Attentional Focusing Instructions Influence Force Production and Muscular Activity During Isokinetic Elbow Flexions

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Abstract

Marchant DC, Greig M, and Scott C. Attentional focusing instructions influence force production and muscular activity during isokinetic elbow flexions. *J Strength Cond Res* 23(8): 2358–2366, 2009—Appropriate verbal instruction is critical to effective guidance of movements. Internal (movement focus) and external (outcome focus) attentional focusing instructions have been shown to influence movement kinetics and muscular activity; this study investigated their effects during a force production task. Twenty-five participants (mean age of 22.72 ± 1.88 years) completed 10 repetitions of single-arm elbow flexions on an isokinetic dynamometer while electromyographical activity of the biceps brachii and net joint elbow flexor torque were measured. Three trials were completed: a control trial to attain maximum voluntary contraction (MVC) data, followed by counterbalanced trials internal and external attentional focus conditions. The external focus exhibited a significantly ($p < 0.05$) higher peak net joint torque (102.10 ± 2.42%MVC) than the internal condition (95.33 ± 2.08%MVC) and also a greater integral of the torque-time curve (99.90 ± 2.91%MVC) than the internal condition (93.80 ± 2.71%MVC). In addition, the external focus resulted in lower peak electromyography (134.43 ± 16.83%MVC) response when compared with the internal focus condition (155.23 ± 22.54%MVC) as well as lower mean integrated electromyography (127.55 ± 12.24%MVC) than the internal condition (154.99 ± 19.44%MVC). Results indicate that an external attentional focus results in significantly greater force production and lower muscular activity during isokinetic elbow flexions when compared with an internal focus. When instructing clients during maximal force production tasks, practitioners should tailor their instructions to emphasize an external focus of attention. Specifically, attention should be directed onto the movement of the object being moved and away from the specific bodily movements involved in the action.

Key Words psychology, cognitive strategies, electromyography, dynamometry, external focus

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Introduction

Verbal instruction and encouragement are regularly utilized in movement execution settings, particularly physical exercise movements associated with sports performance, training, and rehabilitation. Recent research has demonstrated that the emphasis of such instructions can have a significant impact on an individual's attentional focus and the quality of their movements, with important implications within applied settings (see Wulf (21) and Wulf and Prinz (25) for reviews). The instructions provided in this body of research are verbal, which is critical given the importance of effective verbal instruction provided by coaches and other practitioners when directing their clients. This research has been operationalized along the dimension of attentional direction; where attention is directed either externally toward an outcome (or the effects) of the movement being produced (e.g., a goal, target, or intended effect) or internally toward the actual bodily movements being produced during a movement (e.g., technique) (25). Instructions emphasizing an external focus have been shown to be more beneficial than internally focused instructions in guiding performance and learning on a variety of sporting tasks and skills, such as standing balance (12), golf (22), volleyball and soccer kicks (23), and dart throwing (8,14). To explain such effects, the constrained action hypothesis (12,24) suggests that an internal focus results in individuals focusing upon and consciously controlling their movements, which subsequently constrains the motor system and disrupts automatic control processes. An external focus on the other hand directs attention toward the movement effect, which allows unconscious or automatic processes to control the movement in line with the outcome being focused upon (20). Although much research has addressed the impact of attentional focusing on skill execution, its utility in force production and exercise settings has not been fully assessed. Research addressing the potential impact of attentional focuses within such settings is necessary, given the use of instruction and cognitive strategies to guide force production and exercise.

To date, only one study has addressed the effect of attentional focusing instructions on an exercise type force production movement. Investigating the influence of attentional focusing instructions on muscular activity, Vance et al. (20) compared participants' muscular activity using electromyography (EMG) while lifting a barbell in a biceps curl. To direct attention, verbal instructions focused participant's attention either upon the movement of the curl bar (*external* focus) or onto their arm and muscular movements (*internal* focus). It is important to note that these instructions are not intended to manipulate visual attention; participants were not directed to "look" at the bar or their arm. The aim of instructions is to influence what participants concentrate on rather than what they are looking at. As such, participants were instructed to look straight ahead throughout the task and focus on the movements of either their arms or the bar. In the first experiment, external instructions resulted in lower biceps and triceps EMG and faster movement speed when compared with the internal focus instructions. In the second experiment using a modified protocol, average speed of the bicep curl was controlled using a metronome, and again reduced muscular activity of the biceps and triceps was observed when using an external focus. Similarly, reduced EMG of the biceps and triceps was observed under external focus instruction (basket) during basketball free throws as well as greater accuracy when compared with internal instruction (wrist movement) (28). However, even though the lower EMG associated with an external focus has been replicated in comparison to a control or "natural" condition (9), the potential impact on force production has yet to be quantified in research. In both these studies, the observed decrease in EMG activity when external focus instructions were utilized is suggested to represent an increase in movement economy. In contrast, the increased EMG activity and impaired movement quality associated with internal focus instructions were attributed to increased noise in the motor system (28) and as such indicative of greater conscious control of movement execution. Therefore, one would expect to see a direct impact on force production capability in exercise type movements.

In light of these findings, it was suggested that the benefits of an external focus should be seen in those tasks requiring maximal force production such as powerlifting (20). Specifically, "focusing on the object that the force is being exerted upon may result in more effective performance than would focusing upon the body movements that produce the action" (p. 458). With an external focus allowing the motor system to "self-organize" (24), the efficient coordination and direction of forces needed for maximal force production should be attained. Although specific measurement of force production has not yet been directly addressed, a recent study has attempted to quantify this. Wulf et al. (27) demonstrated that focusing on the object being reached for (external focus) resulted in greater height achieved in a maximum jump-and-reach task as well as greater center of mass displacement when compared with focusing on the finger reaching for the object (internal focus). Wulf et al. suggested that this greater jump height was produced by greater force production when an external focus was adopted and that the benefits of an external attentional focus should therefore generalize to maximal force production tasks.

As the above research indicates, verbal instruction in movement settings has a significant impact on the quality of movements being produced. Although verbal instruction and encouragement are the standard protocol during isometric, isotonic, and isokinetic muscle testing and training, particularly when the goal is to increase muscular output (4), research rarely addresses the specific nature of these instructions. Verbal encouragement and psyching strategies have been shown to increase performance as quantified by isometric peak torque values (5,11), force production during a bench press exercise (19), and motor endurance (1). In a review of the literature on psyching strategies and force production, Tod et al. (18) suggested that although the relationship is unclear, psyching strategies may improve performance in force production and endurance tasks. Psyching-up approaches are attempts to improve performance through the use of self-directed cognitive strategies prior to or during movement execution (18). Although no clear understanding of the mechanisms through which force production is proposed to be enhanced by psyching (19), one that has been proposed is through increased focused attention (18). However, the limited conceptualization of this term may in some way explain the sometimes inconclusive findings in this area. For example, although Brody et al. (2) failed to show any benefit of psyching strategies on force production for trained men, they suggested that it did result in an enhanced state of attentional focus. Attentional focus in this case was measured on a scale of 1 (completely distracted) to 5 (extremely focused), with no indication for how or on what attention was focused. Clearly, research addressing the influence cognitive strategies and mental states on force production needs to incorporate a clearer definition of the aspects of attention being addressed. In light of the previously discussed findings covering attentional direction, research is needed using this framework to address the influence of attentional focus on force production. By directing participants' attention prior to and during movement execution, some degree of control is provided over the actual attentional focus employed, a factor lacking in the more naturalistic free-choice or preferred psych-up strategies employed in many previous studies (10). In such situations, it has been suggested that some participants, when left to their own devices, are more likely to focus internally upon their own movements (21) to detrimental effect. Control over or guidance for participants' attentional focus is therefore necessary if conclusions are to be drawn regarding the role of attentional focus on force production and whether it is a key mechanism in the effectiveness of psyching-up strategies.

The aim of the present study was to investigate the influence of attentional focusing instructions on force production and muscular activity during a maximal force production task (elbow flexion), addressing the utility of attentional focusing instructions in exercise settings. This movement is commonplace in many strength training and generic functional movements. As such, this study intends to quantify claims, suggesting that externally focused instructions can be beneficial for maximal force production tasks (20). If movement control and muscular activation are more efficient when an external focus is adopted, we hypothesize that force production should also be benefited.

Methods

Experimental Approach to the Problem

This study examined the influence of verbal attentional focusing instructions on force production during isokinetic elbow flexions. The instructions provide control over cognitive strategies employed prior to and during movement execution. Therefore, the independent variables are the instruction types provided, which are either internal (focusing internally onto movement mechanics) or external (focusing externally onto the outcome of the movement). The emphasis of the verbal instructions provided to participants was based upon that used by Vance et al. (20) in a similar task, with internally focused instructions directing attention to the movements of the arm and muscles, while externally focused instructions directed attention toward the movement of the bar being moved. The movement itself replicates that used in previous research (biceps curls, see Vance et al. (20)); however, in light of concerns of Vance et al. (20), the present study's protocol is enhanced to standardize movement range, speed, and muscular contribution through dynamometry to limit concerns over variability (7). Although previous research has addressed muscular activity, no research to date has addressed the impact of different attentional focusing instructions on force production within a weightlifting setting. Therefore, the focus of the study was that net joint torque about the elbow during flexion is quantified in addition to muscular activity. This will provide a clearer picture of the effects of the 2 attentional focusing instructions provided to participants. The dependent variables measured are both muscular activity (peak EMG [EMG_{pk}] and integrated EMG [iEMG]) and force production (torque). Interindividual variations in performance were addressed through a within-subjects design, with participants using external and internal focusing instructions in a counterbalanced order. Based upon previous research, it is hypothesized that instructions emphasizing an external focus will result in reduced muscular activity and an improvement in force production when compared with internally focused instructions. In addition, the present study sought to assess participants' experiences and preferences of the instructions being used to provide further insight into any observed relationships. Whereas previous research has assessed overall instruction type preference, the present study also addresses preference for instructions for specific situations, namely the development of muscle and the production of maximal force.

Subjects

Twenty-five participants (men 16 and women 9) with mean age of 22.72 (±1.88) years volunteered to take part in the study. Participants were students studying on a sports science program and were not specifically engaged in strength training over at least the previous 3 years. Participants were naïve to the purpose of the study but had experience of the exercise task (all were exercising recreationally with weights as part of a general fitness program on a weekly basis for at least 1 year previously). A general health questionnaire ascertained suitability for participation in the exercise protocol. The methodology was approved at the institutional level, and informed consent was obtained prior to participation.

Procedures

All data collection was carried out within a sport and exercise science laboratory. Participants completed a familiarization session on a day prior to testing, during which no consideration was given to varying attentional focus instructions. During this session, participants were familiarized with the maximum isokinetic contraction procedure, task, and equipment. Subsequently, on a single test day, and following a standardized warm-up, participants first completed 10 repetitions of isokinetic maximum voluntary contractions (MVCs) of the elbow flexors of the dominant arm for normalization (3). Each isokinetic MVC was performed over 100° range of motion, and no specific attentional instruction was given such that this trial was representative of a control condition. Following the control trial, participants completed counterbalanced internal and external attentional strategy trials. To avoid fatiguing effects, participants rested for approximately 5 minutes between the control and each attentional focus trial. During the task, participants rested during the standardized elbow extension phase between repetitions. Prior to the beginning of each attentional trial, participants were given their allocated instructions verbally and in writing by the same researcher. It was stressed that participants should attempt to use these instructions throughout the trial. As it was not the focus of the present study and to control for the influence of such factors, visual feedback from the dynamometer was not provided and no additional verbal encouragement was given during the exercise task. Specifically, the dynamometer monitor was positioned so that the participant could not see any information presented on it. In addition, research has demonstrated significant effects of a presence of an audience

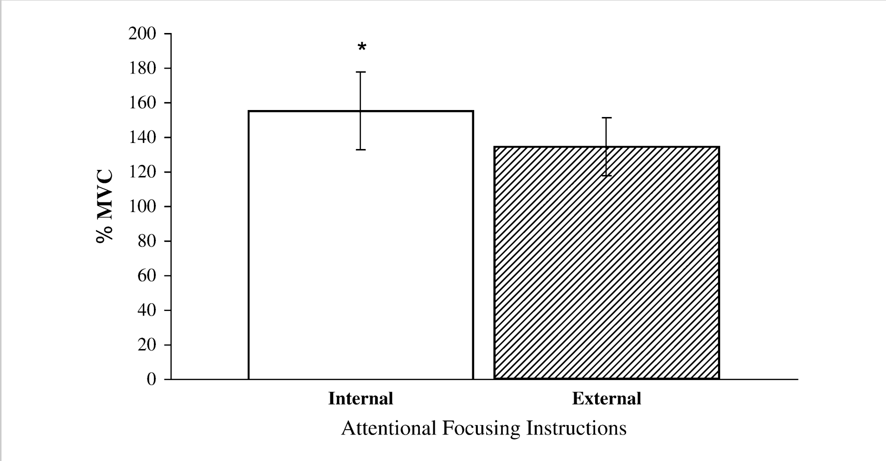

Figure 1. The influence of attentional focusing instructions on peak electromyography activity during the bicep curl (N = 25). Asterisk indicates that the value is significantly greater than the other condition ($p < 0.05$). Data are expressed as mean ± *SE*.

and competition for a weightlifting task, suggesting that research should control for such factors within testing environments (15). Therefore, throughout all stages of the procedure, to control for presence of audience effects, encouragement, and competition, the only individuals present in the laboratory were the participant and researcher.

During all trials, participants were instructed to produce maximal force throughout the full range of elbow flexion while using the instructions provided. The internal and external instructions were similar to those used by Vance et al. (20) where attention was directed either toward participant's arm and muscles (internal) or toward the curl bar (external). For the internal focus trials, participants were instructed to "focus upon the movement of your arm and muscles during the lift," while for the external focus trials, participants were instructed to "focus upon the movement of the crank hand bar during the lift." The internal instruction is in line with suggestions that an external focus should be directed toward the object that force is being exerted upon (20), in this case the dynamometer single-hand hand bar. Participants were also directed to not specifically look at the hand bar/their arm during movements, rather they should look straight ahead and concentrate on mentally focusing upon the emphasis of the instructions that they had been given (20). This avoids the potential confounding influence of visual attention. As highlighted by Wulf (21), this ensures that differences are because of what participants are concentrating on, not that they were "looking" at different aspects of a movement. In all conditions, no force was required during the downward elbow extension movement of each repetition. After completing each attentional focus trial, participants completed the post-task questionnaire. Once the experimental procedure was completed, participants were debriefed and any questions were addressed.

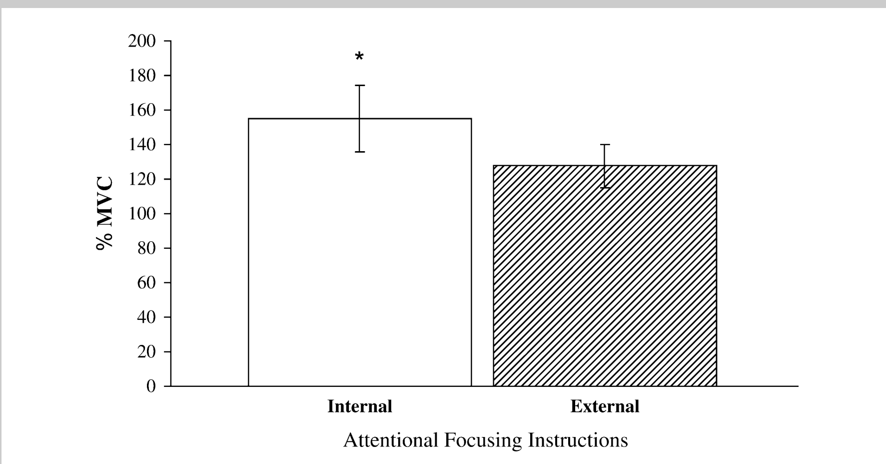

Figure 2. The influence of attentional focusing instructions on integrated electromyography during the bicep curl (N = 25). Asterisk indicates that the value is significantly greater than the other condition ($p < 0.05$). Data are expressed as mean ± *SE*.

Measures

Isokinetic Dynamometry. The functional task used in the present study required participants to complete unilateral isokinetic contractions of the dominant arm (defined as preferred throwing arm) elbow flexors in concentric mode on a Biodex (System 3; Biodex Medical Systems, Shirley, NY) isokinetic dynamometer (precalibrated according to manufacturer's guidelines). Participants were instructed to exert maximal effort throughout the entire range of movement during 10 repetitions of isokinetic concentric elbow flexions at $60°\cdot s^{-1}$ ($1.05\ rad\cdot s^{-1}$). The elbow extension phase between repetitions was performed passively at the

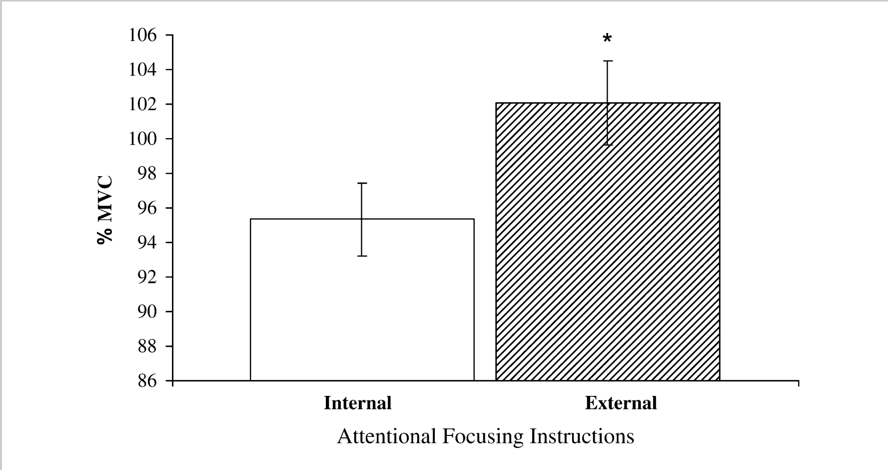

Figure 3. The influence of attentional focusing instructions on peak elbow flexor torque (N = 25). Asterisk indicates that the value is significantly greater than the other condition ($p < 0.05$). Data are expressed as mean ± *SE*.

same speed, thereby standardizing the recovery time between repetitions. The range of movement was standardized to the participant-specific full range of elbow flexion, with the dynamometer lever arm crank axis aligned with the elbow joint axis of rotation. The length of the lever arm was adjusted for comfortable grip, and restraints were applied across the test arm (proximal to the elbow joint so as not to restrict movement) and across the chest to minimize contribution of additional musculature.

Electromyography. Maximum muscular activation capacity may not be reflected by EMG obtained from isometric MVCs and that isokinetic MVCs are more appropriate for normalization purposes in such cases (3). Therefore, the present study utilized an isokinetic MVC method to normalize EMG from the bicep brachii. The isokinetic control trial was used to determine values against which to normalize EMG obtained from the bicep brachii under attentional focus conditions. Telemetric electromyographical activity was obtained (Noraxon, Scottsdale, AZ) for the biceps brachii of the test arm. After site preparation, a pair of disposable bipolar silver-silver chloride passive surface electrodes (Medicotest, Ølstykke, Denmark) was placed on the visual midpoint of the contracted muscle belly of the biceps brachii, orientated parallel to the direction of the muscle fiber alignment, with a separation of 8 mm between the electrodes. A third reference electrode was placed on the (inactive and bony) lateral epicondyle of the elbow. The preamplified electrode leads were connected to an 8-channel transmitter unit (Noraxon Telemyo 2400T) adjacent but not connected to the participant. To avoid inter-experimenter variations, the same experienced researcher applied the electrodes to all participants. The active EMG signal was preamplified (gain 500) and subjected to a 10–1,000 Hz band-pass filter. A sampling frequency of 1,500 Hz was used to collect the EMG signal, with data collection manually initiated prior to the first repetition and terminated following the final repetition. The passive and stationary period immediately preceding the exercise period over which EMG was to be analyzed was used to determine a threshold value to quantify muscle inactivity. This participant-specific offset value was accounted for in all subsequent analyses of the EMG data to eliminate noise artefacts.

Participant's Experience of Attentional Instructions. Participants completed questions on the instructions they used after completing each trial. After the prompt of: When you were asked to focus on your muscles and arm/the movement of the bar, questions were: How mentally demanding did you find this? How physically

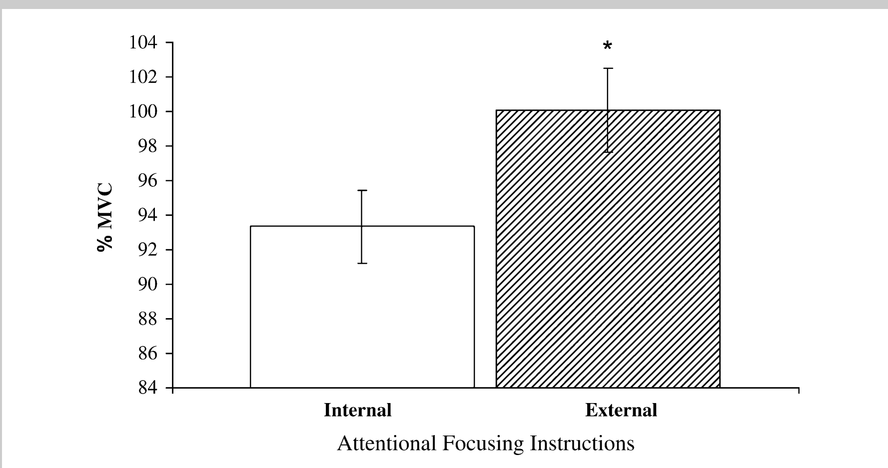

Figure 4. The influence of attentional focus strategy on the torque-time curve integral (N = 25). Asterisk indicates value is significantly greater than the other condition ($p < 0.05$). Data are expressed as mean ± *SE*.

Table 1. Mean responses to post-task questionnaire items for both attentional focusing instructions.

Post-task questions	Attentional focusing instruction	
	External	Internal
How mentally demanding were these instructions? (*SD*)	2.88 (1.60)	3.04 (1.65)
How physically demanding was the task? (*SD*)	3.46 (1.74)	3.88 (1.42)
How easy was it to follow the instructions? (*SD*)	5.50 (1.35)*	6.04 (1.20)
How distracted were you during the task? (*SD*)	3.58 (1.64)*	3.13 (1.54)

*Significantly different from the other condition ($p < 0.05$).

demanding was the task? Was it easy to follow these instructions? and Did you find yourself becoming distracted? Responses were on a 7-point Likert scale of 1 (not very much) to 7 (very much so). In addition, upon completion of the whole task, participants were asked to indicate which instruction type they would most prefer in the following situations: in general, when working out in the gym to develop muscle and when trying to produce maximal force. Twenty-four participants completed this post-task questionnaire accurately.

Statistical Analysis

Gravity-corrected net joint torque of the elbow flexors was considered for the concentric elbow flexion, with data considered only within the isokinetic phase of the movement (Biodex Advantage software). Gravity-corrected peak torque (T_{pk}) was quantified for each of the 3 test conditions and calculated as the mean peak torque over the 10 repetitions. The integral of the torque-time curve (iT) was also quantified for each repetition, and an average value was calculated over the 10 repetitions for each focus strategy. These 2 torque parameters quantified under internal and external attentional focus strategies were then normalized relative to values obtained from the MVC data obtained in the control trial (%MVC). Data processing of the EMG signal was conducted using Noraxon software (MyoResearch XP Master), with raw data Butterworth low-pass (300 Hz) and high-pass (10 Hz) filtered. The processed EMG signal was analyzed to determine the average EMG_{pk} value obtained over the 10 repetitions. The total iEMG, representing the area under the EMG time-history curve, was also calculated as an average over the 10 repetitions. As with the torque data, processed EMG data from the internal focus and external focus trials were expressed relative to the control trial MVC data (%MVC). The test-retest reliability of peak torque and iEMG were determined during familiarization trials. The intraclass correlation coefficients for peak torque were >0.90 representing excellent reliability and for iEMG >0.75 representing good reliability based on the classifications of Portney and Watkins (13).

Dependent measures relating to both the isokinetic (T_{pk} and iT) and the electromyographical (EMG_{pk} and iEMG) data were analyzed using Gender (2) × Attentional Focus Instruction Type (2) analysis of variance, with repeated measures on the latter factor. Gender was included as a between-subject factor to test for potential interaction effects of attentional instructions in this task. Results are presented graphically as the mean ± *SEM* as well as indicated in the text. Paired sampled *t*-tests assessed the differences between participants' experiences of the 2 attentional instruction sets they received.

Results

Electromyography

A significant main effect of the attentional focusing instructions was observed in EMG_{pk} ($F_{1,23} = 4.29$, $p < 0.05$, partial $\eta^2 = 0.15$), with the external condition exhibiting a lower mean EMG_{pk} (134.43 ± 16.83%MVC) than the internal condition (155.23 ± 22.54%MVC) as seen in Figure 1. No significant Gender × Attentional Focus Instructions interaction ($F_{1,23} = 0.98$, $p > 0.05$, partial $\eta^2 = 0.04$) was identified. The main effect of attentional focusing instructions on iEMG during the task was significant ($F_{1,23} = 5.54$, $p < 0.05$, partial $\eta^2 = 0.19$), with the external condition exhibiting lower mean iEMG (127.55 ± 12.24%MVC) than the internal condition (154.99 ± 19.44%MVC) as seen in Figure 2. The Gender × Attentional Focus Instructions interaction was not found to be significant ($F_{1,23} = 1.10$, $p > 0.05$, partial $\eta^2 = 0.05$).

Isokinetic Dynamometry

A significant main effect was observed for attentional focusing instruction type on peak net joint torque ($F_{1,23} = 12.17$, $p < 0.01$, partial $\eta^2 = 0.35$), with the external condition exhibiting greater mean T_{pk} (102.10 ± 2.42%MVC) than the internal condition (95.33 ± 2.08%MVC) as seen in Figure 3. No significant Gender × Attentional Focus Instructions interaction ($F_{1,23} = 1.00$, $p > 0.05$, partial $\eta^2 = 0.04$) was identified. The main effect of attentional focusing instructions on the integral of the torque-time curve was significant

($F_{1,23} = 13.28$, $p < 0.01$, partial $\eta^2 = 0.37$), with the external condition exhibiting greater mean iT (99.90 ± 2.91%MVC) than the internal condition (93.80 ± 2.71%MVC) as seen in Figure 4. The Gender × Attentional Focus Instructions interaction was not found to be significant ($F_{1,23} = 2.39$, $p > 0.05$, partial $\eta^2 = 0.09$).

Participant's Experience of Attentional Instructions

Table 1 presents participants' post-task questionnaire response data. No significant differences were observed between ratings of the mental demand's of the instruction ($t = 0.48$, df = 23, $p = 0.63$) or the task's physical demands ($t = 1.74$, df = 23, $p = 0.096$). Internal focus instructions were rated as significantly easier to follow ($t = 3.19$, df = 23, $p = 0.004$) and resulted in lower feelings of distraction during the task ($t = 2.41$, df = 23, $p = 0.024$) than external instructions. Significantly more participants preferred the internal over the external strategy in general ($\chi^2 = 8.17$, df = 1, $p = 0.004$) with groups of 19 and 5, respectively, and when they would try to develop muscle while exercising ($\chi^2 = 13.50$, df = 1, $p = 0.001$) with groups of 21 and 3, respectively. No difference was observed between the 2 strategies when trying to produce maximal force ($\chi^2 = 2.67$, df = 1, $p = 0.10$) with groups of 16 and 8, respectively.

Discussion

The effects of external (focusing onto an intended movement outcome) and internal (focusing on the bodily movements involved in actions) attentional focusing instructions on force production and muscular activity during isokinetic elbow flexions were addressed. The results supported the prediction that an individual's focus of attention, manipulated through verbal instruction, significantly influences net joint torque production and supported the findings of previous research on muscular activity. Specifically, directing an individual's attention toward the bar being lifted (external focus) resulted in significantly greater force production and lower levels of muscular activity when compared with focusing on the movements of the arm and muscles (internal focus). As such, the present study is the first to quantify that an internal focus is associated with significantly lower net joint torque parameters when compared with an external focus of attention. This therefore confirms the suggestion that externally focused instructions can assist performance not only for complex skill execution but also during force production tasks.

Why should externally focused instructions benefit force production? Instructions that influence an individual's attentional focus can have a significant influence on both the accuracy and the efficiency of their movements. Previous research has demonstrated that an external focus (onto movement intended outcome) results in greater accuracy with less muscular activity when compared with an internal focus (onto movement mechanics) (28). Within a force production setting, the present study indicates that an external focus (onto the movement of the object that force is being exerted upon: the bar), relative to an internal focus (onto the movement of the arm during the action), results in greater force production with less muscular activity. As such, within weightlifting or other maximal force production settings, instructions that direct attention externally toward movement outcomes result in the production of greater maximal forces through the use of less muscular activity. This demonstrates a more efficient recruitment and coordination of the muscles involved in such movements. Instructions directing attention internally result in reduced ability to produce maximal force, and this is linked to inefficient muscular activation that limits force production. Previous research has suggested that an internal focus is associated with an increase in "noise" in the motor system as quantified through greater muscular activity (20,28). The increased noise in the motor system that results from an internal focus means that the observed increased muscular activity is not transferred to gross movement output. Such increased muscular activity hampers movement control, supporting the observed detrimental effects of an internal focus in sports skills requiring appropriate force production such as golf putting (22), dart throwing (8), volleyball and soccer kicks (23), and basketball (28), as well as tasks requiring maximal force production (e.g., vertical jump-and-reach task) (27). In terms of the reduced force production observed here, conscious movement control has interfered with participant's ability to effectively coordinate and produce maximal force during elbow flexion movements. These results provide additional evidence that focusing on anticipated movement effects enhances performance compared with internally focusing on the movements being executed.

The present study substantiates previous suggestions that decreased muscular activity observed with external instructions demonstrates increased automaticity at a neuromuscular level (20). However, one key limitation of the present study is that triceps EMG was not obtained. Previous research has demonstrated associated increases in triceps EMG in line with bicep EMG when an internal attentional strategy is employed and that such effects demonstrate interference between the agonist and antagonist muscle groups during such movements (20). Such interference would also explain the reduced force production observed in the present study when an internal focus was employed, with the external focus promoting more effective coordination between agonist and antagonist muscles. Wulf et al. (27) suggested that the force production benefits of an external focus are not only because of effective recruitment of muscles fibers within a muscle but also because of effective agonist and antagonist muscle group coordination. Therefore, without such data, the exact mechanisms cannot be identified here.

These findings demonstrate the effects subtle differences in instructional emphasis can have on subsequent movement execution. Research addressing force production manipulated by verbal encouragement or instruction should present the specific qualities of the guidance given. Differences in the induced attentional focuses will have a subsequent effect on performance and pose potential confounds in the comparisons between such studies. Furthermore, research addressing the effects of individual's psyching-up strategies on force production need to consider the type of attentional focus employed by participants. Suggesting that such strategies result in enhanced states of attentional focus (2) is limited and now needs to be developed further to incorporate the concept of attentional direction. Such approaches do not take into account the multidimensional nature of attention; the present study highlights that attentional direction is a critical component when influencing force production. Although the present study was not a direct assessment of self-directed psyching-up strategies, the findings indicate that attentional direction should be considered in research addressing such issues. Through effective conceptualization of attentional focus, research may effectively address the influence of cognitive strategies on force production and their associated mechanisms. Additionally, considering the effects observed in this one-off examination, it seems plausible that there are long-term training implications of different attentional strategies, which future research should aim to address.

The post-task questionnaire provides some insight into the participant's experiences of the instructions provided. The type of attentional focus employed did not influence the levels of perceived mental or physical demands during the task. However, the fact that the internal instructions were rated as easier to follow and resulted in less distraction indicates that there were some difficulties in the use of the external focus, over an internal focus, regardless of the improved performance. In addition to these ratings, participants preferred the internal instructions over the external ones in general and for working out in the gym to develop muscle. However, there were no differences in instructional preference for maximal force production, suggesting that some participants may have been unaware of the performance benefits that the external focus gave them. Such findings are not supportive of previous research highlighting preferences for externally related instructions (26). However, the nature of the task potentially influences preferences and experiences, as noted by Marchant et al. (8). Specifically, weightlifting tasks have few external reference points when compared with other skilled movements (e.g., targets and movements of apparatus). This makes the distinction between internal and external focuses difficult and potentially making an internal focus easier because of the salience of muscular contractions and exertion. More appropriate external instructions could be developed to reduce such differences, which experienced coaches, trainers, athletes, exercisers, and physical therapists may be better placed to identify. For example, when movements do not have obvious effects on the environment, an external focus can be manipulated through the use of analogy or metaphor to induce appropriate imagery (21). Similarly, a more realistic or dynamic weightlifting task may provide clearer external reference points to focus upon (e.g., a weighted bar and movement form), or visual feedback (e.g., torque feedback from isokinetic dynamometer monitor) may be employed from force production equipment as has been successfully used to manipulate an external focus during balance tasks to beneficial effect (16). Alternatively, individuals trained in force production (e.g., weightlifters and powerlifters) may be more sensitive to the benefits of an external focus. However, that the significant differences in force production were observed, despite such difficulties further emphasizes the sensitivity of movement quality to even small differences in the emphasis of attentional instructions.

In conclusion, the present study is the first to quantify that an external focus of attention is associated with a significantly greater net joint torque when compared with an internal focus of attention. Furthermore, internally focused instructions resulted in significantly increased muscular activity compared with an external focus of attention, supporting previous research (20). Such findings demonstrate that when individuals are directed to focus externally upon the outcomes or intended effects of a movement (in this case, the object that force was being exerted upon), the resulting movements are more efficient and in line with the desired outcome. There is potential of attentional focus to impact upon functional strength and power training, where it has been suggested that to gain specific muscular adaptations requires controlling the nature of physiological effort through the use of appropriate cognitive and attentional states (6). Therefore, instructions that *increase* force production (external focus) or muscular activity (internal focus) might have practical relevance in rehabilitation and strength training settings when such goals are appropriate. It has also been suggested that athletes can influence their muscular activity depending on the aim of an exercise (e.g., activating injured muscles during rehabilitation) (17). It is thereby possible that using internally focused instructions to increase muscular activity may aid muscular weight training (rather than performance) and the rehabilitation of injured muscles through increased stimulation. Regarding performance, if the aim of a session is to produce a skill-based weightlifting movement such as powerlifting or the production of maximum force, then focusing externally upon the movement outcome (e.g., the weight being lifted) should be more effective in promoting maximal force production. However, research needs to address the long-term impact of training using specific attentional focusing instructions on strength and muscular adaptation.

Practical Applications

Coaches, physical trainers, and others in situations where verbal instruction guides movements for force production should be aware of the impact differently emphasized instructions can have. Similarly, individuals attempting to influence their own force production through psyching-up strategies should also be aware of their attentional focus.

Specifically, instructions or strategies intended to result in increased force production should incorporate an external focus of attention onto the object or weight that the force is being exerted upon or the outcome of the movement. Instructions or psyching-up strategies that emphasize focusing attention internally onto movements and muscle activation will be limited in their effectiveness in such settings but do result in increased muscular activation. Equipped with this knowledge, attention can be directed appropriately depending on the aims of a training session or competition.

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