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The Effects of Verbal Cues on Electromyographic Activity During a Quadriceps Setting Exercise

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Context: A quadriceps setting exercise is commonly used following knee injury, but there is great variation in cues that clinicians provide to patients when performing the exercise.

Objectives: To determine if internal, external, or visual cues result in the greatest quadriceps electromyographical (EMG) activity during a quadriceps setting exercise in healthy individuals.

Design: Descriptive laboratory study.

Setting: University research laboratory.

Patients or Other Participants: Thirty healthy individuals volunteered for this study. Participants were given 1 of 5 cues in a randomized order: internal cue "tighten your thigh muscles," internal cue "push your knee down," external cue "push into the bolster," external cue "push into the strap," or visual biofeedback using the cue "raise the value on the screen as high as you can."

Main Outcome Measure(s): Normalized vastus lateralis electromyographical activity.

Results: Both visual biofeedback (83.2% ± 24.9%) and the press into the strap condition (76.8% ± 24.4%) produced significantly greater ($P < .001$) electromyographical activity than the push knee down (53.2% ± 27.0%), tighten thigh (52.7% ± 27.3%), or push into the bolster (50.8% ± 26.3%) conditions. There was no significant difference ($P = .10$) between the visual biofeedback and press into the strap conditions as well as no significant difference ($P > .38$) between the push knee down, tighten thigh, or push into the bolster conditions.

Conclusion: If the clinical aim during a quadriceps setting exercise is to obtain the greatest volitional muscle recruitment, the use of visual biofeedback or pressing into a strap is recommended.

Key Words: electromyography, lower extremity, attention of focus, verbal cueing

Key Points

- Visual biofeedback produced the greatest (83%) quadriceps electromyographic activity.
- Pressing into a strap produced the second greatest (77%) quadriceps electromyographic activity.
- The most common quadriceps setting cues only produced about 50% maximum electromyographic activity.

Knee arthroscopy is one of the most common outpatient surgical procedures, with increasing rates each year.[1–3] Quadriceps weakness and inhibition are common impairments resulting from knee injury and surgical intervention.[4] Decreased quadriceps voluntary activation (ie, quadriceps inhibition) is caused by both decreased spinal reflex excitability and intracortical inhibition.[5] A limiting factor in maximizing quadriceps strength improvements during rehabilitation is decreased quadriceps voluntary activation.[6] Isometric quadriceps setting exercises (ie, quad sets) are commonly used in early stages of rehabilitation to initiate quadriceps activation following knee injury or surgery. During a quadriceps setting exercise, typically, the patient is seated with the knee in full extension and instructed to perform an isometric contraction of the quadriceps muscle with a variety of methods and instructions. Despite the frequency of quadriceps setting exercise prescription in the rehabilitation setting, there is no consensus between practitioners for standardized cues or attention of focus for the commonly used quadriceps setting exercise. Clinical observation suggests that practitioners use a variety of verbal cues (eg, internal or external focus) or feedback methods (eg, visual and auditory) when prescribing the quadriceps setting exercise. Internal focus is defined as giving instructions to concentrate on their body movements (ie, tighten the thigh muscle), and an external focus of attention is defined as giving a person a focus away from the body movements (ie, push into a bolster).[7] Biofeedback (eg, visual and auditory) provides biological information to patients in real time.[8]

An external focus of attention has been shown to benefit performance in a wide range of motor tasks across varied patient populations in motor learning and control literature.[8–15] Recent research has suggested that an external focus of attention may target underlying intracortical inhibition early in the rehabilitation process as well as improve motor control during completion of more complex coordination tasks later in the rehabilitation process.[16] In addition to the performance benefits of an external focus of attention, participants tend to prefer an external focus compared with an internal focus of attention.[14] Despite these positive findings, 1 study showed that only 4% of the feedback provided to patients in a physical therapy setting used an external focus of attention.[17]

The term *biofeedback* was coined to mean the use of instrumentation to make covert physiological processes more overt to the patient. Visual feedback is the instantaneous knowledge of results while completing a task provided to someone from an external source. Knowledge of results consists of providing feedback to a functional outcome (ie, was the task performed).[18] More specifically, electromyographic (EMG) biofeedback is a process that provides an individual with a real-time visualization of magnitude and muscular tension, allowing the individual to concurrently modify performance.[19] Using visual biofeedback while performing an intervention resulted in an increase in long-term carryover for muscle performance.[20] There is limited research comparing internal cues, external cues, and visual biofeedback, but a visual biofeedback attention of focus has clinically demonstrated improved specificity of muscle performance for interventions.[21]

Although the quadriceps setting exercise is commonly used in clinical practice, the focus of attention and cues used vary substantially. Additionally, the ideal cue or feedback mechanism to enhance exercise performance is still unclear. Therefore, the purpose of this study was to determine if variation in attentional focus alters muscle activation of the quadriceps during a quadriceps setting exercise. It was hypothesized that an external focus of attention will maximize quadriceps EMG activation better than an internal focus of attention and visual biofeedback during a quadriceps setting exercise. A secondary purpose of this study was to quantify which attention of focus resulted in the most quadriceps EMG activation for each participant. It was hypothesized that an external focus of attention will result in the highest quadriceps EMG activation during a quadriceps setting exercise compared with an internal focus of attention and visual biofeedback attention of focus.

METHODS

Participants

This was a descriptive laboratory study, and all the data collected was in a university research laboratory. Study approval was granted by the institutional review board at Creighton University (IRB 2000747). Written informed consent was obtained from each participant prior to participation. Thirty healthy individuals (15 men and 15 women; age = 25 ± 2.5 years, mass = 79.3 ± 14.2 kg, height = 176.9 ± 9.5 cm) volunteered for this study from a convenience sample (Table 1). Participants were included in this study if they were 19 to 50 years old with a Tegner score greater than or equal to 5 (heavy labor, competitive sports, and recreationally active). Participants were excluded from this study if they had experienced a traumatic spine or lower extremity injury within the past 6 months, were not able to achieve 0° of knee extension or more than 10° of knee hyperextension, or if the participant was unable to give consent or understand the procedures of the experiment. Participants signed an approved informed consent form and filled out a prior medical history form. Measures of height (centimeters) and weight (kilograms) were obtained before data collection (Table 1). Testing was performed in a single session, and the limb the patient identified to kick a ball was the only limb tested. To optimize signal quality, the surface EMG electrodes were secured to the skin superficial to the vastus lateralis muscle belly 10 cm superior lateral to the patella, in line with the approximate muscle fiber pennation angle in a bipolar fashion. The vastus lateralis muscle was analyzed as it is the optimal muscle representation of quadriceps function.[22]

Table 1. Participant Demographics (Mean ± SD)

Gender, male/female	15/15
Age, y	25.0 ± 2.5
Height, cm	176.9 ± 9.5
Weight, kg	79.3 ± 14.2
Tegner Activity Scale	5.8 ± 0.8
Leg dominance, left/right	2/28

Maximal Voluntary Isometric Contraction Testing Using an Electromechanical Dynamometer

Participants were seated on an electromechanical dynamometer (Biodex System 3, Computer Sports Medicine, Inc) and positioned using standardized procedures with hips and knees flexed at 90°. Straps were positioned across the chest and pelvis. Participants were instructed to place their arms across their chest and kick into the device (Figure 1), consistent with methods from previous studies.[23–25] The electromechanical dynamometer was interfaced with a data acquisition system (MP150, Biopac Systems, Inc), with EMG and quadriceps torque data sampled simultaneously at 2 kHz.

Participants were instructed to complete 4 submaximal and 2 maximal knee extension warm-up trials (3 at 50% maximum effort, 1 at 75% maximum effort, and 2 near 100% maximum effort) and to familiarize themselves with the testing procedure. Three maximal effort knee extensions were performed for approximately 3 to 5 seconds each, with a 30-second break between trials. Loud verbal encouragement and instantaneous biofeedback of their torque production was displayed on a monitor with threshold lines at 90% and 100% of their maximum peak torque to ensure maximal effort.[26]

EMG signals were processed offline with a custom written analysis program (Labview version 19.0, National Instruments). The surface EMG signals were amplified (gain = 1000), rectified, zero meaned, and digitally filtered using a zero-phase shift fourth-order Butterworth filter with a band pass of 10 to 499 Hz. Peak EMG amplitudes were calculated from a 500-millisecond epoch corresponding to the highest average EMG for each contraction condition. Peak EMG from each contraction was expressed as the root mean square value in millivolts. Peak EMG from the maximal voluntary isometric contraction (MVIC) contraction performed on the electromechanical dynamometer was used to normalize the peak EMG from the quadriceps setting exercise contractions, with values expressed as a percentage of maximum EMG obtained on the electromechanical dynamometer. All subsequent analyses were completed on the filtered signals.

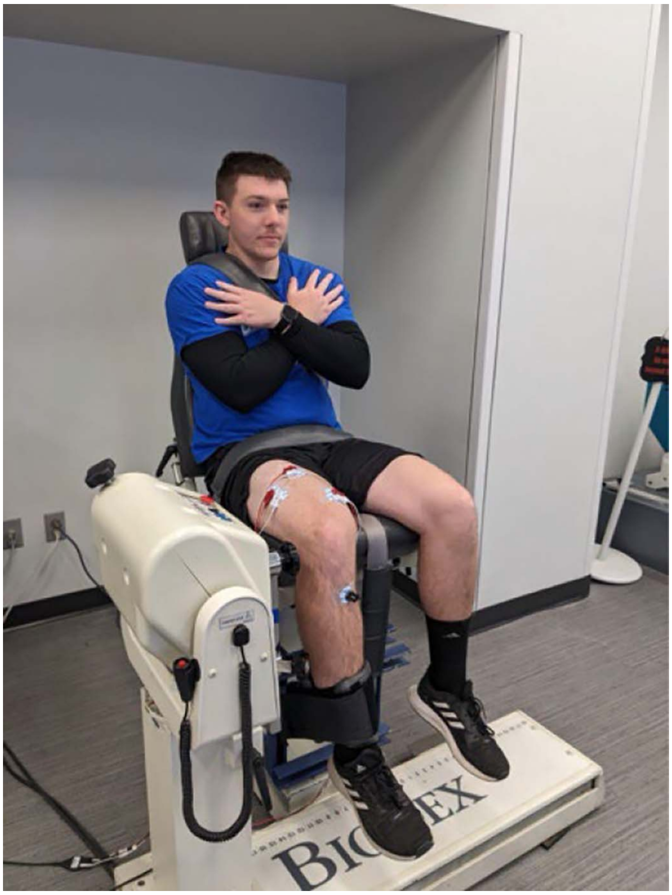

Figure 1. Maximal voluntary isometric contraction testing position using an electromechanical dynamometer.

Quadriceps Setting Exercises

Participants next transferred to a padded plinth in long sitting with 45° of hip flexion and the back supported (Figure 2). The testing leg was extended to 0° of knee extension with a foam bolster with a height of approximately 7.5 cm placed under the testing knee. Participants completed 5 different testing conditions, each using different verbal cues (internal, external, and visual; Table 2). Two internal cues, "tighten your thigh" and "push your knee down," 2 external cues, "push into the bolster" and "push into the strap," and 1 visual biofeedback condition were used. Conditions were block randomized, with conditions 1 to 4 (internal and external cues) always performed before condition 5 (visual biofeedback). The visual biofeedback condition was always performed last because it is known to result in greater quadriceps performance and to minimize the potential for the knowledge of results to crossover into other trials.[26] For each condition, participants were instructed to follow the cue with maximal effort, holding each contraction for 5 seconds, with 30 seconds of rest between each trial. No verbal encouragement was provided during the trials to ensure the quality of effort for each trial and allow fair comparison under different conditions. Two minutes of rest was provided between conditions. The instructions for each condition were given before each contraction. A padded belt was applied approximately 3 to 4 cm superior to the lateral malleolus and secured to the table for the push into strap (condition 4) condition. Visual biofeedback was provided using a biofeedback system (mTrigger Biofeedback System, mTrigger, LLC), with real-time results displayed on a computer tablet (iPad).

Figure 2. Participant testing position. The strap is placed around the distal leg and secured during the push into strap condition only.

Statistical Analysis

The highest average peak EMG for each condition was used to determine which condition resulted in the maximal quadriceps EMG activity for each participant. A repeated measures analysis of variance was used to determine the difference in normalized EMG activity between the conditions. A Bonferroni correction for multiple comparisons was applied using a *P* value of $\leq .005$. Effect sizes (Cohen's *d*) were calculated to provide insights into the magnitude of differences between conditions.

RESULTS

There was a significant difference in peak EMG between the conditions (main effect; $P < .001$; Figure 3 and Table 3). Post hoc comparisons indicated that both visual biofeedback (83.2% ± 24.9%) and the press into the strap condition (76.8% ± 24.4%) produced significantly greater ($P < .001$) quadriceps EMG activity than the push knee down (53.2% ± 27.0%), tighten thigh (52.7% ± 27.3%), or push into the bolster (50.8% ± 26.3%) conditions, demonstrating large effect sizes ($d > 0.92$; Table 3).

There was no significant difference ($P = .10$) between the visual biofeedback and press into the strap conditions, but there was a small effect size ($d = 0.26$; Table 3). There was no significant difference ($P > .37$) between the push knee down, tighten thigh, or push into the bolster conditions, demonstrating minimal effect sizes ($d < 0.09$; Table 3).

The secondary analysis to determine which cue produced the most quadriceps EMG activation for each individual (Figure 4) showed that 67% of the participants demonstrated the most quadriceps EMG activity with the visual biofeedback condition compared with 23% of the participants for which the push into strap cue resulted in the highest EMG activity. The push knee down cue allowed 7% of participants to demonstrate their highest EMG activity, whereas the push into bolster cue resulted in the highest EMG activity for 3% of participants. None of the participants (0%) demonstrated their highest quadriceps EMG activity with the tighten thigh muscles verbal cue.

Table 2. Attention of Focus Provided for Maximal Voluntary Isometric Contraction for Each Condition

Condition	Cue	Cue Prompt
1	Tighten thigh (internal cue)	The goal of this exercise is to generate as much force as possible by tightening your thigh muscles.
2	Push knee down (internal cue)	The goal of this exercise is to generate as much force as possible by pressing your knee down.
3	Push knee into bolster (external cue)	The goal of this exercise is to generate as much force as possible by pressing down into the bolster.
4	Push into strap (external cue)	The goal of this exercise is to generate as much force as possible by pushing into the strap.
5	Visual biofeedback	The goal of this exercise is to generate as much force as possible by raising the electromyographic peak as high as you can (using biofeedback).

DISCUSSION

This study aimed to provide practicing clinicians with evidence for an optimal muscle activation cueing technique during a quadriceps setting exercise. It was hypothesized that an external attention of focus would maximize quadriceps EMG activation compared with an internal attention of focus or visual biofeedback. The constrained action hypothesis proposes that an external focus improves motor performance because it promotes automatic control of movement.[27] This hypothesis further explains that an internal attention of focus induces a more deliberate and conscious control of movement, constraining or disrupting the automatic control process. Inconsistent with previously published work comparing internal versus external attention of focus, results from the current study indicated that only 1 external cue (press into the strap) was shown to result in greater quadriceps EMG activation than the internal cues of push knee down and tighten thigh muscle.[8–15] These results contrast with a study by Marchant et al, who demonstrated greater elbow flexor EMG activity with an internal focus than with an external focus when performing an elbow flexion exercise.[10] A key difference in that study was the use of an elbow flexion isokinetic task that largely isolated the elbow flexor muscles and did not allow for muscular cocontractions to perform the same action. In the current study, the conditions for the quadriceps setting exercise may have allowed contributions from other muscles (eg, hip flexors and hip extensors), not measured in this study, to complete the exercise. The actions of the push knee into bolster and push knee down conditions allow for a short torque lever, which could recruit posterior hip and thigh musculature that perform hip extension, potentially reducing quadriceps activation. Additionally, the material used for a bolster when cued with "push knee into bolster" may provide different feedback based on the substance (soft versus hard bolster). Also, the other external cue (push into bolster) was not significantly different from the internal attention of focus cues. One explanation for these results could be the proximity of the external attention of focus for the bolster placement compared with the strap placement. A near external attention of focus may produce similar results as an internal attention of focus.[27] Specifically, it has been demonstrated that balance performance was not different when participants were cued to focus on keeping feet horizontal (internal focus) and when cued to focus on keeping a set of markers next to their feet horizontal (near external focus of attention), but balance performance was improved when the external focus of attention was further away from the feet.[27] Therefore, it is possible that the verbal cue of "push knee into bolster" did not substantially alter the attention of focus compared with "push knee down" and "tighten thigh muscles," leading to similar quadriceps EMG activation observed in the current study.

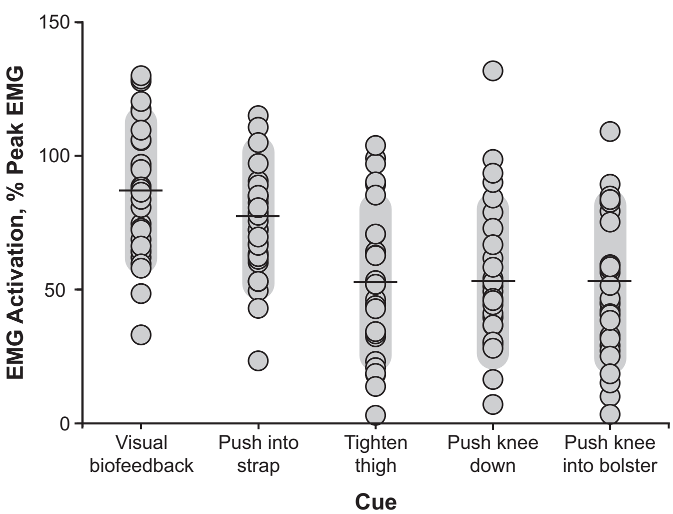

Figure 3. Normalized average percent of quadriceps (vastus lateralis) electromyographic (EMG) activation for each condition. The visual biofeedback mean is 83.2% ± 24.9%, press into strap is 76.8% ± 24.4%, tighten thigh muscles is 52.7% ± 27.3%, push knee down is 53.2% ± 27.0%, and push into bolster is 50.8% ± 26.3%.

The visual biofeedback condition demonstrated greater quadriceps EMG activation than commonly used cues, including "push knee down," "tighten thigh muscles," and "push into bolster." Additionally, visual biofeedback did not demonstrate a significant difference compared with the push into strap cue and was accompanied by a relatively small effect size between these 2 conditions. This suggests that clinical differences between the visual biofeedback condition and the push into strap cue are minimal. Augmented feedback has been shown to improve motor performance through an external source that provides either knowledge of result or knowledge of performance.[28,29] Visual biofeedback used may be representative of the degree to which an external attention of focus may be directed away from the body, specifically that a remote attention of focus improves the outcome of an action.[13] Furthermore, motivation can have an immediate positive impact on performance.[30] Augmented feedback is speculated to rely predominantly on motivational factors, as the adaptations in performance occurred instantly as soon as

Table 3. Paired Conditions Results and Effect Sizes

	Tighten Thigh		Push Knee Down		Push Knee Into Bolster		Press Into Strap	
	P Value	Cohen's *d*	*P* Value	Cohen's *d*	*P* Value	Cohen's *d*	*P* Value	Cohen's *d*
Push knee down	.92	0.02	–	–	–	–	–	–
Push knee into bolster	.62	0.07	.37	0.09	–	–	–	–
Press into strap	<.001	0.93	<.001	0.92	<.001	1.03	–	–
Visual biofeedback	<.001	1.17	<.001	1.16	<.001	1.27	.101	0.26

augmented feedback was provided.[31,32] The addition of visual cues with exercise has shown to improve the motor unit recruitment and discharge rate.[33] Visual biofeedback can be viewed as an intrinsic motivator, as it provides participants with a goal to achieve in each bout, trying to achieve a higher quadriceps EMG peak represented on the screen. This may be explained by participants receiving positive confirmation from the visual biofeedback to continue with or modify their performance in real time to achieve the desired result.[34] This is further supported by the fact that 67% of the participants (Figure 4) demonstrated the most quadriceps EMG activation during the visual biofeedback attention of focus.

There was not a statistical difference between the push knee down, tighten thigh muscle, and push into bolster conditions, with the normalized quadriceps EMG activation around 50% of the MVIC while demonstrating minimal effect sizes between conditions. The quadriceps EMG activation percentages for these healthy, relatively young participants is concerning, as these tend to be the most common cues provided in the clinic for this intervention for patients who have a knee injury or underwent a knee surgery. This is consistent with previous research demonstrating decreased performance when instructed to focus on movement.[8–15]

Limitations

A limitation of this study was that the population included all young, active, and healthy adults. The purpose of the study was to determine the optimal cue for quadriceps EMG activation to aid in the early phases of rehabilitation after knee injury or surgery. The results cannot be generalized to a population with an acute knee injury or immediately following surgical intervention. Future studies should determine if results carry over into a clinical population. An additional study limitation is that a type 2 error may explain the reason for the nonstatistical differences between the cue of visual biofeedback and the press into strap conditions. Although increasing the sample size may have benefit, the small effect size demonstrated between these 2 cues suggests that differences are not likely clinically significant. Another limitation was that the longer duration (~30 to 35 minutes) of the testing protocol may have resulted in decreased participant attention in the later conditions, which may have impacted the quadriceps EMG activation for those conditions. The authors do not consider this to be a substantial limitation because the visual biofeedback condition was always tested last and resulted in the highest normalized quadriceps EMG activation (83%). Additionally, because the visual biofeedback condition was always performed last, a more robust design of randomization of all conditions may have different outcomes. Future studies may consider also randomizing this condition to minimize the potential for effects of diminishing attentional focus.

Clinical Relevance

If the clinical aim during a quadriceps setting exercise is to obtain maximal volitional muscle recruitment, the use of visual biofeedback or pressing into a strap is recommended. The future direction of this research will assess these attention of focus cues on a postoperative patient population to enhance clinical practice to achieve improved quadriceps EMG activity during the early stages of rehabilitation.

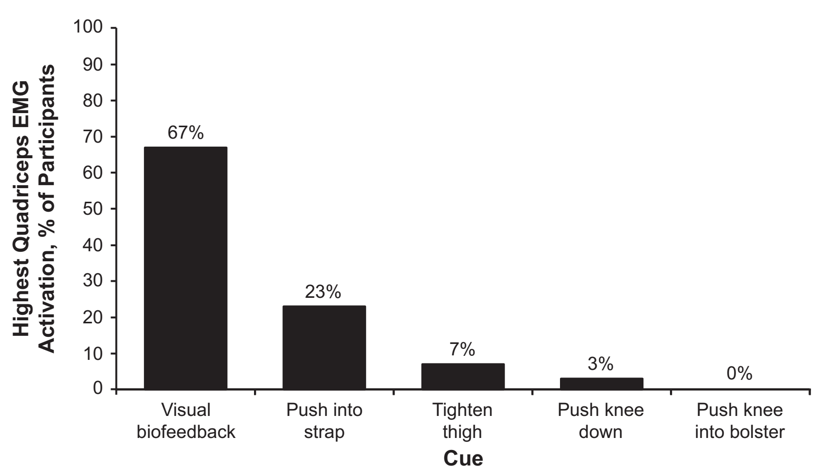

Figure 4. Frequency of highest quadriceps electromyographic (EMG) activation for individual participants. Visual biofeedback represented 67% of participants' highest quadriceps EMG activation, followed by push into strap at 23%, push knee down at 7%, push into bolster at 3%, and tighten thigh muscle at 0%.

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