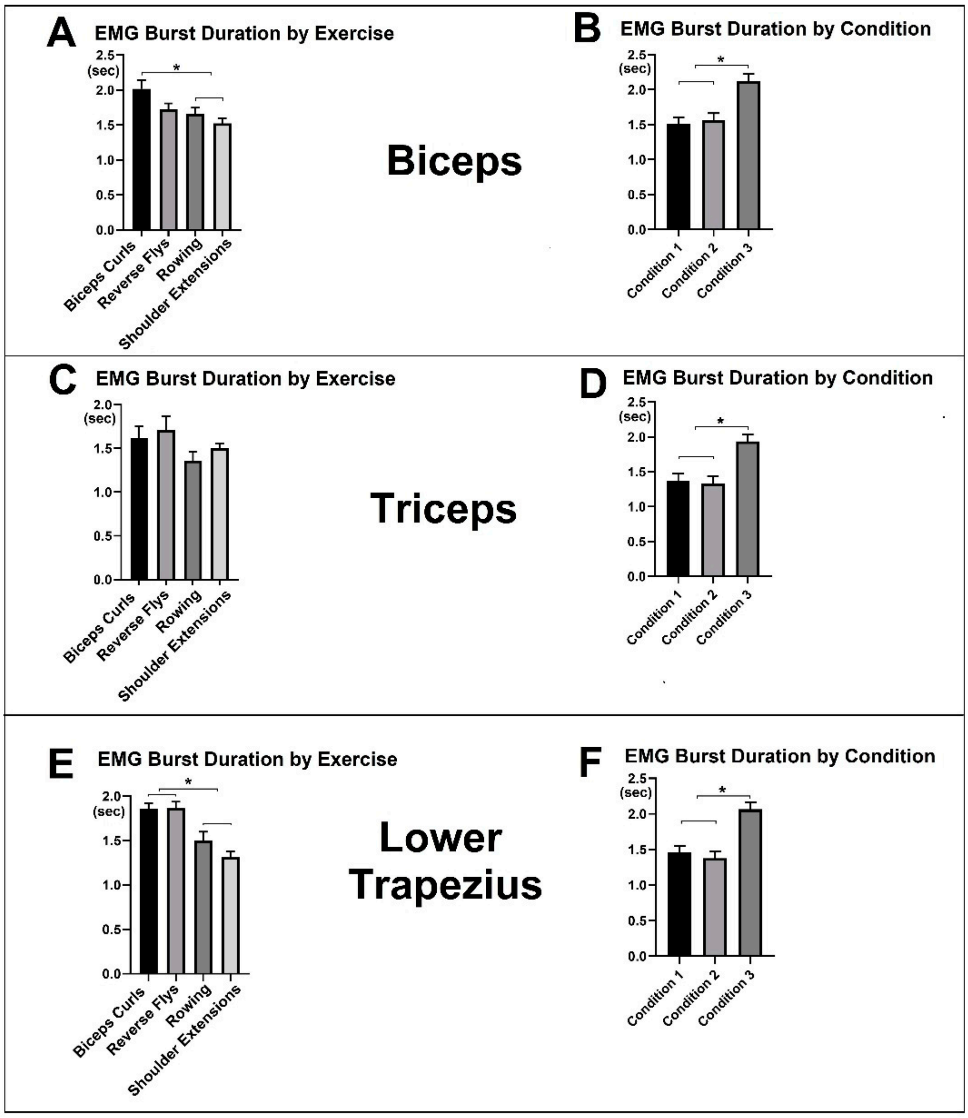

Figure 7. Differences in EMG burst duration (s) of each muscle (biceps, triceps, and lower trapezius) by Exercise (**A**,**C**,**E**) and by Feedback Condition (**B**,**D**,**F**): Condition 1: Without instructions about dots, images, or cues. Condition 2: Dots image (visual feedback). Condition 3: Dots image (visual feedback) and verbal instruction (verbal feedback). * represents statistical significance between exercises or feedback conditions ($p < 0.05$).

There was a main effect of the three feedback conditions on EMG burst duration ($p < 0.01$, effect size: η2 = 0.959, observed power = 1.00). C3 (Dots image and cues) required significantly longer EMG burst duration compared to C2 (Dots image without verbal instruction, $p < 0.01$, Figure 7B) and C1 (Without instructions $p < 0.01$, Figure 7B).

Triceps

There was no difference in EMG burst duration among the exercise types (Figure 7C).

There was a main effect of the three feedback conditions on EMG burst duration ($p < 0.01$, effect size: η2 = 0.955, observed power = 1.00). C3 (Dots image and cues) required significantly longer EMG burst duration compared to C2 (Dots image without verbal instruction, $p < 0.01$, Figure 7D) and C1 (Without instructions $p < 0.01$, Figure 7D).

Lower Trapezius

There was a main effect of exercise type on the EMG burst duration ($p < 0.01$, effect size: η2 = 0.736, observed power = 1.00). Biceps Curls and Reverse Flys showed longer EMG burst duration compared to Rowing and Shoulder Extensions ($p < 0.01$, Figure 7E).

There was a main effect of the three feedback conditions on EMG burst duration ($p < 0.01$, effect size: η2 = 0.965, observed power = 1.00). C3 (Dots image and cues) requires significantly longer EMG burst duration compared to C2 (Dots image without verbal instruction, $p < 0.01$, Figure 7F) and C1 (Without instructions $p < 0.01$, Figure 7F).

EMG burst duration (s) of each muscle (biceps, triceps, and lower trapezius) showed significant differences between feedback conditions in each exercise (Figure 8).

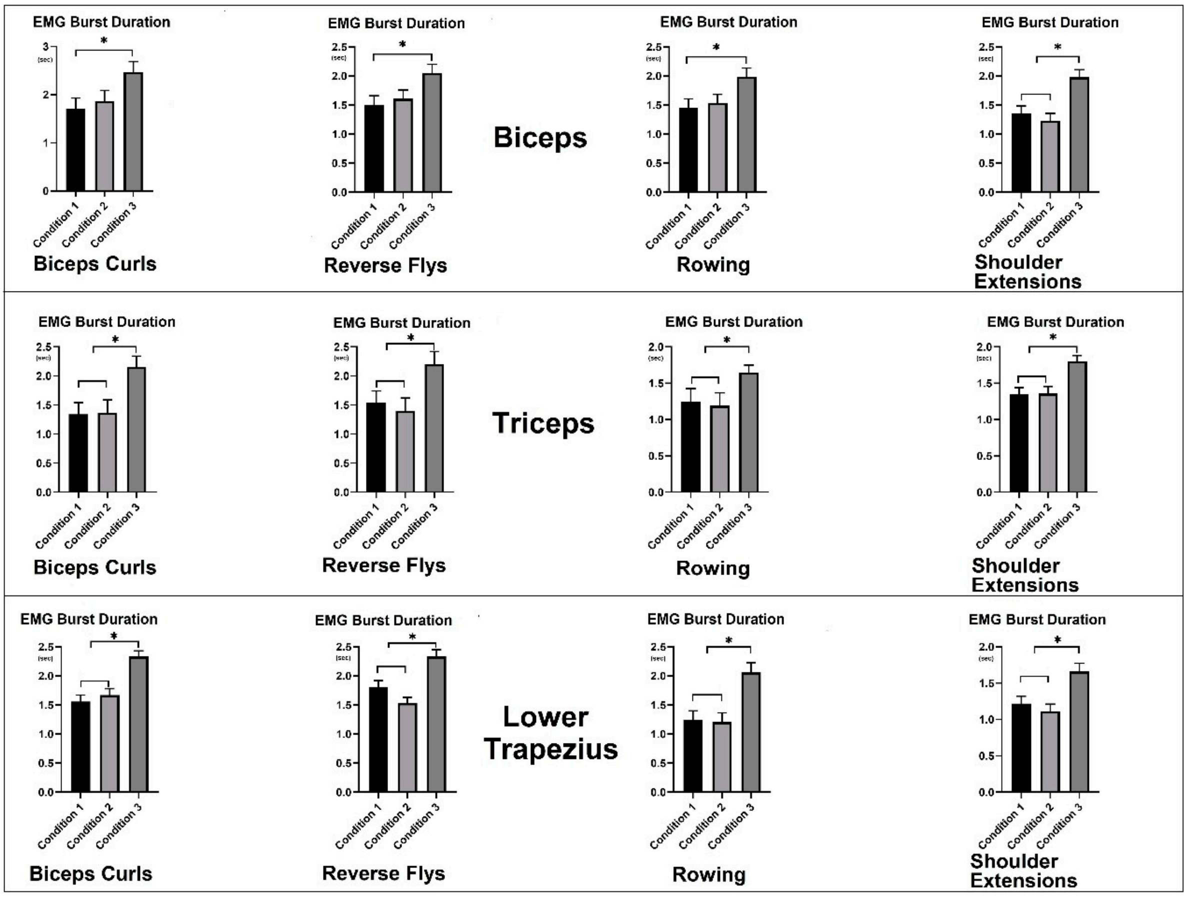

Figure 8. Differences in EMG burst duration (s) of each muscle (biceps, triceps, and lower trapezius) by each Exercise and by Feedback Condition: Condition 1: Without instructions about dots, images, or cues. Condition 2: Dots image (visual feedback). Condition 3: Dots image (visual feedback) and verbal instruction (verbal feedback). * represents statistical significance between exercises or feedback conditions ($p < 0.05$).

4. Discussion

The objective of this study was to investigate the effects of providing visual and/or verbal feedback on the improvement of scapular stabilization (SS) and associated muscle activation in four standard exercise movements: Biceps Curls, Reverse Flys, Rowing, and Shoulder Extensions. Our primary findings indicated that “reConnect Your Dots” movement language, the combination of MI, visual feedback with IFA, and verbal feedback (EFA), contributed to improved scapular stabilization (SS) and enhanced muscle activity during these exercises.

4.1. AC Joint Displacement

Differences between Feedback Condition

The decrease in horizontal and vertical AC displacement in the combination of visual and verbal feedback condition, C3, suggested that the "reConnect Your Dots" movement language, IFA combined with EFA (combination of visual and verbal feedback), was effective for improving SS in the four arm movement patterns. It is important to note that significant differences existed between C1 and C3 and between C2 and C3, whereas there was no difference between C1 and C2. C1 was designed to rely solely on the participants' previous knowledge of the movements presented and their individual background in movement; therefore, no specific verbal instructions were provided in this condition. As previously mentioned, there are numerous verbal cues or instructions to describe one movement and our goal was to test the "reConnect Your Dots" movement language, not any other specific movement language. When the dots image was introduced in C2, there was no significant change in the movement patterns and, in some cases, there was actually increased scapular movement. The goal of this study was to test the combination of IFA and EFA (C3); however, an interesting aspect of movement language is imagery, so we therefore added C2 to our study.

When verbal cues were added to the image (C3), there was an overall decrease in AC joint movement, indicating greater SS. This effect may be attributed to the simplicity of the cues used, which provided instructions about the outcome of the movement of a particular point on the body. Simple and familiar cues, incorporated into EFA practice, have been shown to be beneficial for motor learning, particularly in the early stages [19,20]. Krajenbrink et al. reported that even though EFA was a more effective form of practice than IFA [20], this advantage was only observed in the early phase of practice and not the subsequent phases of motor learning [34].Additionally, a comprehensive meta-analysis indicated that EFA is far superior to IFA in terms of motor performance and learning, regardless of age or skill level. However, research has also shown that using IFA for movement preparation and EFA for movement execution resulted in greater movement success [22,35].

The cues used in the current study involved constructing an image of points on the body (motor imagery), related to corresponding joints, with cues instructing which points should move, and in what direction, and which points should remain stable (verbal cues). The success of this technique may lie, at least in part, in structuring a typical IFA learning situation to be more like EFA because the instructions were focused on a visible outcome (the motion of particular dots) [36,37]. That is, the image of the points on specific joints directed attention to an abstract representation of the body and body movements, which likely created enhanced proprioception or kinesthetic awareness (improved IFA) [38], "preparing for movement" [22,35].

When attention was directed toward moving or relocating the dots, the focus converted to the outcome of the movement by verbal feedback (increased EFA) [22,35].

Differences between exercises

Our findings showed that Reverse Flys and Rowing induced significantly more horizontal AC joint displacement compared to Biceps Curls and Shoulder Extensions. These exercises involve moving the arms from a front to a back position, engaging posterior muscles such as the triceps brachii, lower trapezius, rhomboids, and serratus anterior [36,39]. Perhaps results showed more displacement because women tend to have weaker posterior muscles compared to anterior muscles like the biceps brachii and pectoralis major [36,37] and most of our participants were female. The greater displacement during movements toward the back suggests possible inadequate stabilization by the lower trapezius while the triceps brachii controls the arm movement [36].

There was a significant main effect of exercise type on vertical displacement. Biceps Curls exhibited significantly less vertical displacement compared to Reverse Flys, Rowing, and Shoulder Extensions. This is attributed to the nature of the Biceps Curls movement, which primarily involves altering the angle of the elbow joint while stabilizing the shoulder and shoulder blade. In contrast, Reverse Flys, Rowing, and Shoulder Extensions entail lateral rotation of the humeral head while maintaining stability in the shoulder and shoulder blade, resulting in potentially greater vertical displacement. Rowing additionally involves both humeral head movement and elbow joint angle adjustment, as the arms move backward from a forward position. Shoulder Extensions engage the upper trapezius and deltoid muscles, potentially causing vertical movement in the shoulder and shoulder blade [40].

4.2. %EMG Peak Amplitude

No significant increase in %EMG peak amplitude was observed for the feedback conditions.

However, significant differences in %EMG peaks between exercises were noted: biceps brachii for Biceps Curls, lower trapezius for Reverse Flys, and triceps brachii for Shoulder Extensions. These findings align with the expected muscle activation patterns for these exercises. For instance, Biceps Curls target the biceps brachii, along with other anterior upper humeral muscles, resulting in higher %EMG peaks. The stable upper attachment sites at the scapula during this movement lead to forearm movement toward the shoulder joint, with the triceps brachii and lower trapezius contracting to stabilize the humerus and scapula [40], respectively. Given that the biceps brachii primarily drives the action, it is expected to be the dominant contracting muscle [41].

Reverse Flys showed greater lower trapezius %EMG peaks, indicating more activation in the lower trapezius. Perhaps this was because of the position of the humerus. The starting position of the movement is with the arms raised 90° to the torso. This position in itself challenges the scapular position—one must work to keep the scapula down when raising the arms. As the arm moves posteriorly, the primary movers are latissimus dorsi and teres major, while the lower trapezius continues to maintain control of the scapula [33]. While the biceps and triceps act as stabilizers in this movement, the triceps showed slightly greater %EMG than the biceps, which is congruent with expected results—posterior movements would recruit posterior muscles.

The Shoulder Extension is similar to Reverse Flys in that the humerus is rotating backward in the glenohumeral joint while the scapula remains stable. In the Shoulder Extension, the triceps brachii had greater %EMG peaks. In this movement, the triceps are responsible for stabilizing the scapula while simultaneously adding stability to the humerus. Although the primary mover is not the triceps (latissimus dorsi), because the humerus is moving backward, posterior muscles will most likely contract more to assist in movement (and stability). The lower trapezius should assist primarily in stabilizing the scapula as the humeral head rotates backward within the joint capsule [33]. The lower trapezius, however, did not show %EMG peak during this movement, which supports the vertical displacement results for Shoulder Extensions, which showed more displacement. In other words, there was more movement in the shoulder during Shoulder extensions due to the lack of lower trapezius activation.

4.3. EMG Burst Duration

The differences observed between exercises in the biceps and lower trapezius align with the expected muscle activation patterns for these exercises, as mentioned above. However, our findings regarding feedback condition differences provide significant insights into the effects of visual and verbal feedback combinations on movement performance.

We observed a significant increase in EMG burst duration for all three muscles: biceps brachii, triceps brachii, and lower trapezius, during the “reConnect Your Dots” movement language condition, C3, which was the combination of visual feedback (motor imagery, internal focus of attention) and verbal feedback (external focus of attention). The increase in burst duration may suggest more focus or concentration on the movement, which may promote increased SS, thereby reducing AC joint displacement and promoting overall body stability (or core stability) [3,4,42].

Muscles originating from a stable scapula can produce more force on the arm [34], enabling greater arm power and increased range of motion (ROM) in the glenohumeral joint. The biceps brachii, triceps brachii, and lower trapezius attach to the scapula and contribute to its stabilization during performing an action. We observed that the combination of MI (visual feedback) and verbal feedback led to longer EMG burst durations, indicating greater and continuous muscle activation, thus improving AC joint stability.

Many research studies have supported the idea that strengthening muscles that stabilize the scapula improves arm movement techniques and therefore decreases susceptibility to injury [43–45]. Our findings suggest that the use of the combination of visual and verbal feedback simultaneously brings a similar effect of activating muscles for arm movement control in terms of AC joint stability. In addition, since scapular stabilization is highly dependent on core stabilization [3,4,42], our findings indicate that the combination of two types of feedback might assist in core muscle stability as well.

5. Limitations and Future Studies

One limitation of this study was the small sample size. In the future, studies should include more participants. Similarly, this study only focused on four arm movements. More movements, including legs and full-body exercises, should be tested. Additionally, it would be a more thorough investigation of SS if more SS muscles, such as the rotator cuff muscles, teres major, and serratus anterior, could be tested for %EMG peak activation.

6. Conclusions

The results of this study supported the first hypothesis, that if SS increased using the "reConnect Your Dots" movement language, then AC joint displacement would decrease, vertically and horizontally. The results also partially supported the second hypothesis, that %EMG peak amplitude would increase for the lower trapezius and triceps brachii muscles. However, the EMG peak did not increase significantly for the lower trapezius, and contrary to the hypothesis, the biceps brachii muscle activation increased throughout the movements rather than decreased. And although the EMG peak results were not significant, the EMG burst duration was significantly changed in C3. This indicated a longer muscle contraction and therefore showed a positive change.

This study attempted to establish an effective motor learning environment, utilizing a combination of IFA and EFA, to improve arm movement exercise patterns and increase SS. The results showed a positive correlation between the use of the "reConnect Your Dots" movement language and improved (reduced) AC joint displacement, suggesting improved scapular stability, but this might have been more significant if individual proprioception could have been controlled or assessed. Future studies are necessary to determine how effective this movement language could be for teaching other movement patterns.

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