The Effects Of Attentional Focus On Muscle Activation And Performance During Squat Exercise

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Abstract: This study aimed to examine the effects of different attentional focus instructions on muscles activity and performance during squat exercise. Participants were randomly divided into three groups (i.e., internal focus (IF), external focus (EF) and control). Electromyography (EMG) was used to measure muscle activity of the lower limbs (i.e., vastus lateralis, bicep femoris, gluteus maximus) while Movement Competency Screen measured the performance of the squat. There was a significant interaction between the groups, muscles and test. No between group differences in EMG reading of the three muscles during pre test. However, the EF group showed significantly lower EMG reading than IF and control group in the post as well as retention tests. There was also a significant interaction between group and test in performing the squat. Both EF and IF groups were significantly better in performing correct squat repetitions than the control group during post and retention tests. In conclusion, the combination of muscle activity and performance showed that EF of attention's instructions were more efficient because it reduced muscle contraction and improved performance compared to IF instruction which only improved performance but increased muscle contraction.

Keywords: Focus of attention, muscle activation, EMG, squat

1. INTRODUCTION

Squat is an exercise used to strengthen lower limb muscles such as the quadriceps, hamstrings and erector spinae muscles [1]. Although it is effective in strengthening the lower limbs, squat is a complicated movement because it involves multi joints movements [2]. Squat requires both coordination and balance of the body to perform, with the hip, knees, and ankles in parallel with no mediolateral movement, while the heels must be planted on the floor [3]. Proper technique needs to be taught to reduce tension in the joints and the potential of injury to the lower back and knee [3, 4, 5]. Kritz and colleagues [3] introduced Movement Competency Screen (MCS), a squat movement screening, to ensure the squat is correctly performed. The MCS provides guidance for the performer to be aware of the appropriate movements and load level in order to minimize injuries associated with overloading of biomechanical movement patterns

Squat has been examined by several researchers [e.g., 6, 7], and found that the exercise positively correlated with increased muscular strength and endurance. In addition, the exercise also improved the speed and power of track and field athletes [8, 9, 10].

Over the past decades, skill acquisition researchers have begun focusing on methods to improve sport performance in terms of the use of appropriate verbal instructions to help athletes performing skills. Traditionally, coaches use instructions that direct their athletes' attention to movements and coordination of their bodily parts when learning specific sports skills [11]. Attentional focus refers to what the individual needs to focus on when performing tasks. In another word, verbal instructions that direct learners to concentrate on when trying to learn a skill. Two types of attentional focus of instruction (internal and external focus) have been identified by researchers that are utilized by coaches or instructors on their charges. Internal focus of attention instructions requires the learners to focus on bodily movements when performing a motor skill [12], while an external focus of attention instruction involves focusing on the outcome of the movement(s) and environment during the implementation of the skill [13]. For example, higher jumps were achieved while performing the vertical jump when the participants were provided external focus instructions"concentrate on the ceiling and try to touch it" instead of the internal focus instructions "focus on your fingers and try to touch the vanes as high as possible", [14].

Related studies examining the different focus of instructions on motor skills have shown that external focus of instruction was more effective in improving learning skills than in internal focus instruction [11, 12, 15, 16, 17]. The study on performing the 10-meter sprints showed that external focus istructions "focus on driving the ground back as explosively as you can" resulted significantly faster sprint times than the internal focus instruction "focus on driving your legs back as explosively as you can" which are commonly used by track and field coaches [18]. Similarly, an external focus of instruction was also able to produce more force with lower muscle activation during isokinetic elbow flexions compared to internal focus [19].

Theoretically, internal focus of attention will affect the movement resulting in action constraints [13]. The constrained action hypothesis suggests that focusing internally will cause conscious action at the same time interfere with the motor movement control process. Thus it reduces the action naturally and causes a reduction in performance [13].

Most studies examining different attentional instructions have focused on measurable behavioral outcomes [12, 18]. However, these studies could not fully explain the constraint action hypothesis. In order to test the theory objectively, some studies have been conducted to see the effects of attentional focus on the neuro-muscular activity [17, 20, 21, 22]. Electromyography (EMG) is a popular technique in sports biomechanics to detect muscle activity, which has been used widely to study muscular coordination during movement such as running, walking and biking. The use of EMG allows the activation pattern of the muscles during locomotor movement to be analyzed in terms of activity level and activation time. [23]. Recent studies using EMG found that the external focus instructions resulted in lower muscle activity. For example, study by Vance et al. [21] tested participants performing bicep curls using internal and external focus instruction and found that EMG muscle activation was much higher for internal focus instruction than external focus instruction. There are two implications for lower muscle activities. Firstly, lesser contraction of the muscles would allow related movements to be performed for a longer period (i.e., muscle endurance; [24]). Secondly, indication of lower muscle activities would support the constraint action hypothesis [13]. However, a study on muscle activities in performing bench press showed no difference in EMG reading in both external and internal focus instructions [25]. Besides that, a recent study on bench press activity at 60% of 3RM showed the used of both internal and external focus instruction increase muscle activity rather than no focus instruction (control group) [26]. These findings contradicted the constrained action hypothesis.

Although previous studies have shown a positive impact on the external focus, there is a lack of evidence on the effects of attentional focus on muscle activity and performance measurement with correct technique. Therefore, the purpose of this study was to examine the effect of attentional focus on muscle activation and performance when performing squat. This study hypothesised that external focus instructions will produce lower muscle activity and increase correct squat technique repetitions performance.

2. RESEARCH METHODS

2.1 Participants

Thirty six female undergraduates, aged between 20 and 25 years old with Body Mass Index (BMI) less than 26, participated voluntarily in this study. All participants were not actively involved in sports activities nor exposed to strength and conditioning training programme. The participants were randomly assigned into three groups (i.e., internal focus, external focus and control). Both external and internal focus groups received interventions separately and the instructions were provided discretely to the respective groups. No treatments were provided to the control group and they were only invited to perform the post and retention tests only.

2.2 Instrument

2.2.1 Muscle activation measurement

The equipment used to measure muscle activity during squat exercises in this study was Electromiography (EMG) (Delsys, Boston, MA, USA) with 16 electrodes. EMG Works 4.1.1 and EMG Works Analysis were used to analyze and interpret muscle activity data. EMG electrodes were attached to parts of the leg muscles involved in squat exercises. The selected muscles were gluteus maximus muscles, biceps femoris, and vastus lateralis based on study by Contreras, Vigotsky, Schoenfeld, Beardsley and Cronin [27]. The EMG electrode attachment method on the muscles as suggested by Rainoldi, Melchiorri, and Caruso [28] and accessed from the SENIAM website [29].

Table 1. EMG electrodes attachment guideline

Muscle	Anatomical Marker Guidelines
Biceps femoris	50% position between the ischial tuberosity line to the lateral side of the popliterus cavity. Start from ischial tuberosity.
Vastus lateralis	Distance 2/3 of superior side patella to anterior superior iliac spine. Measurement start from patella.
Gluteus maximus	The midpoint of the second vertebral sacral with a greater traochanter. Start from second sacral vertebra.

2.2.2 Performance measurement

To measure correct squat performance, the movement was recorded using a video recorder (Sony, Japan) placed at 3.6 meters from the participants' saggital side and 1 meter from the floor [30]. The recordings were then transferred to a laptop for analysis. Correct squat movements were analyzed using the KINOVEA software (Bordeaux, Nouvelle Aquitaine) based on the squat exercise criteria described in the MCS form [3]. Performance was assessed based on the number of squat repetitions that conformed the MCS criteria as shown below.

Table 2. Squat Movement Competency Screen (MCS) criteria.

Body parts	MCS criteria
Head	Centered
Shoulders	Held down away from the ears. Elbow held behind the ears throughout the squat.
Lumbar	Neutral throughout the squat.
Hips	Movement start here, aligned and extension is obvious.
Knees	Stable, aligned with the hips and feet.
Ankles/Feet	Aligned with the knees and hips. In contact with the ground especially the heels at the bottom of the squat and feet appear stable.
Depth	Thighs parallel with the ground.
Balance	Maintained.

2.3 Procedure

The study was conducted in an enclosed biomechanics laboratory complete with EMG equipment. The duration of the study was six weeks. During the first week, a familiarization session was conducted for the participants to understand the protocol of the study. Subsequently, a pre-test was conducted on all participants before they were randomly divided into three groups (internal focus, external focus, control). The participants warmed up performing calisthenic exercises before commencing the tests and intervention. In all tests, the participants wore appropriate clothings with the EMG electrodes attached to the muscles. They were required to perform a squat exercise for one minute according to the rhythm of a metronome (MA-2 Korg, Tokyo, Japan) rhythm. They need to squat with knees bent at 90° with a straight back and return to standing position when they hear "beep" sound.The metronome was set at 80 bpm as a guide to controlling the speed of squat.

Instructions for the internal focus group were “Stand in upright position with knees and hips at or near full extension, feet approximately shoulder width apart. Descend until thighs are at least parallel to the ground or lower. Keep the back straight throughout the squat. Bend both knees to squat and the knees should not exceed the tip of the toes when bent. Return to upright position according to the rhythm of the metronome”. The external focus group was instructed to "Imagine as if you are going to sit on a chair and stand up". The control group were directed to perform as many squat repetitions as possible.

Both internal and external focus of attention groups practiced the movement separately for two sessions a week. Each practice session lasted around one hour. At the end of the six weeks intervention, a post test was conducted according to the same procedure as the pre-test. Retention test was conducted after a one week without any intervention using the same procedure as stated during pre-test.

2.4 Statistical analysis

A three group instructions (internal, external and control) x three tests (pre, post and retention) x three muscles (vastus lateralis, bicep femoris and gluteus maximus) ANOVA with repeated measures on the last factor was used to analyse the EMG readings. Separate 3 groups (internal, external, control) x 3 test (pre, post, retention) ANOVA with repeated measures on the second factor was used to analyze the squat performance. Shapiro-Wilk test was used to test for normal distribution of the data, all data was found to be normally distributed. The partial eta square (η_p^2) was used to assess effect size, the value of .02, .13 and .26 is considered as small, medium and large, respectively [31]. Statistical significance level was set at $p \leq 0.05$. All statistical analyses were conducted using SPSS version 23 (IBM, New York, USA).

3. RESULTS AND DISCUSSION

3.1 Muscle activity

A 3 group (internal, external, control) x 3 test (pre, post, retention) x 3 types of muscles' EMGs (vastus lateralis, biceps femoris, gluteus maximus) ANOVA with repeated measures on the last factor was used to analyze the differences in EMG muscle activation.

Table 3: Mean and standard diviations of muscles' EMG readings according to groups and tests

Muscle	Group	Pre		Post		Retention	
		Mean (%)	**SD**	**Mean (%)**	**SD**	**Mean (%)**	**SD**
Vastus Lateralis	External	61.06	3.84	51.90	2.72	57.09	2.99
	Internal	58.68	2.93	55.23	3.15	62.31	4.03
	Control	60.69	3.79	55.33	3.10	58.34	2.91
Bicep Femoris	External	33.99	2.39	25.46	2.65	27.67	2.51
	Internal	32.62	3.19	32.42	3.30	32.62	3.19
	Control	31.29	1.87	29.83	2.25	30.45	2.41
Gluteus Maximus	External	30.74	2.54	27.83	2.24	34.98	3.68
	Internal	33.22	3.48	32.57	3.27	30.30	2.61
	Control	32.19	3.42	31.23	3.60	31.80	3.21

Table 3 showed the result of percentage muscle activation on vastus lateralis, bicep femoris and gluteus maximus for three group attentional focus (external, internal and control) in pre test, post test and retention test during squat exercise. There was a main effect for group, $F(2,33)=4.72$, $p<.016$, $\eta_p^2 = .22$. The EMG readings of the internal focus group (M=41.11, SP=3.23) was significantly higher than the external focus group (M=38.97, SP=2.79). No difference was found between the control group (M=40.13, SP=3.01) with external and internal focus group. The internal focus group produced the highest average muscle activity, while the external focus group showed the lowest average muscle activity.

There was main effect for test, $F (2.66) = 103.93$, $p <.001$, $\eta_p^2 = .75$. The average EMG readings during pre test (M = 41.61, SP = 3.25) was significantly higher than post test (M = 37.98, SP = 3.63) and retention test (M = 40.62, SP = 3.66). The average retention test muscle activity was also significantly higher than the post test.

There was a main effects for muscle, $F (2, 66) = 1527.05$, $p <.001$, $\eta_p^2 = .97$. The average of vastus lateralis' EMG reading (M = 57.84, SP = 3.69) was significantly higher compared to femoral bicep muscles (M = 30.71, SP = 3.34) and gluteus maximus muscles (M

= 31.65, SP = 3.51). There was no significant difference between femoral biceps muscles and gluteus maximus.

There was a significant interaction between the groups (internal focus, external focus and control) with the involved muscles (vastus lateralis, bicep femoris, glutues maximus) according to the test (pre, post, retention), F (8,132) = 12.76, $p < .001$, $ŋ_p^2 = .43$. Overall, muscle activities in the pre-test showed no significant difference between the three muscles (vastus lateralis, bicep femoris, gluteus maximus) between the three groups (external focus, internal focus, control). However, during the post-test, the three muscles of the external focus group showed significant lower EMG readings than the internal focus and control group. No significant difference was shown between the internal focus and control group. In the retention test, both the external focus and control groups' EMG readings were significantly lower than the internal focus group. No significant difference was shown by external and the control group.

3.2 Squat performance

A separate 3 groups (internal, external, control) x 3 test (pre, post, retention) ANOVA with repeated measures on the second factor was used to analyze the squat performance.

Table 4. Mean and standard deviations of the squat repetitions

Test	**Pre**		**Post**		**Retention**	
Group	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
External	15.2	6.6	29.6	5.9	25.4	3.4
Internal	16.0	6.7	27.1	6.6	26.1	6.0
Control	15.9	6.9	18.2	7.9	17.0	8.3

Table 4 showed the result of squat performance (repetitions) for external focus group, internal focus group and control group in pre test, post test and retention test. There was main effect for group F (2, 33) = 4.25, $p<.023$, $ŋp^2 = .20$. External focus group (M=23.41, SP=5.29) performed significantly more correct squat repetitions than the control group (M=17.02, SP=7.70). However there was no difference between the correct squat repetitions by external and internal focus groups (M=23.11, SP=6.43). There was also no difference between the internal focus group and the control group.

There was an interaction between group and test in squat performance, F(4,66)=13.04, $p<.001$, $ŋ_p^2 = .44$. No significant difference in performing the squat movement between the three groups during pre-test. However, the external focus group (M=29.6, SP=5.9) and internal focus groups (M=27.1, SP=6.6) were significantly better than the control group (M=18.2, SP=7.9) during post test. Similar findings were shown in retention test with the external focus (M=25.4, SP=3.4) and internal focus groups (M=26.2, SP=6.0) scored significantly better than control group (M=17.0, SP=8.3).

The purpose of this study was to examine the effects of different focus attentional focus on muscle activities of the lower limbs and performance of the squat exercise. The findings showed lower muscle activities of the external focus group compared to internal focus and control group. This study also showed both intervention groups improved their performance in squat during post and retention test compared to the control group. Based on the research findings from both aspects of muscle activities and performance, we found two essential findings in this study. Firstly, external focus of attention instructions not only reduced muscle activities but enhanced the performance of squat repetition as well compared to instructions using internal focus of attention which only improved performance but not lower muscle contractions. The results supported the findings from previous studies [17, 19, 21, 22, 32, 33]. The findings of this study also supported the constraints action hypothesis theory [13]. Besides reducing muscle activity, external focus of instructions may also reduce fatigue and conserve energy consumption when performing the squat [24, 34].

Other than muscle activities, this study also measured the correct technique of squat repetition using the MCS criteria. The results showed that there was performance improvement for both intervention groups compared to the control group, although no significant differences were indicated by both the focus groups. It may be because all participants in this study were novice and can be considered to be at the cognitive learning stage [35] or verbal-cognitive [36], which is the initial stage of motor learning before progressing to the assosiative and autonomous stage. This early learning stage requires high cognitive effort for processing movement form (internal) or movement outcome (external) through verbal instructions given during a session skills learning [37]. According to Huber [38], at this level, additional information such as verbal instructions are essential to develop a fundamental movement. Individuals who learn motor skills without receiving visual or verbal cues will have difficulties in acquiring them. Providing instructions help to improve performance for both internal and external focus of attention groups. Obviously the control group's performance was not as good as the intervention groups because they did not receive specific instructions and feedback on learning the squat.

The results of this study also indicated the use of external focus of instructions to be effective strategy to learn new skills. Although there were no significant differences between external focus group with internal focus group, the use of simple external focus instructions in this study "imagine like sitting on a chair and getting up" looks more efficient as it improved correct squat technique compared to the lengthy internal focus instructions. The findings of this study supports the opinion stated in Woo, Chow Koh's study [39] that manipulated the use of creative verbal instructions, short and relevant contributed to positive learning outcomes. However, internal focus instruction does not necessarily have a negative impact on a particular task such a complex movement like squat. Instruction focusing on the features of the movement (internal focus) can help to structure the coordination pattern basic movement function of the motor skills to be implemented, especially among novice participants [40], because of that, internal focus instruction also improve performance in this study.

Lower muscle activity by the external focus group could also reduce the risk of injury. From Gullett, Tillman, Gutierrez and Chow's study [41] comparing muscular activity during front and back squats showed that front squats were more effective than back squats because of the overall use of muscles with compressive strength and lower muscle activity, thus preventing knee injury and knee joint. The reduction in injury risk based on the findings of the low muscle activity by the external focus group in this study was also reinforced by the use of MCS criteria as performance measurements, because only squat movement with the correct technique were considered as performance measure in this study. This is important as proper squat execution can prevent injuries [2].

4. CONCLUSION

In conclusion, this study proved that external focus instructions were not only able to reduce related muscles activity, but also improve the performance of the correct squat technique. It is recommended to trainers or coachs to use external focus instruction as a method of squat teaching in order to use minimum energy to delay the fatigue process and reduce the risk of injury. However, the internal focus instructions are still relevant to use as they are also helpful to performance improvement. In addition, this study also suggests that (MCS) is a relevant movement competency tool to measure squat with correct technique.

Future studies could test the effects of focus instruction on using MCS criteria against the movement of other strength and conditioning exercises such as lunges, deadlifts, bench press and bent-over row. In addition, this study is conducted only on novice participants, so it is recommended that next study can compare between novice and experienced participants using the same procedure as in the study this, to know the effects of focus instruction on muscle activity and performance with correct technique using MCS. Further studies are also recommended by adding load elements during squat exercises to augment the complexity of the exercise.

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