The Effect of Internal vs. External Focus of Attention Instructions on Countermovement Jump Variables in NCAA Division I Baseball Players

By

Alexandra L. Kershner
B.S., Duke University, 2015

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Chair: Andrew C. Fry

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Mary Fry

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Trent J. Herda

Date Defended: Wednesday, April 26th, 2017

The thesis committee for Alexandra L. Kershner certifies that this is the approved version of the following thesis:

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Chair: Andrew C. Fry

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Abstract

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Alexandra L. Kershner
The University of Kansas, 2017

INTRODUCTION: Coaches utilize verbal instruction to focus an athlete's attention on pertinent aspects of a skill. Focus of attention can be classified as either internal or external (13). An internal instruction directs focus to bodily movements or the action itself whereas an external instruction pertains to the desired movement outcome, an implement (golf club, ball, etc.) or the environment (87, 13).

PURPOSE: To compare the effect of internal and external focus of attention instructions on force-time characteristics of the countermovement jump (CMJ) in collegiate baseball players.

METHODS: Forty-three resistance trained men ($\bar{x} \pm$ SD; age = 20 ± 1.5 years; height = 186.4 ± 6.6 cm; body mass = 88.9 ± 8.8 kg) on an NCAA Division I baseball team volunteered to participate in this study. Each participant performed a total of 16 CMJs (2x4 jumps in both an internal and external focus condition). Jump height (JH), peak velocity (PV), mean concentric velocity (MCV), peak force (PF), mean concentric force (MCF), peak power (PP), mean concentric power (MCP), average eccentric rate of force development (ECC-RFD), relative mean concentric force (rCON) and relative net concentric impulse (rCON Impulse) were calculated from force-time and position data. Paired samples t-tests and Cohen's *d* effect sizes were used to examine differences between conditions. Subjects also completed manipulation check surveys following each set of jumps.

RESULTS: When subjects were instructed using an external focus they demonstrated significantly ($p < 0.05$) greater JH (48.0 ± 5.6 cm), PV (3.6 ± 0.3 $m \cdot s^{-1}$), MCV (2.31 ± 0.22 $m \cdot s^{-1}$), MCP (4,442.41 ± 716.35 W), ECC RFD (1,512.5 ± 249.1 $N \cdot s^{-1}$), and rCON impulse (3.4 ± 0.3 $Ns \cdot kg^{-1}$) as compared to jumps performed with the internal focus (46.4 ± 5.4 cm; 3.5 ± 0.3 $m \cdot s^{-1}$; 2.25 ± 0.23 $m \cdot s^{-1}$; 4,350.85 ± 729.79 W; 1,461. 2 ± 252. 8 $N \cdot s^{-1}$; 3.3 ± 0.3 $Ns \cdot kg^{-1}$). According to the manipulation checks, subjects adopted the desired focus of attention in 73.8% of the internal trials, and 66.6% in external trials.

CONCLUSIONS: Trials in which subjects were instructed with an external focus of attention displayed significantly greater JH, PV, MCV, MCP, ECC-RFD, and rCON impulse. These results support the Constrained Action Hypothesis and related literature which state that external focus of attention enhances automaticity and subconscious control of motor patterns (101). It is interesting to note that there was superior recall of the internal instructions during the manipulation checks. This may suggest that the subjects thought about or consciously processed these instructions to a greater extent. Conscious processing may also explain the reduced internal condition performance.

PRACTICAL APPLICATION: The present study demonstrates that several CMJ jump variables were significantly influenced by the stipulated instructions. These results indicate that instructions can alter the efficiency and performance of a skill and should be designed and applied appropriately. According to the literature and the present study, if an optimum performance metric (jump height, peak velocity) is desired, external focus of attention instructions should be used.

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Chapter 1: Introduction

"It is hard to imagine a variable more central to performance than the ability to direct and control one's attention (Nideffer, 58).

Background

Words are the foundation of communication. Pieced together, they convey meaning and purpose. In addition to allowing individuals to share information, words can have a physiological effect on the brain (53). They alter genetic expression, chemical release, and growth or decay of certain cortical regions (53). Thus, verbal communication between two people (e.g. coach and athlete) can tangibly affect function and performance.

Universally, coaches use words (via instructions) to communicate intent and proper technique for a certain skill (7). Ideally, these instructions guide the athlete's focus to pertinent aspects of the action. By promoting a specific focus, coaches can then affect the athlete's thought process in the execution of that task (13).

Depending on the intent for a movement or skill, this focus may internal or external. An internal focus directs attention to bodily movements, joint angles or details of the action itself (87). An external focus, however, directs attention to the effect of the movement, an implement (golf club, ball, etc.) or the environment (13, 87). Current research comparing the two styles almost unanimously recognizes that externally focused instruction prior to the execution of a skill facilitates superior performance. Such increases in performance are primarily attributed to automaticity, as internal instructions tend to disrupt motor patterns through a shift to conscious control (101).

If attentional focus can affect instruction processing in the athlete, sports performance practitioners would undoubtedly benefit from being able to recognize optimal timing and context for these instructional styles. Specifically, there would be immediate impact and application for the approach that maximizes acute performance variables like force, velocity and power. More importantly, several studies have shown that instructions can have an effect on not only immediate, but long-term performance (82). If certain instructions promote learning, athletes and coaches can capitalize on short-term adaptations by transferring those abilities to other (possibly sport specific) skills.

Before either short or long-term adaptation can occur, coaches must recognize the complexities and contextual aspects of designing and applying attentional focus instructions. Utilizing the appropriate focus requires an understanding of the neurological, psychological and motor mechanisms behind altered attentional focus performance. The coach must also recognize and adapt their instructional style to the skill level or learning style of the athlete. Finally, these adaptations demand dedication to designing and delivering instructions in a way that will evoke the desired response. The following review will highlight these aspects as they are applied to a study of countermovement jump performance (CMJ) in a population of NCAA Division I baseball players.

Purpose

The purpose of this study was to measure acute differences in CMJ performance (jump height, power, velocity, force, rate of force development, and impulse) given opposing focus of attention instructions (internal vs. external) in NCAA Division I baseball players.

Hypothesis

The primary hypothesis was that using external focus of attention instructions would improve CMJ height and other related CMJ variables as compared to using internal focus of attention instructions.

Independent Variable

The independent variable for this study was the attentional focus instruction conveyed to the athlete: internal or external. Our protocol required each athlete to perform eight non-continuous CMJs in two different instructional conditions. The internal focus of attention instruction was, "In this condition, just concentrate on extending your knees and hips as explosively as possible." The external focus of attention instruction was, "In this condition, just concentrate on pushing away from the ground as explosively as possible."

Dependent Variables

The dependent variables for this study were jump height (JH), peak power (PP), mean concentric power (MCP), peak velocity (PV), mean concentric velocity (MCV), peak force (PF), mean concentric force (MCF), mean eccentric rate of force development (ECC-RFD), relative mean concentric force (rCON), and relative net concentric impulse (rCON Impulse).

Delimitations

This study was delimited to NCAA Division I baseball players at the University of Kansas (males, age 18-24). We used one specific set of internal and external attentional focus instructions and the jump test was delimited to a countermovement vertical jump without an arm swing. For statistical analysis, we compared the internal and external conditions using paired samples t-tests and Cohen's *d* effect sizes.

Assumptions

We assumed that all subjects had adopted the specified focus based on the instructions provided for each set of CMJs. We also assumed that all athletes could consistently perform similar CMJ technique over the course of the entire session.

Definitions

1. **Focus of Attention**: The subject of one's mental focus at any particular instant.
2. **External Focus**: Focusing attention on the outcome of an action, the environment or a temporally/spatially distal movement effect (e.g. trajectory of a ball or toward a target) (87-89).
3. **Internal Focus:** Focusing attention on the specifics of the movement, certain bodily dimensions (joint angles, velocities, patterns), and how they interact to create a movement pattern (87-89).
4. **Manipulation Check**: A post-trial survey designed to measure what subjects were thinking about during the procedure.
5. **Countermovement Vertical Jump (CMJ)**: "A movement in which the jumper starts from an upright standing position, makes a preliminary downward movement by flexing at the knees and hips, then immediately and vigorously extends the knees and hips again to jump vertically up off the ground (39)."
6. **Ground Reaction Force (GRF)**: The force exerted by the ground onto a body in contact with it. This force is equal and opposite to the force applied by the body onto the ground.
7. **Impulse**: The integral of force over the length of time for which that force is acting.
8. **Velocity**: Change in position with respect to time.
9. **Power**: Force multiplied by velocity OR work divided by time.
10. **Take-off Velocity**: An individual's instantaneous velocity as they leave the floor. In most instances, synonymous with peak velocity (PV).
11. **Mean Eccentric Rate of Force Development** (ECC-RFD): The average of the peak eccentric force and the instantaneous eccentric force when GRF returned to body weight.

12. **Relative Mean Concentric Force (rCON)**: Mean force during the concentric phase of the jump, relative to body mass (N/kg).
13. **Relative Net Concentric Impulse (rCON Impulse)**: The integral of vertical GRF during the concentric phase (above body weight), relative to body mass (Ns/kg).
14. **Instructions**: A few sentences given prior to a specific skill or action detailing how to execute the procedure (13).
15. **Cue(s):** A short one or two-word phrase immediately preceding or during the execution of an action or skill (13).
16. **Feedback**: A few sentences following the performance of a skill or action, intended to provide the athlete with information on how they did in the previous repetition and how they can improve prior to the next trial (13).
17. **Electromyography (EMG)**: A technique for evaluating and measuring the electrical activity of skeletal muscle.

Chapter 2: Review of Literature

Introduction

Effective communication between coach and athlete is essential for optimal performance. Through this communication, coaches attempt to convey purpose, technique, and proper execution of a skill. Regardless of context, this interaction is multidimensional, involving both visual and verbal components. The visual aspect consists of demonstration and physical reinforcement, whereas the verbal encompasses instruction, cueing and feedback. Utilized concurrently, these two components significantly enhance motor learning and comprehension (96).

Types of Coaching. Coaches use both verbal and visual components to guide the learner's attention to pertinent aspects of a task or skill. By directing attention to a particular focus, they can affect the athlete's thought process in the execution of that task (13). If effective, this focus of attention will become the subject of mental concentration rather than just a fleeting thought or visual focus (13).

Depending on the coach's intent for a movement or skill, the focus may include information about the location of certain body parts, coordination of sub-movements and/or the goal of the motion (87). With many choices, understanding which form to use, and where to direct the athlete's attention is difficult and often situation dependent. Therefore, it is necessary to recognize how an athlete responds in certain contexts and to different types of coaching.

While they should not be used in a mutually exclusive manner, verbal and visual coaching may have different levels of utility in certain situations. For example, the verbal component may direct a learner's attention to aspects that wouldn't otherwise be picked up by just watching a demonstration (87). In order to optimize the interaction between the two components, one must have a deeper understanding of each individually. This study will focus on just the verbal component because it is more controllable and repeatable in the laboratory setting.

Verbal Coaching

Types of Verbal Coaching. Verbal coaching consists of instruction, cues and feedback. While similar, these terms are not interchangeable. According to Benz et al. (13), instructions are medium to long phrases delivered prior to performance of a skill. Cues are shorter (one or two words) and delivered immediately before or during the execution of a skill. Feedback is information administered following the performance of a skill. Instructions convey how to perform a movement, cues remind the athlete about key aspects of the movement and feedback refines the movement prior to the next set. All three, if applied correctly, will focus a subject's attention on the crucial aspects of a task. In our study, we chose to use instructions (over cues and feedback) because they ensured the information was consistently delivered and detailed enough to convey the necessary information.

Internal and External Focus of Attention. For each of these methods of verbal communication there are two primary types of attentional focus – internal and external. An internal focus directs attention to bodily movements, joint angles or details of the action itself (87). Alternatively, an external focus directs attention to the effect of the movement, an implement (golf club, ball, etc.) or the environment (13, 87). For example, when performing the bench press, an internal focus instruction might be, "focus on extending your arms and squeezing your chest" whereas an external would be, "focus on explosively pushing the bar to the ceiling." While both instructions describe the same movement pattern, the words themselves may trigger distinctive processing within the brain. Analogies (and/or metaphors) are an extension of the external focus. They provide the athlete with goal-specific directions that trigger a familiar image or pattern (84). For optimal retention, the mental image or context should be meaningful to the subject (84).

Knowledge of attentional focus and the various ways it can be applied is crucial because there is extensive literature demonstrating that it can significantly alter performance (positively or negatively). Under the assumption that an individual is proficient in a specific task, most studies find that adopting an external focus of attention significantly increases execution (*see Pertinent Studies*). Given the prevalence of this outcome, it is worth investigating the theories that explain its occurrence. Understanding these neurolinguistic and psychological mechanisms can help coaches apply instructions in a way that will positively influence performance (13, 101).

Proposed Mechanisms of Enhanced Performance

As mentioned previously, words can directly affect the brain. For instance, positive words can increase frontal lobe activity, control production of neurochemicals and even alter the expression of certain genes (53). With these extraordinary manifestations as a baseline, the following hypotheses and theories attempt to explain how words can actually alter processes at the cerebral, nervous and muscular level.

Working Memory. To understand word processing in the brain, it is necessary to analyze the working memory. Working memory is the portion of short-term memory that processes immediate conscious perceptual and verbal stimuli (Oxford English Dictionary). It is only capable of storing ± 7 pieces of information at one time, and thus easily overloaded (45, 49). In the multiple component model, working memory is described as three interconnected domains: the phonological loop, the visuospatial sketchpad and the general central executive (50). The central executive regulates attention by preserving task goals while reducing distraction or outside influence (50). Thus, the central executive domain of working memory is likely where instructions are organized and perceived in terms of actionable information.

Working memory directs attention based on existing neural pathways (4, 76, 77). Furley et al. (29) illustrate this idea by comparing working memory to a thermostat. Instructions specify the initial settings or temperature. These directions enable the working memory to constantly readjust focus and pick up on important task information, even in the presence of distraction. It also ensures that the athlete utilizes existing and strong neural pathways. Essentially, properly instructing an athlete can 'load the working memory,' priming them for accurate processing and attention (29).

The more practice an individual gets with a particular skill, the stronger these neural networks become. For example, Wu et al. (85, 86), analyzed fMRI of participants tapping their fingers in a certain pattern until they were able to do so automatically. They found that no one area of the brain increased its activity. However, the cerebellum, cingulate motor area, supplementary motor area and putamen showed significantly greater connectivity. The authors suggest this increased connectivity results in more efficient neural networking and greater motor coordination despite an overall decrease in activation (85, 86).

The way the working memory processes verbal instruction also depends on the type of information received. For example, declarative (explicit) knowledge is information that can be described, whereas procedural (implicit) knowledge is something that can elicit or control behavior, but cannot be put into words (38, 45). Declarative (explicit) knowledge is working memory dependent, whereas procedural (implicit) is subconscious and requires little working memory (8). As a result, skills that are learned or instructed implicitly (external focus) require less conscious thought and tend to be longer-lasting and more robust under conditions of psychological stress (38).

Internal instructions can be a form of declarative (explicit) knowledge because they give the athlete “rules” for a certain skill or cause them to consciously process verbal information about the movement pattern (8, 38). As it is working memory dependent, internal instruction can overload the working memory (8) and cause the athlete to overthink a movement. However, movement patterns that are learned or instructed implicitly can remain subconscious, not using up information processing resources in the working memory (38, 45). Automatic or implicit skills should not be instructed with an internal focus as it may cause a return conscious processing (14, 68, 69, 70).

Constrained Action Hypothesis. Building on the concept of working memory, Wulf, McNevin and Shea (90) developed the Constrained Action Hypothesis (CAH). The CAH explains why individuals (proficient in a skill) respond favorably to an external focus of attention. According to The CAH, the brain defaults to subconscious self-organization when performing well-practiced skills. In other words, it subconsciously coordinates its motor patterns in the most efficient way possible. When one focuses on specific body parts instead of the movement as a whole, the individual tries to control or adjust the skill in their conscious mind. Therefore, an internal focus interferes with the normal motor process as the individual tries to incorporate the new instruction into their existing movement pattern.

To investigate The CAH, Kal et al. (34) tested the effect of secondary task loading (a cognitive letter fluency task) on primary motor task performance (speed of flexing and extending the leg while in a seated position). They administered the secondary task protocol to individuals performing the primary motor task with either an external focus or an internal focus. With this dual constraint, the external focus condition performed the primary motor task faster than the internal focus condition. Kal et al. (34) believe that the internal focus caused individuals to consciously control the primary task. When the secondary task was introduced, they were unable to accomplish both effectively due to working memory constraints and interference. In the external condition, however, they were able to execute the primary task subconsciously, allowing the conscious mind to focus on only the secondary task.

Functional Variability. The notion that an external focus stimulates automaticity is supported by studies of functional variability. Specifically, external focus conditions tend to demonstrate higher frequency adjustments and movement amplitudes as measured by mean power frequency (MPF) (7, 87, 90). These mechanisms allow the motor system to compensate for error in the movement pattern through small, constant corrections (52, 55, 91). To illustrate, in external conditions, variability around specific joints tends to be high, but variability of the movement outcome is low (27, 28, 40, 48, 95). On the contrary, when the motor system is constrained (in internal focus conditions), degrees of freedom (at the joint) are constricted and movement outcomes are inconsistent (30, 55).

Similar to functional variability, the Optimal Control Theory suggests that attentional focus promotes a specific goal within the movement pattern (42). With an external focus, the goal is the movement outcome, whereas with an internal focus, the goal is execution of specific joint angles and sequences (42). As such, an external attentional focus may increase the variability of the movement pattern from trial to trial, but reduce error in the overall movement outcome (42).

Self-Perception & Non-awareness. The Working Memory, Constrained Action Hypothesis, Functional Variability and Optimal Control theories each concern neurological and motor processes. However, there are several psychological theories thought to be equally important in explaining the effect of instruction on attention and performance.

Studies of professional and expert athletes find that many share similar mental strategies. For the most part, these athletes tend to adopt ‘non-awareness’ strategies or execution of a skill without thinking about it (74). They eliminate situational details, focus on “just doing the task” and quiet the conscious mind during execution (74). This strategy is similar to an external focus in that it promotes thinking beyond the body. Singer et al. (74) found that individuals using a ‘non-awareness’ strategy, even with an unfamiliar task and when loaded with a secondary task, were more accurate.

The concept that an internal focus of attention degrades performance is often attributed to its promotion of focus on “the self.” Self-reflection may cause the athlete to worry about how others see their performance (98). For example, when they perform a specific task or skill in the presence of others, the participant may become self-conscious and negatively self-evaluate (100). It is also possible that when the subject entertains self-conscious thoughts, it occupies space in the working memory. Information in the working memory is processed consciously and can disrupt automatic motor patterns (10, 73). Additionally, during times of stress or performance anxiety, individuals resort to thinking about the skill in terms of the “rules” with which that skill was initially learned. This may cause them to use highly specific internal-like instructions which tend to constrain the motor system and cause overthinking (64).

In summary, internal instruction is detrimental to performance because it induces self-conscious thought and micro-choking. Giving social comparative feedback, however, can enhance performance. In particular, positive social-comparative feedback may increase self-efficacy, decrease self-consciousness and promote automaticity (75, 98). In addition, enhanced expectancy (telling an individual you expect them to achieve a certain result) can increase behavioral flexibility and adaptability, creating less-constrained movement patterns (75). By only providing feedback following trials that are successful, coaches can improve performance (17) and build positive affect, a trait correlated with an increase in dopamine (a potential strengthening agent of neural connections) (3).

As they are alike in induced result, using enhanced expectancy and social comparative feedback may be similar to adopting an external focus. If they are, they should operate through similar mechanisms. Pascua, Wulf & Lewthwaite (61) designed a study to compare and determine whether these strategies are mutually exclusive. Subjects that were given both external focus instruction and positive social comparative feedback (told they were doing better than the average score of the other subjects), performed better in both performance and learning tasks than either condition separately or the control condition. These results suggest that the two strategies operate somewhat independently but have additive benefits.

Expert vs. Novice

Given the wide spectrum of theories presented, researchers are still unsure what produces altered attentional focus performance. Until the mechanism(s) are explicitly defined and understood, more research is needed to explore how certain contexts affect internal and external focus performance. One such context to consider is whether the coach is dealing with a novice or expert performer. A novice is an individual who is relatively new to, or performing a skill for the first time. An expert is someone who has performed a skill so many times they execute it automatically. Understanding the skill level of the athlete is important because cognitive psychologists postulate that there is a difference in internal processing between experts and novices (74).

It is likely that the disparity in processing strategies is related to the fact that novices are typically instructed using internal cues (74). Often, they are told to focus on joint angles, certain body parts and the movement pattern itself (74). This approach seems logical because beginners need to understand how to orient their bodies and sequence a movement pattern. The Deautomatization of Skills Hypothesis (DOH) concurs, suggesting that because novice performance is not yet automatic, learners must consciously concentrate on the systematic components of the skill (9). In support of this hypothesis, there are several studies showing that novices perform better under an internal, rather than external focus of attention (9, 16, 27, 28).

When instructed with an internal focus, novices tend to utilize controlled processing. Controlled processing is slow and requires a great amount of attentional demand (73). However, when skills become more familiar and practiced, automatic processing begins to develop. Eventually, the same skill occurs with greater automaticity and less attentional demand (73). By the time an individual becomes an expert, they may not have to think about what they are doing (74).

Fitt's model of skill acquisition echoes this progression of novice to expert. In the 'initial cognitive' phase, novices are subjected to the basic rules of the movement pattern through verbal instructions (15). Their performance is unpredictable as they attempt to piece together and experiment with different methods (15). In the 'associative' phase, the individual becomes more consistent in that skill, practicing until that skill becomes refined. Finally, they reach the 'autonomous' phase, where they can perform the movement with minimal conscious effort. Based on this sequence, Peh et al. (62) suggests coaches use a parallel transition from internal to external focus of attention with their athletes. For example, an internal focus of attention can assist novices in the initial 'cognitive' phase as they piece together movements from individual motor components. However, as they transition into the ‘associative’ and ‘autonomous’ stages, individuals may benefit more from an external focus, as it promotes automatic execution of the skill (62).

The transition from internal to external focus instructions with increasing skill level is one approach. However, few studies have looked at the legitimacy of other strategies. Singer et al. (74) devised a study to see if it would be possible for novices to bypass the slow, controlled processing and begin with an expert strategy. In this study, novices were instructed to use the ‘non-awareness’ or external focus strategy that experts do. Results showed that novices throwing a ball with their non-dominant hand were able to perform better with a ‘non-awareness’ strategy than an ‘awareness’ (internal focus) one. However, they were equally successful with a mixed (internal & external) strategy called the ‘Five-Step Approach’. This method required the novice to plan the movement ahead of time, but focus on only one (external) cue during performance. Even in the presence of a secondary (verbal) task, novice performance was superior with the ‘non-awareness’ and ‘Five-Step Approach’ strategies. Traditional thinking may suggest that novices be instructed in a way that promotes conscious processing of situational details and body parts, but it is probably more advantageous to use a combination of both internal and external.

A Review of Pertinent Studies

Having reviewed the major theories, it is worth looking at the existing body of literature for examples of their application and contextual dependencies. As of 2013, there were more than 80 studies analyzing the effect of external and internal focus of attention on performance and skill (101). The subject matter of these experiments range from balancing tasks to dart throwing. However, most of the studies fall into three major categories – movement effectiveness (balance or accuracy), movement efficiency (muscular activity, maximal force production and speed/endurance) and learning (retention and transfer) (101). Given the scope of the current study, the maximal force section will highlight three studies that relate to ours in terms of protocol and application. These include a vertical jump and reach task (93), a standing long jump (65) and an unloaded CMJ (81).

Movement Effectiveness

Balance. Balance is a unique skill that demands the subject maintain vestibular control while simultaneously coordinating all postural muscles (63). Most tests of balance require the subject to stand on or interact with a specific implement. When testing attentional focus in these studies, focusing on reducing movement of the balance apparatus (external focus) as opposed to movement of the feet or body (internal) minimizes sway and increases performance (101). This same result is seen when subjects balance on ski-simulators (87, Experiment 1), stabilometers (87, Experiment 2), inflated rubber disks (97), and Pedalos (82).

Accuracy. Movement effectiveness is also studied using tests of accuracy. Many accuracy studies measure the athlete's control of a sporting implement (golf clubs, balls, darts, etc.). Focusing attention on the implement (external), as opposed to the body part controlling the implement (internal) results in superior performance. For instance, golfers are more accurate with the placement of the ball when instructed to focus on the club (88), or the trajectory (both external) (11) as opposed to their arms (88, 94) or wrists (internal) (11). Other accuracy tasks such as basketball free-throws, darts, beanbag toss, volleyball serves, and soccer passes (1, 18, 40, 92) tend to be more accurate when instruction and/or feedback is externally focused.

Movement Efficiency

Muscular Activity. In some cases, adopting an external focus may enhance movement efficiency through reduced muscle activity and better-organized motor patterns. For example, Vance et al. (83) measured EMG activity in participants performing a bicep curl. Participants were instructed to focus on their arms (internal) or on the bar (external). Those in the external condition performed the movement faster despite similar EMG activity. In a second experiment controlling for time, the external condition exhibited reduced iEMG activity in both agonist and antagonist muscles. Likewise, in studies of basketball free throw shooting (104, 105) and dart throwing (40), the external conditions also demonstrated increased accuracy and reduced EMG activity.

Most noteworthy in terms of the proposed study, Wulf et al. (98) measured EMG activity of lower body musculature in a vertical jump and reach task. Not only were jump heights greater in the external focus condition, EMG activity was generally lower. In addition, there was no difference in muscle onset time, indicating differences in jump height were due to more efficient muscular coordination rather than initial control.

These results demonstrate that proper attentional focus can improve performance while simultaneously reducing the neural and muscular cost to the athlete. If coaches can instruct the athlete in a way that preserves energy, time in the weight room becomes more efficient and can have positive impact on the athlete's health and performance.

Maximum Force Production. Maximal force occurs when peak motor unit recruitment coincides with proper joint sequencing (101). Both vertical jump and standing long jump tests require this coordination to achieve optimal force production. The following study excerpts will examine the differential effect of external/internal focus of attention on these tests.

1. Increases in Jump-and-Reach Height Through an External Focus of Attention, Wulf et al. (93). The purpose of this study was to measure participants' response to external and internal focus of attention instructions while executing a vertical jump-and-reach task. Using a

Vertec as the measuring apparatus, researchers instructed participants to perform a maximal vertical CMJ, displacing the highest vane possible. Each participant completed five neutral focus, five internal focus and five external focus jump trials. In the control, participants received no instruction. In the external condition, they were instructed to concentrate on the rungs of the Vertec, and in the internal condition they were instructed to concentrate on the tips of their fingers reaching the highest rung possible.

Participants reached higher and increased center of mass height in the external focus condition, as compared to the internal focus or neutral focus. As a result, the main effect of attentional focus was significant. Critics of this study argue that the external and internal focus of attention were not sufficiently different. They claim that focusing on the rungs of the Vertec versus the fingers effectively produced the same visual focus, as both need to be in the line of sight during the action of touching the rungs (62).

2. Standing Long Jump Performance is Enhanced When Using an External Focus of Attention, Porter et al. (65). Similar to the vertical jump-and-reach test, the standing long (broad) jump requires optimum muscular coordination and efficiency. Accordingly, strength and conditioning professionals use the standing long jump as a test of maximal power production (12, 71, 78). For this test, Porter et al. (65) used a between-subjects design to evaluate 120 untrained participants. Subjects completed five standing long jumps in only one (of the two) conditions. If they were in the internal condition, they received the instruction “When you are attempting to jump as far as possible, I want you to focus your attention on extending your knees as rapidly as possible.” If they were in the external condition, they were told, “When you are attempting to jump as far as possible, I want you to focus your attention on jumping as far past the start line as possible.” Similar to the Wulf et al. (93) study, subjects in the external condition jumped significantly farther than the internal condition. Again, this may indicate greater force producing capabilities, or more efficient movement patterns when instructed with an external focus of attention.

Unfortunately, neither of the aforementioned studies actually measured ground reaction force. Therefore, one cannot conclude that increases in jump performance were caused by greater force producing capabilities. The current study, however, measured force, power and velocity.

3. Effect of Instructions on Selected Jump Squat Variables, Talpey et al. (81). This study was the basis for the current study in terms of purpose and protocol. The similarities between the two studies allow readers to make direct comparisons. However, our study also adapted certain components to refine the following protocol.

In addition to the vertical and standing long jump, the countermovement jump (CMJ) is a common measurement of maximal force (81). An unloaded CMJ produces greater peak power, peak velocity and displacement than CMJs at other loads (21). Talpey et al. (81) evaluated 18 male subjects using a within-subjects repeated measures design. In each condition, participants performed two sets of four CMJs on a force plate. In addition to the force plate, researchers attached a linear position transducer to a stretching stick held across participants' shoulders to eliminate arm swing. In the external condition, participants received the instructions "…just concentrate on jumping for maximum height." In the internal condition, they were told "… just concentrate on extending the legs as fast as possible to maximize explosive force." Like both Wulf et al. (93) and Porter et al. (65), the external instruction condition produced greater mean jump height and velocity. The internal condition, however, produced greater peak force. These results reinforce that type of instruction has an effect on certain variables in terms of the way an athlete produces force in the vertical and horizontal planes.

Speed and Endurance. Similar to tests of maximal force production, both speed and endurance tasks benefit from external attentional focus. Porter et al. (66) found an increase in speed of an agility task (L-Run) and a 20-meter sprint when participants adopted an external focus. Stoate & Wulf (79) actually observed no increase in swim speed of experienced swimmers given an external focus of attention (compared to control), but swim speed of the internally focused condition was significantly slower.

In terms of endurance, an external focus of attention increased the number of repetitions to failure performed when lifting a 75% load (44), and the time to failure of an isometric "wall-sit" (41).

Transfer, Retention and Learning

Much of the literature summarized above examines changes in immediate performance. However, several studies indicate attentional focus can also induce long-term learning effects. In this context, learning is a change that becomes relatively permanent. Most studies demonstrate learning through retention and/or transfer tests without additional attentional focus reminders (59, 100). In one particular study, subjects completed a primary task with either an internal or an external focus. Then they completed variations of that task without reminder of the initial focus. Participants in the external focus condition not only executed the initial task faster, they showed greater performance in each of the transfer tasks (82). Ultimately, coaches care about lasting performance; if an external focus can amplify learning, coaches will not have to instruct athletes as frequently and there will be greater transfer to sport performance.

Designing Instructions

Using the reviewed studies as examples, one can see that there are various methods and justifications for the way instructions are designed and applied. When comparing these studies, it is critical to understand how the instructions were devised and whether or not they were appropriate for the specific application or population. The following is a review of guidelines Wulf et al. (101) uses to design instructions for attentional focus studies.

First, in opposing internal and external instructions, the two phrases should be as similar as possible (101). If feasible, they should differ by only a few words (101), and should contain similar types of information (e.g., one should not introduce a visual focus if the other does not). Second, the instructions should be as specific as possible to ensure the command will induce the desired focus (101). Finally, instructions should include direction, distance and description. Direction specifies "up" or "down", "toward" or "away" whereas distance describes "near" or "far". Description can be as simple as an action verb (e.g. snap, push, explode, drive) or as complex as mental imagery (84).

Distance. To demonstrate the importance of including direction and distance in instruction, several studies have shown that increased physical space between subject and focus can play a major role in performance. For example, Porter et al. (67) discovered that both near and far external focus instructions elicited greater standing long jump performance. However, participants instructed to focus on something farther away performed significantly better than those focusing on a nearby object. Similar results were also seen in balancing and golf accuracy tasks (11, 48).

The mechanism for enhanced performance given a further focus of attention may be the increased separation between the movement 'process' and 'outcome' (84). In other words, a 'near' focus may make the process less distinguishable from the body (72).

Frequency. Another component to consider when designing instructions is the effect of frequency. The ideal frequency of instruction delivery depends on the attentional focus. If promoting an internal focus, reduced frequency tends to be superior (92) whereas the opposite is true with an external focus (92). This reinforces the notion that an external focus increases the automaticity of motor patterns, while an internal focus disrupts natural processing.

Performance Test and Population

Unloaded CMJ and the Arm Swing. The proposed study used an unloaded countermovement vertical jump (CMJ) to measure the effect of external and internal attentional focus instructions. The CMJ is common in performance research due to its universal application in sport (51, 57). The kinetic and kinematic variables of the CMJ can also provide information regarding movement tendencies, preparedness, and response of an athlete to a particular stimulus (57).

In a review of vertical jump field tests, Markovic et al. (44) established that the CMJ without an arm swing was the most reliable test of lower body power. It is also an ideal measure of performance because repeated trials of CMJs lack systematic bias (learning effect or familiarization) in high school, collegiate and professional athletes (57). This data suggests that familiarization trials prior to CMJ evaluation may be unnecessary, regardless of skill level.

The rationale for not using an arm-swing originates from research demonstrating that the arm-swing requires greater coordination and contributes significantly to overall jump performance (44). In fact, one can increase vertical jump performance by training the shoulder and hip flexor muscles without explosively training the legs (103). Similarly, some have suggested that the hip flexors generate two-thirds of the vertical GRF, while the shoulder musculature "pulls" or generates the remaining one-third (23). The use of an arm swing can also increase the vertical displacement of the center of mass because arm swing opposes hip extension (23). Essentially, arm swing slows the angular velocity of the lower limbs promoting generation of greater force in the lower extremity (23). According to these theories, it would appear that tests without an arm swing may be purer measures of lower limb power.

The current study utilized an unloaded CMJ because research shows that peak power, velocity and displacement are maximized when subjects use 0% 1RM loads (21, 80). Additionally, the unloaded CMJ is used in many different sport and resistance training programs. Finally, we know that unloaded CMJ performance is somewhat affected by focus of attention instructions (81).

Baseball & Lower Body Power. Baseball is not traditionally associated with jumping proficiency. However, baseball motions (hitting, throwing, running or jumping) all require lower body power and explosiveness (33). This lower body power is generated from ground reaction forces which sequentially activate musculature through the torso to the upper body (60).

In addition to the requirement of lower-body power, baseball movements are ballistic, requiring high velocities and the efficient transfer of potential and kinetic energy from the ground up (22, 26). Also, hitting, pitching and jumping are singular explosive motions. This trend is mirrored by a study characterizing baseball players as reliant on “maximal rested explosive muscular actions” instead of repeated efforts (37).

While jumping itself is only a small part of the baseball skill set, the CMJ and other plyometric exercises have application within the baseball population. Results of a survey distributed to all 30 MLB strength and conditioning coaches support this assumption. Twenty-one of the respondents reported that they utilize plyometric exercises in their programs to develop lower body power (25).

Conclusion & Contribution

There is overwhelming evidence to support the use of an external focus of attention in most contexts. However, a large number of practitioners still believe in the power of the internal focus. In fact, 84.6% of Olympic level track and field athletes surveyed by Porter et al. (66) report that their coaches use instruction pertaining to body movements. Of these athletes, 69.2% also admitted to utilizing an internal attentional focus when instructing themselves (66). If these tendencies occur with elite populations, they are most likely happening at all levels. Therefore, it is essential that we educate coaches and practitioners on the advantages of properly applied attentional focus instructions.

This study contributes to a growing field of applied strength and conditioning research. To date, most attentional focus studies have used recreationally trained or novice populations. This was the first study to use a trained collegiate population in an attentional focus study of CMJ performance. Obviously, these results need to be replicated several times before we can draw conclusions about the proper way to instruct this level of athlete. However, our analysis presents compelling evidence in support of using external focus instructions when athletes are performing well practiced ballistic or plyometric movements.

Coaching is an art form rooted in science. Understanding the power of words, significance of context and importance of focus, coaches must choose their words carefully. By picking the appropriate focus of attention and applying it to the correct context, coaches can have a significant impact on performance.

Chapter 3: Manuscript

Introduction

Coaches utilize verbal instruction to focus an athlete's attention on pertinent aspects of a skill. Depending on the context, this focus of attention can be either internal or external (13). An internal instruction directs focus to body movements, joint angles or the action itself, whereas an external instruction pertains to the desired outcome, an implement (golf club, ball, etc.) or the environment (13, 87). Choosing words carefully is critical as proper instructions can "load the working memory," priming the mind for processing and attention appropriate for that skill (29).

Numerous studies show that adopting an external focus of attention can improve performance in a multitude of domains (balance, accuracy, power, speed, endurance). In particular, a study by Talpey et al. (81), analyzed the impact of different instructions on countermovement jump performance (CMJ). While their instructions were not explicitly external or internal, they reported a significant improvement in jump height when individuals adopted the "jump height" or external-like focus.

For comparison purposes, we replicated the Talpey et al. (81) protocol (with some modifications). As such, both studies utilized an unloaded, no arm-swing CMJ. Many studies use the CMJ because of its universal application to sport, as well as its reliability and factorial validity (44, 51, 57). It also provides information about an athlete's movement tendencies, preparedness, response to a particular stimulus and lower body power (44, 57).

Our study adapted and expanded the Talpey et al. (81) methods to include more explicitly designed focus of attention instructions and a manipulation check survey. Another difference was the use of an elite population in our study: NCAA Division I baseball players. Recognizing that instructions can significantly affect CMJ performance in an untrained population (81), we adopted this variation in hopes of understanding the effect of attentional focus instructions on trained athletes executing a well-practiced skill.

Baseball players were an ideal population for this study because, similar to the CMJ, their sport requires ballistic, high velocity movement and efficient transfer of kinetic energy from the ground to the rest of the body (22, 26). Also reminiscent of the CMJ, baseball players rely on "maximal rested explosive muscular actions" (37). As such, the CMJ test may be a useful and accurate measurement tool for this population.

The purpose of this study was to measure acute differences in CMJ performance (jump height, power, velocity, force, eccentric rate of force development, and impulse) given opposing focus of attention instructions (internal vs. external) in NCAA Division I baseball players. The findings of this study may help coaches and practitioners determine how to design instructions to best elicit desired performance results.

Methods

Experimental Approach to the Problem. To measure the effect of different instructions on CMJ performance, we used a within-subjects repeated measures design. Prior to the experimental session, all subjects underwent familiarization trials as part of their strength and conditioning program. In these trials, each subject completed two sets of the protocol (minus the instruction) in the weight room. During the single laboratory testing session, subjects heard two sets of instructions in a counterbalanced order. One instruction condition had an internal focus, while the other instruction had an external. Using random assignment, half of the subjects completed the internal condition first, and half completed the external condition first.

Subjects. Forty-three NCAA Division I baseball players (mean ± SD, age = 20 ± 1.5 years; height = 186.4 ± 6.6 cm; body mass = 88.9 ± 8.8 kg) were recruited. At the time of the study, all subjects were participating in a 3-4x/week resistance training and conditioning program. All had at least 6 months' experience with resistance training, 5 years' experience playing competitive baseball and were considered "experts" at the CMJ. Athletes were recruited through voluntary participation and signed an informed consent form. The study was approved by the University of Kansas Human Research Protection Program.

Procedures. Upon arrival at the laboratory, participants were taken through a standardized warm-up. First, participants jogged for four minutes at a self-selected pace. Then, they completed a three-minute general stretching routine targeting the hamstrings, quadriceps, gastrocnemius, and gluteal muscles. Next, they performed four 20-meter submaximal running build-ups at 60, 70, 80 and 95% maximal effort. Following each run they were instructed to walk slowly back to the starting line. After the running warm-up, participants were given two minutes of rest and then asked to perform two sets of four warm-up CMJs (in the experimental set-up, *see Measurement of Squat Jump Variables*), at 50% and 95% effort, respectively. Participants then rested for another two minutes. Following the warm-up, an experimenter (coach) gave each subject a set of baseline instructions, "In each trial, the goal is to jump as high as possible." Then, the coach gave the first set of attentional focus instructions. The instructions were as follows: **Internal Focus**: "In this condition, just concentrate on extending your knees and hips as explosively as possible." **External Focus**: "In this condition, just concentrate on pushing away from the ground as explosively as possible." The instructions were designed to be similar in terms of length, sentence structure and those used by Talpey et al. (81).

Figure 1: Sample experimental set-up.

No other instructions were given regarding the technique of the CMJs. The same coach delivered all instructions and made every effort to keep tone, inflection and eye contact consistent for each participant. The use of a coach to deliver instructions was critical for two reasons. First, coaching implies a direct connection between athlete and instructor. If instructions are administered via audio recording, the human-to-human interaction is lost. Additionally, when the athlete has to hold eye contact with the coach, the likelihood that they are giving undivided attention to the instruction is greater. Second, we wanted this study to be directly applicable to coaching, so it was vital to make this aspect as realistic as possible.

Immediately after hearing the instructions, subjects performed four maximal CMJs. Between any two CMJs in the same set, they were instructed to rest and reset on the force plate so they were directly below the linear position transducer (roughly 3-5 seconds). After the first set of four CMJs, participants were given a three-minute rest. During this break they were asked to complete a manipulation check survey. They then heard the same instruction set, and performed the second set of four jumps in that condition. A five-minute rest was enforced between sets, during which they completed another manipulation check. At the conclusion of the five-minute rest, the protocol was repeated for the alternate instruction condition.

Manipulation Check. During each rest, participants were asked to fill out a short one question survey. The survey asked "What were you focusing on during the previous 4 trials? If you did not focus on anything in particular, leave the question blank." They were instructed to be honest, even if they did not focus on the instructions provided.

Measurement of Jump Squat Variables. Participants performed the CMJs on a force platform (Rough Deck HP, Rice Lake Weighing Systems, Rice Lake, WI), while holding a light stretching stick (132 cm length, 3.8 cm diameter, weighing ~ 1kg) across their shoulders as if performing a back squat. The force plate sampled at 1000 Hz. A position transducer (Transducer Techniques, Temecula, CA) hanging from the ceiling directly above the force platform was affixed to the middle of the stretching stick (Figure 1). The downward countermovement (dip) was not controlled or standardized.

From the force platform + linear position transducer system we measured jump height (JH), peak power (PP), mean concentric power (MCP), peak velocity (PV), mean concentric velocity (MCV), peak force (PF) and mean concentric force (MCF). In addition, we analyzed mean eccentric rate of force development (ECC-RFD), relative mean concentric force (rCON) and relative net concentric impulse (rCON Impulse). JH was calculated as the height of the stretching stick at its highest point (peak of the jump) minus its initial height. PP, PV and PF were taken from the entire force curve prior to takeoff (both eccentric and concentric phases). MCF, MCP and MCV were measured from just the concentric phase of the jump. ECC-RFD was calculated as the average of the peak eccentric force and the instantaneous eccentric force when GRF returned to body weight. Relative mean concentric force (rCON) was measured as the average vertical force during the concentric phase of the jump relative to body mass (N/kg), and relative net concentric impulse (rCON Impulse) as the integral of the vertical GRF during the concentric phase, relative to body mass (Ns/kg).

For force, power and velocity, we measured both peak and average values. We included both because of discrepancies in the literature as to which is a better predictor of jump height and vertical jump performance. Most of the debate surrounds the measurement of power. For example, Baker et al. (6) used mean power for determination of optimal loading in a jump squat. However, other authors have found that peak power is a greater predictor of vertical jump performance (2, 31). Nevertheless, both versions of the aforementioned variables are reliable (32).

Statistical Analysis. Prior to statistical analysis, we removed one subject's data due to software measurement error. To begin, we averaged each subjects' eight internal condition trials, and separately, their eight external condition trials. This eliminated outliers and/or variation in technique. Using the mean internal and external values for each subject, we then averaged all 42 internal condition values and compared them to the averaged external values using paired samples t-tests. The Statistical Package for the Social Sciences (version 23; SPSS, Inc. Chicago, IL, USA) was used to perform statistical testing, with a significance of $p < 0.05$. We also calculated the Cohen's *d* effect size for each difference of means. These effect sizes are described as: 0.2 = small, 0.5 = moderate and 0.8 = large.

Results

Force-time and Position Variables. Data were analyzed using paired samples t-tests. According to the results of these tests (see Table 1), when subjects were instructed using an external focus they demonstrated significantly ($p < 0.05$) greater jump height, peak velocity, mean concentric power, mean concentric velocity, mean eccentric rate of force development, and relative net concentric impulse as compared to jumps performed with the internal focus. There was a moderate to large positive effect size (Cohen's *d*) for each of the significant variables. Peak force, peak power, mean concentric force, and relative mean concentric force were not significantly different but demonstrated positive effect sizes.

Table 1: Descriptive results (mean ± SD) and statistical comparisons for the two instruction conditions.

Jump Variable	External Condition	Internal Condition	Cohen's *d*	p
Jump height (cm)	48.0 ± 5.6	46.4 ± 5.4	0.6	0.001
Peak velocity (m·s)	3.59 ± 0.30	3.51 ± 0.31	0.7	<0.001
Peak force (N)	2,383.9 ± 318.7	2,378.4 ± 308.7	0.1	0.742
Peak power (W)	7,778.3 ± 1,018.2	7,725.8 ± 1,049.9	0.2	0.288
Mean concentric velocity (m·s)	2.31 ± 0.22	2.25 ± 0.23	0.8	<0.001
Mean concentric force (N)	1,962.1 ± 245.0	1,956.5 ± 247.4	0.1	0.539
Mean concentric power (W)	4,442.4 ± 716.4	4,350.9 ± 729.8	0.4	0.010
Mean eccentric rate of force development ($N \cdot s^{-1}$)	1,512.5 ± 249.1	1,461.2 ± 252.7	0.6	<0.001
Relative mean concentric force ($N \cdot kg^{-1}$)	19.74 ± 1.66	19.68 ± 1.73	0.1	0.548
Relative net concentric impulse ($Ns \cdot kg^{-1}$)	3.38 ± 0.30	3.32 ± 0.29	0.6	<0.001

Manipulation Check. Manipulation check surveys were collected after each set of jumps, a total of four per subject. These surveys were coded using a method described by Porter et al. (66). The primary investigator sorted each survey into one of four categories: *internal only*, *external only*, *mixed* or *other*. To be coded as *internal* or *external only*, the response had to resemble or consist of phrasing mentioned in the instruction set with no mention of the opposing type. The following are examples of *internal* and *external only* responses, respectively: internal - "…extending my knees and hips as explosively as possible;" external - "…pushing off the ground as hard as possible." To be coded as *mixed* the response had to contain both internal and external instructions, e.g. "…I focused on pushing away from the ground explosively while getting my hips more extended in the jump." Finally, responses were coded as *other* if they consisted of information not classifiable as internal/external or reported no particular focus, e.g., "…this time I focused on absolutely nothing. I was just trying to clear my head and not overthink anything." When comparing responses in the two conditions, more subjects reported the correct (desired) focus in the internal focus condition, than in the external focus condition (see Table 2). As a result, more subjects reported a *mixed* or *other* focus in the external instruction condition.

In addition, we also calculated the number of times subjects switched their focus within a particular condition. For example, if they reported an *internal only* focus after the first set of four jumps, but a *mixed* focus after the second set, they were considered to have switched their focus. Roughly the same number of subjects switched their focus in the internal and external conditions. Three subjects switched focus in both the internal and external conditions and 17 subjects were perfect in terms of reporting the correct focus of attention for the specific condition.

Table 2: Descriptive results of the manipulation check.

Focus Code	External Condition	Internal Condition
Internal Only	3.5%	73.8%
External Only	66.6%	7.2%
Mixed	22.6%	10.7%
Other	7.3%	8.3%
Switched Focus	25%	30%

Internal only = focus pertaining only to the internal focus instructions, *external only* = focus pertaining only to the external focus condition, *mixed* = focus pertaining to both internal and external instructions, *other* = focus not pertaining to either internal or external instructions. Switched column indicates how frequently participants switched their focus within the same condition.

Discussion

The hypothesis that externally focusing attention increases CMJ height and related variables is supported by the results of this experiment. Several studies have proposed mechanisms to explain these observed increases in jump height. Such mechanisms include but are not limited to: increased maximal force production, greater intra and inter-muscular coordination, reduced co-contraction, enhanced neural adaptation and muscular recruitment (101). Given the limited scope and methods of our study, this discussion will focus on the possible contributions of force, power and velocity variables to increased jump height.

The primary finding was that jump trials instructed with an external focus demonstrated significantly ($p < 0.05$) greater JH, PV, MCP, MCV, ECC-RFD and rCON impulse as compared to jumps performed with the internal focus. The variables of PF, PP, MCF and rCON force were not significantly different, but demonstrated positive effect sizes.

Of particular interest is the significant increase in ECC-RFD. Most studies analyze concentric or peak RFD as predictors of vertical jump performance (47). However, Laffaye & Wagner (36) argue that ECC-RFD is a better predictor of vertical jump performance because it can illustrate the elasticity of the muscle-tendon structures during the stretch shortening cycle. They also propose that an increase in ECC-RFD can indicate faster muscle recruitment and greater force production during the eccentric phase (36). Even though these inferences are based on studies with an arm swing, it is worth mentioning that our study still found a significant increase.

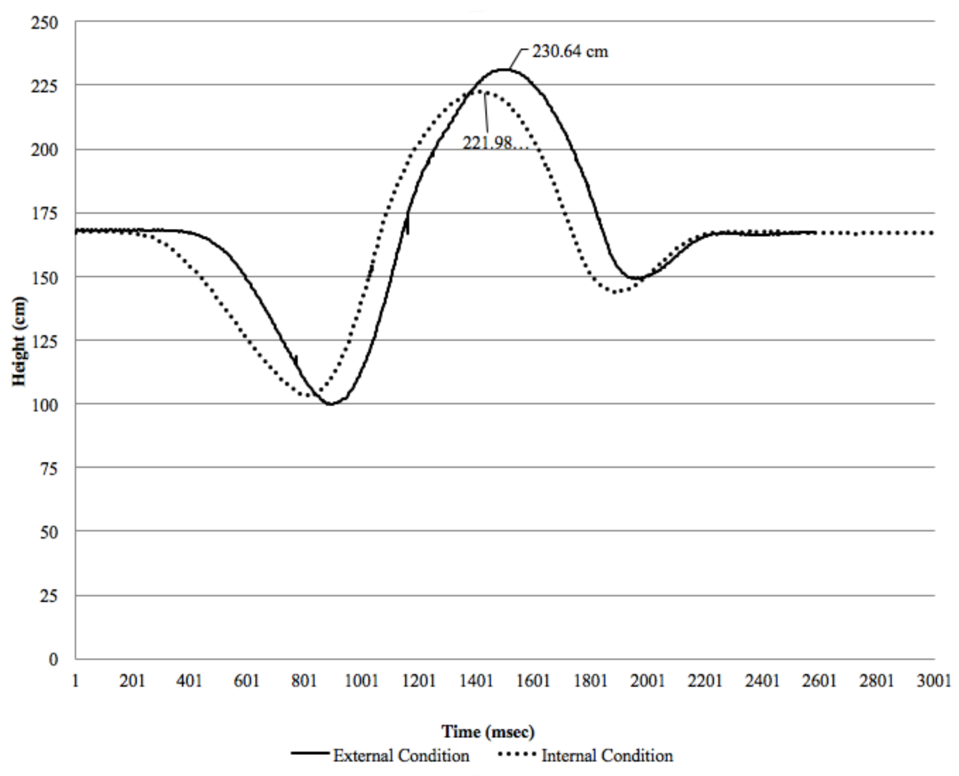

Figure 2: Example of position graph comparing internal vs. external focus conditions for a representative subject.

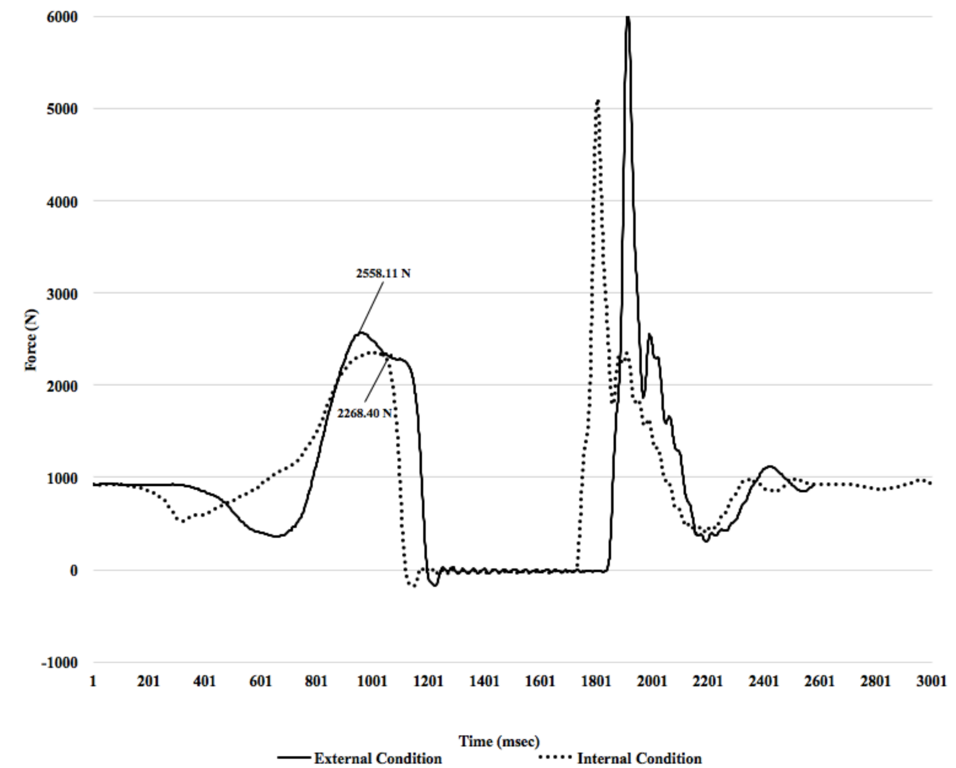

Figure 3: Example of force graph comparing internal vs. external focus conditions for a representative subject.

In the same study, Laffaye & Wagner (36) classified certain athletes based on values of ECC-RFD, rCON and rCON Impulse. They described baseball players as having an "explosive profile," characterized by high values of ECC-RFD and rCON. Our population of baseball players matched this profile with regard to high values of ECC-RFD, but not rCON.

It is also interesting to note the significant increase in relative net concentric impulse (rCON Impulse). Greater concentric impulse suggests an increase in the length of the concentric phase, the force, or both (19). However, relative net concentric impulse is a strong predictor of jump height regardless of countermovement depth (46). The same cannot be said for peak power and peak force, which depend heavily on the depth of the squat (46). One particular study observed that individuals with larger vertical impulses displayed simultaneous increases in vertical velocity at take-off and greater jump heights (24).

Take-off velocity is also chiefly important in vertical jump performance as the final height of the body's center of gravity is dependent on both vertical velocity and position at take-off (24). In addition, all three major equations for determining jump height (work-energy, flight time, and impulse-momentum) require take-off velocity to determine jump height (39). In our study, peak velocity (PV) is largely synonymous with take-off velocity. Therefore, the concurrent increases we noted in PV and rCON Impulse are consistent with the literature. Our results also indicate a relationship between PV and mean concentric velocity (MCV). An increase in PV, which occurs in the concentric phase, seems to parallel the increase in mean velocity of that phase.

With considerable differences in both peak and mean concentric velocity, it seems surprising that peak power (PP) was not significant. This result was especially remarkable considering claims that PP is one of (if not the most) influential variable(s) in predicting jump height and vertical jump performance (2, 31). Comparing our study to those that made these claims, differences in significance may be attributed to our method of measuring PP. Most studies restrict the calculation of peak power to the concentric phase, yet we measured PP over the entire contact phase. Depending on technique, PP occurred in the concentric phase for some, and the eccentric for others. Therefore, the PP measurement captured the data in a way consistent with other studies only when the individual happened to exhibit PP in the concentric phase. For comparison purposes, future studies should limit PP measurements to the concentric phase.

Similar to many attentional focus studies, our results showed an increase in performance within the external condition (65, 81, 93). The prevailing theory for these results, the

Constrained Action Hypothesis, suggests that the brain defaults to subconscious self-organization when performing a well-practiced skill (like the CMJ). In other words, it subconsciously coordinates motor patterns in the most efficient way possible. When we redirect focus to specific body parts (e.g. extend the hips and knees) instead of the movement as a whole (e.g. push away from the ground), the individual tries to control or adjust the skill in their conscious mind. Therefore, the internal focus interferes with the normal motor process as the individual tries to incorporate the instruction into their current movement pattern (90).

The CAH may also explain our manipulation check results. As seen in *Table 2*, individuals in the internal focus condition demonstrated better recall of the instruction set. Their enhanced recall may be the result of having to process the internal instruction in their conscious mind. Alternatively, the internal instruction may have sounded different or more complex, causing them to think about it longer and store it in the working memory. Either way, this difference in recall may signify a cause for differential performance in the two conditions.

The CAH may also explain the connection between improved performance in the external condition and the skill level of the participants. In our population, all subjects were well practiced or 'experts' in the CMJ. Based on the CAH, elite performers should be more successful when not consciously thinking about bodily movements. Singer et al. (74) concur that trained performers tend to be more successful when adopting "non-awareness" strategies. Expertise also relates to the athlete's previous experience with coaching. At the Division I level, most athletes receive frequent coaching and diverse cues. This exposure to varied instructions may explain their ability pick up on nuances in the instruction and apply it to their performance. Had our study used novice athletes, it is possible that any kind of instruction would have been disruptive because these individuals are not accustomed to manipulating movement based on coaching.

Our study was limited in that we did not measure downward (dip) displacement during the countermovement. Countermovement depth may be a key variable given the relationship between depth and power or force, as well the ability for joint angles to explain differences in technique that leads to variance in CMJ performance (81). Another limitation of our study is that subjects experienced both conditions within a single experimental session. It is possible that subjects in the second condition had the advantage or disadvantage of still holding the opposing instructions in their conscious mind. Finally, this study did not include a neutral focus, so it is not possible to determine if performance decreased with the internal focus condition, or if it was just worse than the external condition.

Future studies should continue evaluating the effect of attentional focus instructions on movement efficiency. Several studies have used EMG to measure muscular activity in subjects with an external or internal focus. In one vertical jump study, the external focus condition not only produced greater jump heights, but also demonstrated simultaneously reduced muscle activity (98). These results are significant because they indicate that the external focus can improve performance while lowering the neural and muscular cost to the athlete.

Unfortunately, none of the existing studies have analyzed EMG with an elite population. Seeing as trained performers are already efficient in certain movement patterns, it would be interesting to see if attentional focus instructions can have the same affect on muscular efficiency.

Practical Application

The present study demonstrates that attentional focus instructions significantly influence several CMJ jump variables (including jump height). The finding that instructions can alter efficiency and performance of a skill indicate that they need to be designed and applied to suit the context. According to the literature and present study, if coaches want to optimize a specific performance metric (jump height, velocity, power, and rate of force development), they should use external focus of attention instructions.

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Appendix

The Effect of External vs. Internal Focus of Attention Instructions on Selected Countermovement Jump Variables

Informed Consent

INTRODUCTION

The Department of Health, Sport and Exercise Sciences at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. This study will be conducted in the Jayhawk Athletic Performance Laboratory (Robinson Center 207). Sports performance monitoring equipment will be used to analyze vertical jump performance. The following information is provided to help you make an informed decision on whether or not to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this study is to analyze differences in countermovement (vertical) jump (CMJ) performance when individuals are instructed to focus their attention on different aspects of the movement.

A countermovement jump is a movement in which the jumper starts from an upright standing position, makes a preliminary downward movement by flexing at the knees and hips, then immediately and vigorously extends the knees and hips again to jump vertically up off the ground (Linthorne, 2001). We will compare jump height, power, velocity, force, eccentric rate of force development, concentric force and impulse (from the CMJ) given opposing instructions.

Eccentric rate of force development is the average force produced during the descent of the jump. Concentric force is the average force developed during the ascent of the jump. Impulse is the length of time the force is applied (force x time), or the time spent on the ground during the jump. It is hypothesized that instructing athletes with an external focus will elicit different values for certain variables compared to the internal focus.

PROCEDURES

A time-line of the testing procedures and an overview of the testing sequence are below. You will be asked to visit the Jayhawk Athletic Performance Laboratory (Robinson Center, Rm. 207) for one experimental session.

Experimental Session (45 minutes): Upon arrival at the laboratory you will be debriefed regarding the study. Then you will be asked to complete both a consent form and a health exercise status questionnaire. Anthropometric data will be collected (age, height, weight, etc.).

You will undergo a standardized ~10-minute warm-up consisting of both general and jump specific warm-up routines. You will then stand on a force plate holding a stretching stick (132 cm length, 3.8 cm diameter, weighing ~1 kg) across your shoulders. A coach will give you a set of verbal instructions and you will perform 2 sets of 4 maximal countermovement jumps (3 min. rest between sets). During the rest between sets, the coach will give you a one question survey to complete. You will then be given a different set of instructions and repeat the same jump and survey protocol.

RISKS

As with all types of physical activity, the countermovement (vertical) jump protocol in this study carries a low risk of injury or harm to the musculoskeletal system. A medical history questionnaire will also be required prior to participation, which will include personal and private information.

BENEFITS

You will be given a chance to learn significant insight regarding sport performance technology data collection, and the importance of proper instruction. Following completion of the study, you will be allowed to observe how your vertical jump results compare to the rest of the group.

PAYMENT TO PARTICIPANTS

There will be no compensation for participation in this study.

PARTICIPANT CONFIDENTIALITY

Confidentiality will be maintained by coding all information with individual identification numbers. The master list will be kept in a locked file cabinet in an Anderson Strength Center office (Rm. 1687). By signing this form, you give permission for the use and disclosure of your information for the disclosure of this study. Only qualified research personnel at the Jayhawk Athletic Performance Laboratory and University of Kansas Institutional Review Board (IRB) will have access to the database containing study information. Your identifiable information will NOT be shared unless (a) it is required by law or university policy, or (b) you give written permission. All study data entered into statistical analyses and publications reports will refer to group mean data. No individual or group other than the research team will be given information, unless specifically requested by the IRB. Jayhawk Athletic Performance Laboratory employees will only be granted access to the performance data collected. All electronic data will be kept on password protected computers. All data will be stored for a minimum of three years or until papers and abstracts can no longer be published off the data, at which point this data will be destroyed. Only abstracts and papers without identifying information will be transmitted through email with the study participation and research personnel that are involved with the project.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form, you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

INSTITUTIONAL DISCLAIMER STATEMENT

In the event of injury, the Kansas Tort Claims Act provides for compensation if it can be demonstrated that the injury was caused by the negligent or wrongful act or omission of the state employee acting within the scope of his/her employment.

INFORMATION TO BE COLLECTED

To perform in this study, researchers will collect information about you. This information will be obtained from the medical questionnaire form. Your name and personal information will not be associated in any way with the information collected about you or with the research findings from this study. The researchers will use a numbering system in which you will be randomly assigned to any number between 1 and 48 as your study identification. All screen forms will only contain the subject number that is assigned to you. All the data collected will be stored on a password protected computer in a locked office in the Anderson Strength Center (Rm. 1687).

REFUSAL TO SIGN THIS CONSENT AND AUTHORIZATION

You are not required to sign this consent form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign the informed consent form, you cannot participate in the study. You have the option to cancel your authorization at any time.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose further information collected about you, in writing, at any time, by sending your written request to: Andrew C. Fry, 1301 Sunnyside Avenue 146C, Robinson Center, Lawrence, KS 66045.

If you cancel permission to use your information, the researchers will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s) listed at the end of this consent form.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or (785) 864-7385, write the Human Research Protection Program (HRPP), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ _____________________

Type/Print Participant's Name Date

____

Participant's Signature

Researcher Contact Information:

Ali Kershner, MSE
Principal Investigator
KU Sport Performance
1651 Naismith Dr.
University of Kansas
Lawrence, KS 66045
650-776-9202

Andrew C. Fry, PhD
Faculty Supervisor
Health, Sport and Exercise Sciences
101A Robinson Center
University of Kansas
Lawrence, KS 66045
785-864-4656

Manipulation Check

Instruction Set A (B) Set 1 (2)

Please answer the following question:

1. What were you focusing on during the previous four jumps? Be as specific as possible.

☐ Check this box if you did not focus on anything in particular

________________________________ ________________________________

Type/Print Participant's Name Date

____

Participant's Signature

Pre Exercise Testing Health & Exercise

Questionnaire

Name ____ Date______________

Home Address ____

Phone Number _______________________ Email ________________________

Birthday (mm/dd/yy)____/_____/_____

Person to contact in case of emergency____

Emergency Contact Phone ______________________

Personal Physician ____________________________ Physician's Phone_______________

Gender ________ Age ______(yrs) Height ______(ft)______(in) Weight______(lbs)

Does the above weight indicate: a gain____ a loss____ no change____ in the past year?
If a change, how many pounds?___________(lbs)

A. JOINT-MUSCLE STATUS (Check areas where you currently have problems)

Joint Areas
( )Wrists
( )Elbows
( )Shoulders
( ) Upper Spine & Neck
( )Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( )Feet
( )Other_______________________
( )Other_____________________

Muscle Areas
( )Arms
( )Shoulders
( )Chest
( ) Upper Back & Neck
( )Abdominal Regions
( ) Lower Back
( )Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet

B. HEALTH STATUS (Check if you currently have any of the following conditions)

( )High Blood Pressure
( ) Heart Disease or Dysfunction
( )Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( )Arthritis or Gout
( ) Edema
( )Epilepsy

( )Acute Infection
( )Diabetes or Blood Sugar Level Abnormality
( )Anemia
( )Hernias
( ) Thyroid Dysfunction
( )Pancreas Dysfunction
( ) Liver Dysfunction

( ) Multiply Sclerosis
( )High Blood Cholesterol or
( )Triglyceride Levels
( )Allergic reactions to rubbing alcohol
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

** NOTE: If any of these conditions are checked, then a physician's health clearance will required.*

C. PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical examination______________________________

Physical problems noted at that time____

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES __________NO

If YES, what limitations were recommended?__________________________________
____

D. CURRENT MEDICATION USAGE (List the drug name, the condition being managed, and the length of time used)

MEDICATION	CONDITION	LENGTH OF USAGE
_____________________	______________________________	___________________
_____________________	______________________________	___________________

E. PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. Check if you have recently experienced any of the following during or soon after physical activity (PA); or during sedentary periods (SED))

PA SED
( ) ( ) Chest Pain
( ) ( ) Heart Palpitations
( ) ( ) Unusually Rapid Breathing
( ) ( ) Overheating
( ) ( ) Muscle Cramping
( ) ( ) Muscle Pain
( ) ( ) Joint Pain
( ) ( ) Other________________________

PA SED
( ) ( ) Nausea
( ) ( ) Light Headedness
( ) ( ) Loss of Consciousness
( ) ( ) Loss of Balance
( ) ( ) Loss of Coordination
( ) ( ) Extreme Weakness
( ) ( ) Numbness
( ) ( ) Mental Confusion

F. FAMILY HISTORY (Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

G. EXERCISE STATUS

Do you regularly engage in aerobic forms of exercise (i.e., jogging, cycling, walking, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

What is your fastest 5 km time? ______________

What is your fasted 10 km time? _____________

What is your fasted mile time? _______________

What is your fasted times at other distances not listed? ____________________________________

Do you regularly lift weights? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours

What is your back squat 1 repetition maximum (RM)? _____________

What is your deadlift 1 RM? ____________

What is your power clean 1 RM? ____________

What are your other 1 RMs that are not listed? ____

Do you regularly play recreational sports (i.e., basketball, racquetball, volleyball, etc.)? YES NO

How long have you engaged in this form of exercise? ______ years ______ months

How many hours per week do you spend for this type of exercise? _______ hours