CHANGING KICKING PATTERN: EFFECTS OF FOCUS OF ATTENTION AND A CONSTRAINTS APPROACH

by

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AND A CONSTRAINTS APPROACH

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ABSTRACT

The purpose of this study was to determine the effects of instruction and scaling up on a constraint (velocity of kick) on changes in kicking pattern. Twelve adult female novice kickers (ages 18-22 years) were randomly placed into one of four practice conditions: (a) control group with no instruction, (b) scale up on a constraint with no instruction, (c) instruction with internal focus on position of limb segments, and (d) instruction with external focus on goal of movement. Participants in each condition were required to practice kicking with the dominant leg twice per week for 2 weeks (4 sessions). Practice consisted of 12 kicks per session. Participants in the constraint condition and instruction conditions were reminded to increase velocity or focus on instruction every four trials. A Condition X Session MANOVA for motor pattern change indicated no significant qualitative differences in motor pattern. Significant absolute main effects for shank lag by condition and thigh lag by session along with a significant interaction did not indicate differences in motor pattern. It was concluded that there were no qualitative differences (pattern changes) in kicking pattern across conditions.

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INTRODUCTION

The idea that "practice makes perfect" is a well-known saying in the realm of learning physical skills. Motor learning researchers have determined that it is not only practice that improves performance, but also how one practices that may be equally important (Magill, 2007). The practice makes perfect concept is oftentimes referred to as the traditional form of instruction. That is, the instructor breaks down complex activities into simpler parts for the performer who practices each part until they have mastered the coordination dynamics. Once the coordination dynamics are mastered for each part of the skill, the instructor allows the individual to put the parts together and practice the entire skill. However, recent evidence indicates that it is not just how much the performer practices but also what information performers should focus on during practice that is equally important to final performance. In fact, the learner's focus of attention may be the most important consideration when learning a new skill or developing an effective motor pattern (Wulf, 2007).

Attentional Focus

Evidence indicates that the focus of an individual while performing a motor skill has an impact on the learning and retention of the skill (Wulf, McNevin, Fuchs, Ritter, & Toole, 2000; Wulf, McNevin, & Shea, 2001; Wulf & Prinz, 2001; Wulf, Shea, and Park, 2001). An internal focus approach is defined as an approach that focuses on the participant's own body movements, whilst an external focus approach is defined as an approach that focuses on the effects of those movements (Wulf, 2010). Directions that specify the body segments and their appropriate movements during the pattern are internally focused. External focus, in contrast, requires the skill learner to focus on the outcome of the movement rather than the movement pattern itself. Motor learning researchers have examined external and internal focus of attention for a variety of skills such as a volleyball serve (Wulf, 2002); a ski simulator task (Wulf, Hob, & Prinz, 1998); a stabilometer (McNevin, Shea, & Wulf, 2003); kicking (Zachry, 2005; Wulf, McConnel, Gartner, and Schwarz, 2002); and while training with weights (Vance, Wulf, Tollner, McNevin, & Mercer, 2004). In every instance, it has been concluded that an external focus is more effective for performance and retention of skills.

Wulf, McConnel, Gartner, and Schwarz (2002) examined the effect of internal and external focus on the performance of a sport skill. They utilized forty-eight novice and skilled volleyball players to perform a volleyball serve in a regular indoor-volleyball court. A 3x3-target area was placed in the center of the opponent side of the court and marked with tape to enhance target visibility. The 3x3 target was surrounded by a 4x4 meter and 5x5 meter area. Accuracy points were awarded based on how close to the center of the target area was hit by the serve. Zero points were awarded if the ball was hit out of bounds or hit the net, 4 points were awarded if the ball made it to the 3x3 target area, 3 points were awarded if the ball made it to the 4x4 target area, 2 points were awarded if the ball made it in the 5x5 target area, and 1 point was awarded if the ball made it in the opponents court but outside of the target areas. In addition to accuracy, the form utilized by each participant was subjectively determined by a volleyball expert. Each participant was provided with basic techniques of a volleyball serve and the serve was demonstrated by an expert server. Those in the internal focus group were told to toss the ball high in front of the hitting arm, snap the wrist while hitting the ball to produce forward rotation, arch their back and accelerate first the shoulder, then the upper arm, then the lower arm, and finally your hand. The external focus group participants were told to toss the ball straight up, imagine holding a ball in your hand and cupping the ball with it to produce forward rotation of the ball, shortly before hitting the ball, shift your weight toward the target, and hit the ball is if using a whip, like a horseman driving horses. Individuals were given feedback after every five trials. Participants performed two sessions of 25 practice trials separated by one week. A retention session followed practice one week later consisting of 15 trials. There was no augmented information or instruction given during the retention session. Results indicated that during practice advanced players showed more improvement than novice players, and that external-focus feedback was more effective in performance improvement than internal-focus feedback regardless of skill level. Movement form improved generally across practice, but advanced players and the external-focus group showed more improvement than novice and internal-focus group participants. During the retention test, performance was better in the advanced and external focus conditions. There was no significant change in form for internal and external focus feedback participants in the retention session. The study concluded that external-focus feedback has a significant positive effect on performance.

Wulf, Hob, and Prinz (1998) examined the differential effects of internal and external focus on ski-simulator performance. Thirty-three individuals were required to move from side to side on a ski-simulator with as large an amplitude as possible. The ski-simulator was a moveable-wheeled platform comprised of two codependent footplates, atop two parallel metal rails. The shape of the rails allowed for sideways movement of the platform. Individuals in the internal focus group were required to exert force on the outer foot while moving on the simulator. The external focus group was directed to exert force on the outer wheel rather than focus on the body segment. The control group was not given any augmented information. Participants performed twenty-two 90-second trials for two practice days and twenty-two 90-second trials on a separate retention day. Results indicated greater improvement in the external focus group than the internal focus group. The external focus group also scored better on the retention test, with no difference between the internal focus and control group. The study concluded that it is best to direct attention towards the apparatus rather than the performer's body.

McNevin, Shea, and Wulf (2003) examined individuals using a stabilometer to assess the effects of attentional focus on balance. The stabilometer is a platform that tilts to the left or right, and the goal is for the participant to stand on the platform and keep it in a horizontal position. Markers are placed on the platform, often directly in front of the performer's feet or a short distance from the feet. The markers serve as focal points for participants in the external focus conditions. Participants in the internal focus condition are instructed to focus on keeping their feet horizontal. Participants in the external focus condition are instructed to focus on keeping the stabilometer horizontal. It is important to note that participants were instructed to not look at their feet or the markers to avoid influences of visual information. Participants were instructed to look straight ahead. Participants instructed to adopt an external focus generally demonstrate more effective learning than those provided with internal focus.

Vance, Wulf, Tollner, McNevin, and Mercer (2004) examined electromyography (EMG) to indicate changes in neuromuscular activity associated with internal and external focus of attention. Participants were asked to perform two sets of 10 repetitions under each focus of attention. Individuals in the internal focus condition were asked to focus on their biceps muscle during the task. Individuals in the external focus condition were asked to focus on the curl bar. Participants were instructed to look straight ahead and focus their concentration on the curl bar or the biceps muscle. Participants were not instructed regarding the speed of execution. An electrogoniometer measured elbow flexion and extension angle. Surface mounted Ag/AgCL electrodes were used to measure electric activities for the biceps and triceps. Participants performed unweighted, maximal-effort isometric contraction (MIC) of the elbow flexors at 90 degrees of elbow flexion and full elbow extension before beginning the curl task. EMG magnitude was determined by a percentage of MIC. Participants performed four sets of curls counter-balanced by internal or external focus. Results indicated that movements were generally executed faster (higher angular velocity) with external focus. Average EMG activity was not different between both groups but it generally increased across repetition. Integrated EMG increased across repetitions but was smaller in external focus condition than in the internal focus condition. Researchers concluded that external focus improved movement automaticity, economy in the movement production, and required less initial motor unit recruitment. Movement speed could account for the difference in results, and a second experiment was completed to control for velocity differences. In the second experiment, participants were instructed to synchronize the time of their biceps curl so that the end of each upward and downward movement coincides with one click on a metronome. Results indicated that integrated EMG activity was less for the external focus condition. Results from both experiments suggest that focusing on movement effect may result in better coordination of agonist and antagonist muscles for improved movement economy.

Two studies have examined changes in the performance of kicking tasks relative to focus of attention. Zachry (2005) examined the effectiveness of internal versus external focus instructions for American football field goal kicking. Participants who had never kicked a football before were given a demonstration and general instructions about the technique. They then performed kicks into a net that was hung from the ceiling at a distance of 5m. A 10x10 inch target was marked in the center of the net, with the goal to kick the ball so that it hit the square target. Participants in the internal focus condition were instructed to focus on the part of the foot that would be contacting the ball. Participants in the external focus condition were instructed to focus on the part of the ball that they would be contacting with their foot. Participants in the control condition were given no additional instructions. Results identified that kicking accuracy was significantly higher in the external focus condition. The percentage of successful external focus condition kicks was 80%; internal focus condition was at 68%, while the control was at 66%.

Wulf, McConnel, Gartner, and Schwarz (2002) completed a study to examine any possible interaction of feedback frequency and attentional focus. They used fifty-two participants required to perform a lofted soccer pass. Participants were instructed to approach the ball from an angle of approximately 45 degrees, perform a relatively long last step, and position the non-kicking foot to the side of the ball. Individuals were given a demonstration of kicking the ball at a target placed 15 meters away from the participants. Points were awarded based on how close the individual was to the center of the target. Participants were divided into four groups according to focus (internal and external) and feedback frequency (100% and 33%). Participants performed 30 practice trials followed by 10 trials for a retention test separated by one week from last practice trial where no feedback was provided. The internal focus group was told to position your foot below the ball's midline to lift the ball, position your body weight and non-kicking foot behind the ball, lock your ankle down and use the instep to strike the ball, keep your knee bent as you swing your leg back and straighten your knee before contact, and strike the ball with the swing of the leg being as long as possible. The external-focus group was told to strike the ball below its midline to lift it (kick underneath it), be behind the ball not over it and lean back, stroke the ball toward the target as if passing to another player, use a long lever action like the swing of a golf club before contact with the ball, and strike the ball creating a pendulum-like motion with as long a duration as possible. Results indicated that for practice trials all groups showed an increase in accuracy of passes. However, the external-focus feedback group was more accurate than the internal-focus feedback group. For internal focus conditions, the 33% feedback group was more accurate than the 100% feedback group. For external focus conditions, the 100% feedback group was more accurate than 33% feedback group. The retention test indicated a general increase in accuracy across trials. It was concluded that external focus of attention improves performance and learning if frequency of feedback is at 100%. In addition, frequency of feedback has a differential effect depending on the focus of the performer.

Constrained Action Hypothesis

The explanation for why external focus results in better performance than internal focus is the constrained action hypothesis. The constrained action hypothesis (CAH) specifically addresses how motor processes are affected by internal versus external foci of attention (McNevin 2003). Proponents of CAH indicate that internal focus does not allow performers to use more automatic control processes. That is, individuals that focus internally are required to follow specific instructions pertaining to the movement of their limb segments. Consequently, individuals intervene with control processes that would otherwise allow the motion to proceed naturally (Bell, 2009). On the contrary, external focus requires concentration on the effects of the movement without direction to individual body segments. According to Wulf (2007), external focus allows quick and reflexive processes to control the movement, which results in the desired outcome becoming almost a by-product. It allows the learner freedom of movement pattern and for the pattern to develop in a “natural coordinated state”.

Dynamic Systems Perspective

An alternative explanation to the CAH explanation is a dynamic systems perspective. Dynamic systems are complex systems with many interacting components that are subject to change through self-organization. The human body is a dynamic system where coordination is the process of mastering redundant degrees of freedom (Bernstein, 1967). More recent interpretations of Bernstein’s “release on degrees of freedom” indicate that an increase or decrease in mechanical degrees of freedom is dependent on the constraints of the task (Hong & Newell, 2006; Newell & Vaillancourt, 2001). Specific task constraints may have an effect on the coordination of kicking patterns and subsequent use of the open kinetic chain. Performers developing motor skill must compress components of the motor system into workable units through joint linkages or synergies called coordinative structures. As the performer progresses in skill development, the synergies change allowing new motor patterns to emerge. Constraints and order parameters play a major role in determining new patterns of movement. Order parameters are generally mechanical principles that the system takes advantage of when forming more efficient patterns. For example, Thelen (1989) determined that the order parameter for infant walking was the pendular action of the legs. That is, as infants become more proficient walkers their legs increase their pendular activity resulting in more efficient production of forces and increased velocity of stride. Southard (2002) determined that the order parameter for throwing was the open kinetic chain. As young throwers increased in throwing efficiency they were able to capitalize on the transfer of angular momentum to increase throwing velocity. The increase in velocity resulting from the transfer of angular momentum was realized because the arm acted as an open kinetic chain. The performer is not dictating the use of the order parameter, rather, the motor system naturally takes advantage of this mechanical principle making the change in pattern self-organizing.

Constraints set boundaries on the system and guide the system toward new stable attractors or motor patterns. Constraints are called non-essential variables and arise from the individual, the environment, or the goal of the movement. An individual constraint might be the physical characteristics of the performer. An environmental constraint could be the running surface for a cross country athlete. A goal constraint could simply be attempting to increase the velocity of performance such as throwing or kicking a ball. Constraints are termed non-essential because a constraint has no information for the performer concerning the pattern of movement itself. Constraints therefore, would be the ultimate focus of attention relative to the CAH. That is, constraints would maximize the ability of the performer to “naturally” coordinate a movement.

Clark and Philips (1993) used the dynamic systems approach to explain the development of new walking patterns in infants. The researchers tested the stability of walking patterns by attaching a weight to the ankle on infants and adults. For infants, the weight attached was equivalent to 5% of their body weight. For adults, the weight attached was equivalent to 7.5% of their body weight. The study found that by scaling up on a control parameter, infants exhibited adult-like coordinative patterns. That is, the thigh acted as a forcing oscillator that drove ahead of the shank and then reversed its direction which left the shank to swing through ahead of the thigh before heel strike. Infants had a different thigh-shank coordinative pattern when the weight was not attached. The study suggested that an adult like phasing relationship between the thigh and shank emerges developmentally when the infant's thigh can more faster than the shank.

Southard (2011) compared the constraints approach with focus of attention. He required inexperienced throwers to focus internally, externally, or on a known goal constraint for throwing (velocity of throw). The directions for the internal focus group were to first rotate their trunk, followed by their upper arm, then the forearm, and finally the hand. The external group was instructed to use their body like a whip when throwing the ball. The constraints group was instructed to scale up on a goal constraint. That is, throw the ball with as much velocity as possible. Southard found that scaling up on the constraint with no other instruction improved the throwing pattern and throwing accuracy better than either external focus or internal focus. He operationalized throwing improvement by assessing the degree to which the performer utilized the order parameter—the open kinetic chain. His data also indicated that the external focus resulted in more efficient throwing patterns and performance than the internal focus group. Retention data one week following practice indicated that the effects of the constraint approach were not temporary. That is, the patterns gained as a result of scaling up on the constraint of velocity were maintained at the retention session. Southard's study is the only study that systematically examined a change in motor pattern as well as examining a change in performance. The dependent measures for previous studies examining focus of attention have been limited primarily to performance variables. There are no studies that have examined the effects of focus of attention and a constraints approach on the fundamental skill of kicking.

Purpose of Study

The purpose of this study was to compare the effect of an internal focus of attention, external focus of attention, and scaling up a constraint (velocity of the kick) on changes in kicking pattern. It is hypothesized that scaling up on a constraint will result in a more effective kick pattern than internal focus and external focus of attention.

Significance of Study

This study should help kinesiologists to understand the most effective way to instigate motor pattern change while emphasizing performance in kicking. This information should provide coaches, performers, and movement based professionals with some strategies for learning and improving motor skills.

METHODS

Participants

Twelve female university students (18-22 yrs) signed a university approved consent form prior to participation in the study. All participants were right-leg dominant and had not experienced an injury that would prohibit the development of their kicking pattern. Participants were determined to have an inefficient kicking pattern with little or no organized kicking experience. Inexperienced was defined as never played on an organized soccer team. Inefficient was defined as incomplete use of the order parameter—the open kinetic chain.

Apparatus

Two-dimensional kinematic data was collected with a Vicon Peak Motus Motion Analysis System (Vicon Motus Systems Inc., Centennial, CO) in the motor behavior laboratory at Texas Christian University. One digital camera was mounted on a tripod and placed 5 meters away from the participant and perpendicular to the principle axis of motion (x axis). The camera was mounted at 1.9 meters from the floor. The camera was positioned to record the participant's entire kicking pattern from movement forward to follow through following contact with the ball. The system was calibrated with a 16-point three-dimensional frame prior to data collection. A field rate of 60 Hz was used with a shutter speed of 1/1000 to allow for a clear view of each segment of the ballistic kicking motion. Reflective markers were placed on the twelfth rib, greater trochanter of the femur, lateral epicondyle of the femur, lateral malleolus of the fibula, and the small toe. The marker locations allowed for measurement of linear velocities of the trunk, thigh, shank, and foot. Data was prepared for analysis using commercially prepared software (Vicon Motion Analysis Systems Inc.). A jugs radar gun (Radar Sports, Oceanside, NY) was used to provide feedback for participants in the constraints condition concerning the velocity of the kick.

Procedure

Each participant was assessed for kicking efficiency prior to the first data collection session to determine if they were eligible to participate in the study. Kicking efficiency was determined by the degree to which participants used the open kinetic chain. The open kinetic chain is a series of links with a fixed base (such as the trunk) and an open end (such as the leg segments being free to rotate). The open kinetic chain allows for the transfer of velocity from proximal to distal segments. The result is an increase in velocity of the final distal segment in the chain. This transfer is possible if two criteria are met. The first criteria is that the proximal segment be more massive than its distal neighbor. The second is that the distal neighbor lag (in time) behind its proximal neighbor. Effective kickers begin the kicking motion by first rotating the trunk. The angular momentum (Moment of Inertia X Angular Velocity) created by trunk rotation is conserved within the open kinetic chain. When angular momentum is transferred to the next less massive distal segment, the distal segment must increase angular velocity to make up the inertial difference. This transfer of velocity continues down the chain to the last distal segment. The first criteria for this transfer is met as a result of the anatomical structure of the human body. The second criteria (relative position of limb segments) may be used to determine the efficiency of the performer. That is, the more distal segments that experience positive distal lag, the more effective the kicking pattern. Participants exhibiting trunk rotation followed by sequential distal segment lag (efficient kicking pattern) were dismissed from the study. The idea is that kicking efficiency is more likely to improve if starting at a lower level of performance. Qualified participants were randomly assigned to one of four conditions. Conditions were varied by the nature of instruction and augmented feedback concerning performance.

Conditions were determined by the nature of augmented information. For the internal focus condition participants were instructed with statements specific to segment position: (a) first rotate your trunk; (b) followed by your thigh; (c) followed by your shank; and (d) ending with your foot. Participants were provided feedback regarding kicking pattern for whichever segment required improvement after every fourth trial. For the external focus condition participants were instructed with a statement regarding the outcome of the kick: when kicking the ball, use your leg like a whip. Participants in the external focus condition were reminded of their directions after every fourth trial. Participants in the internal focus and external focus conditions kicked at a preferred velocity. Participants in the constraint condition received no instructions regarding how to perform the kicking pattern. The constraint participants were only informed to kick the ball with as much velocity as possible. Participants in the constraint condition were reminded to increase ball velocity after every fourth trial and were given their average velocity for the previous four trials. At each session, participants in the constraint condition were informed of their average velocity for the previous session and told to kick the ball with as much velocity as possible. Velocity is a known constraint that instigates change in motor pattern for activities utilizing the open kinetic chain (Southard, 2010). The control condition received no instruction and no information regarding kicking pattern. The objective of participants in the control condition was to complete 12 kicks per practice session. Control condition participants were given a short break every four trials. The time of the break was similar to the time required to provide feedback to participants in the internal focus, external focus, and velocity conditions. The participants in all conditions were told not to practice between sessions and during the 1-week period following session 4.

Prior to data collection participants in each condition were required to warm up by stretching the muscles of the hip and leg. Following warm-up, the participants kicked a soccer ball (70 cm circumference and 430 g) into a padded mat (8 m wide and 3 m high) 5 meters away. All kicks were allowed with one-step to the ball and kicked with the right foot. Each participant completed four practice sessions (12 kicks per session) according to his or her condition. Before the first practice session, each participant was instructed that the goal of the task was to improve his or her kicking pattern.

One week after the completion of the last practice session, each participant completed a retention session consisting of 12 kicking trials. The purpose of this session was to determine which condition best retained the pattern they had acquired throughout the previous sessions. No instructions or feedback was given to any participants during the retention session. At the completion of the retention session, all participants were asked to respond to questions regarding the difficult of adhering to the instructions. Participants in the external focus and internal focus conditions indicated that the instructions were not difficult to adhere to, however they indicated that the feedback and instruction became repetitive.

Design and Statistical Analyses

A 4 x 4 (Condition x Session) mixed design was used to examine motor pattern change with session as a repeated measure. A two-way multivariate analysis of variance (MANOVA) was performed on the dependent measures of trunk, thigh, shank, and foot lag. The dependent measure of thigh lag was obtained by subtracting the time to peak velocity of the trunk from the time to peak velocity of the thigh. The dependent measure of shank lag was determined by subtracting the time to peak velocity of the thigh from the time to peak velocity of the shank. The dependent measure of foot lag was obtained by subtracting the time to peak velocity of the shank from the time to peak velocity of the foot. Times to peak values were determined from commercially prepared trajectory graphs created by the PEAK system of motion analysis. Significant MANOVA was followed by univariate analysis of variance to determine dependent measures responsible for significance. Scheffe post hoc procedure was used to determine means responsible for significance. A Huyhn Feldt adjustment was made to compensate for sphericity violation. Analysis of the retention session was accomplished by using a one-way MANOVA with condition as the independent measure with dependent measures of trunk, thigh, shank, and foot lag. Significant MANOVA was followed by univariate analysis of variance to determine dependent measures responsible for significance. Scheffe post hoc procedure was used to determine means responsible for significance. A Huyhn Feldt adjustment was made to compensate for sphericity violation. The retention session was analyzed separately to avoid possible intervening variables resulting from the performance of practice conditions. An alpha level of .05 was accepted for all statistical analyses.

For this study, changes in kicking pattern are represented by changes in the temporal position of peak velocity of distal segments relative to their proximal neighbors. Changes from positive to negative values or negative to positive values would represent a qualitative change in the relative motion of the kicking pattern. Changes in the absolute amount of segmental lag within consistent positive or negative values would not represent changes in the relative timing of the kicking motion and therefore were not considered a qualitative pattern change. Participants fully utilized the open kinetic chain when they had a positive distal lag for the thigh, shank, and foot.

RESULTS

Segmental lag

The 4 X 5 (Condition x Session) MANOVA for segmental lag indicated significant main effects for Condition (Hotelling's T= .053), F (9, 2090) =4.09, p<.01; Session (Hotelling's T= 8.23), F (12, 2090) = 8.23, p<.01; with a significant Condition X Session interaction (Hotelling's T= .133), F (36, 700) =2.58, p<.01. Follow-up univariate analysis indicated that shank lag (F (3, 719) =6.33, p<.01) was responsible for the significant main effect by condition. Scheffe post hoc analysis indicated that condition 2 was greater than condition 3 for shank lag. Follow-up ANOVA indicated that Thigh Lag (F (4, 719)-17.10, p<.01) and Shank lag (F (4, 719) =7.59, p<.01) were responsible for the main effect by session. Post hoc analysis indicated that for thigh lag, session 1 was greater than remaining sessions and session 2 was greater than session 4. For shank lag, post hoc analysis indicated that the retention session was greater than session 2. The Huyhn-Feldt epsilon adjustment did not affect significance. See figures 1, 2, and 3 for means representing thigh, thank, and foot lag by session and condition.

Follow-up ANOVA indicated that Thigh Lag (F(12,719)= 2.71, p<.01) and Shank Lag (F(12,719)= 4.65, p<.01) were responsible for the significant Condition X Session interaction. Post hoc analysis indicated that for thigh lag, Session 1 was significantly greater than remaining sessions for all conditions except condition 3 where there was no significant different between session 1 and session 2. Post hoc analysis for shank lag interaction indicated that session 2 was significantly less than remaining sessions for condition 1 but not significantly different by session for conditions 2, 3, and 4. See Figures 1, 2, and 3 for means representing thigh, shank, and foot lag by condition and session.

It is important to note that the significant differences were for absolute values only. The segmental lag data for thigh and shank was positive across conditions and sessions. The lack of relative differences indicates that motor patterns remained constant by condition and session.

DISCUSSION

Results from this study indicate that the hypothesis (scaling up on a constraint will result in a more effective kick pattern than internal and external focus conditions) is not accepted. The data indicated that there were quantitative but not qualitative differences across sessions and conditions. Changes in pattern for this study are recognized by utilization of the open kinetic chain. That is, individuals with a more effective pattern will have positive segmental lag. Less efficient kickers would display negative lag (proximal segment reaches peak velocity before the distal segment) for at least one segment. The data indicates that performers started with positive lag for the thigh and shank segments segments and maintained this positive lag by condition and session. Foot lag was consistently negative with the only positive values occurring at Sessions 1 and 2 for control condition and session 4 for the velocity condition. Despite the differences in quantitative values, none of the differences were significant. In addition, there were no changes in pattern when augmented information was removed one week after practice.

Individuals were included in the study if they indicated that at least one segment displayed negative lag (typically, no thigh lag). It may be that individuals adjusted their body segments exhibiting trunk rotation and segmental lag when placed in front of the cameras for data collection. An alternative explanation could be that individuals developed an effective pattern years before but had not practiced kicking in the meantime. Consequently, they displayed an ineffective pattern at the analysis session but experienced a practice effect for data collection.

The absolute changes represented in the results could represent an improvement in pattern since we do not know what the ideal absolute differences in lag values are for kicking. Southard (2009) found maximized absolute differences within mature throwing patterns which also depend upon the open kinetic chain. The changes in absolute values that were observed, particularly in thigh and shank lag, may be moving towards maximizing absolute values. However there is no data yet that indicates the maximum absolute values for kicking. Southard (2009) demonstrated that wrist lag decreases across age and skill to an optimal value, more lag is not necessarily better in the development of a skill. In relation to kicking, there are likely optimal lag values for the body segments that have not been determined. The movement of the pattern to these optimal values may be a result of practice. Past research has shown this in complex motor skills like driving (Lewis, 1956), and less complex skills such as handwheel cranking (Glencross, 1973) and tracking (Franks & Wilberg, 1984). Southard's study also indicates that an increase in the number of segments or joints experiencing distal lag should not be the only consideration when defining skill level. The participants in the present study demonstrated quantitative changes in thigh and shank lag and were likely moving towards an optimal value that is representative of an effective kicking pattern.

The negative foot lag that was experienced by participants across session and condition is indicative that individuals are not taking maximum advantage of the open kinetic chain. However, this is not necessarily indicative of an ineffective kicking pattern. The demonstration of negative distal foot lag in experienced kickers is representative of the idea that it is not necessary for all segments to experience positive distal lag to exhibit an effective kicking pattern (Southard, 2014). Southard required both experienced and inexperienced kickers to practice kicking for 6 practice sessions (12 kicks per session). He encouraged performers to scale up on the goal constraint of velocity. Southard found that the velocity of the foot at impact is not independent of effective striking mass when attempting a maximum velocity kick. When experienced kickers locked the foot with the shank it increased their effective striking mass. However, increasing striking mass also reduced foot velocity since there was negative lag between the shank and foot. Participants in his study used a quasi-whip like kicking motion where foot velocity was sacrificed to increase effective mass. The sacrifice resulted in an increase in ball velocity following impact. He concluded that reduction in foot velocity was a natural solution adopted by the motor system to increase the velocity of the ball.

If kickers plantar flex the foot and effectively lock it with the shank, this would increase striking mass while reducing the effect of the open kinetic chain and reducing foot velocity. There may be an optimal trade-off to explain the balance between utilization of the open kinetic chain and increase striking mass. Southard (2014) determined that experienced performers utilized an effective mass-ankle velocity tradeoff more than inexperienced performers, which suggests that increasing effective striking mass may be an adaptation to attain an optimal performance. Participants in the present study demonstrated negative distal foot lag. This could indicate they may have been moving towards a pattern to increase effective striking mass. It should be noted that the control condition began with positive foot lag but progressed to negative lag with practice indicating possible movement toward a more effective pattern for increasing ball velocity. The velocity condition was the only other condition exhibiting positive foot lag which appeared only at session 4.

Further studies using a younger population may be beneficial in determining the effect of scaling up on a constraint in developing kicking pattern. Individuals of a younger age who have not had practice or instruction in how to kick would be ideal. Individuals at an age of 18 and older may have a pattern that will not indicate change over a short period of time. A younger population would predictably have a less developed pattern due to less usage of the kicking motion and would thereby be more susceptible to change in the pattern based on focus of attention and a constraint.

FIGURES

Figure 1

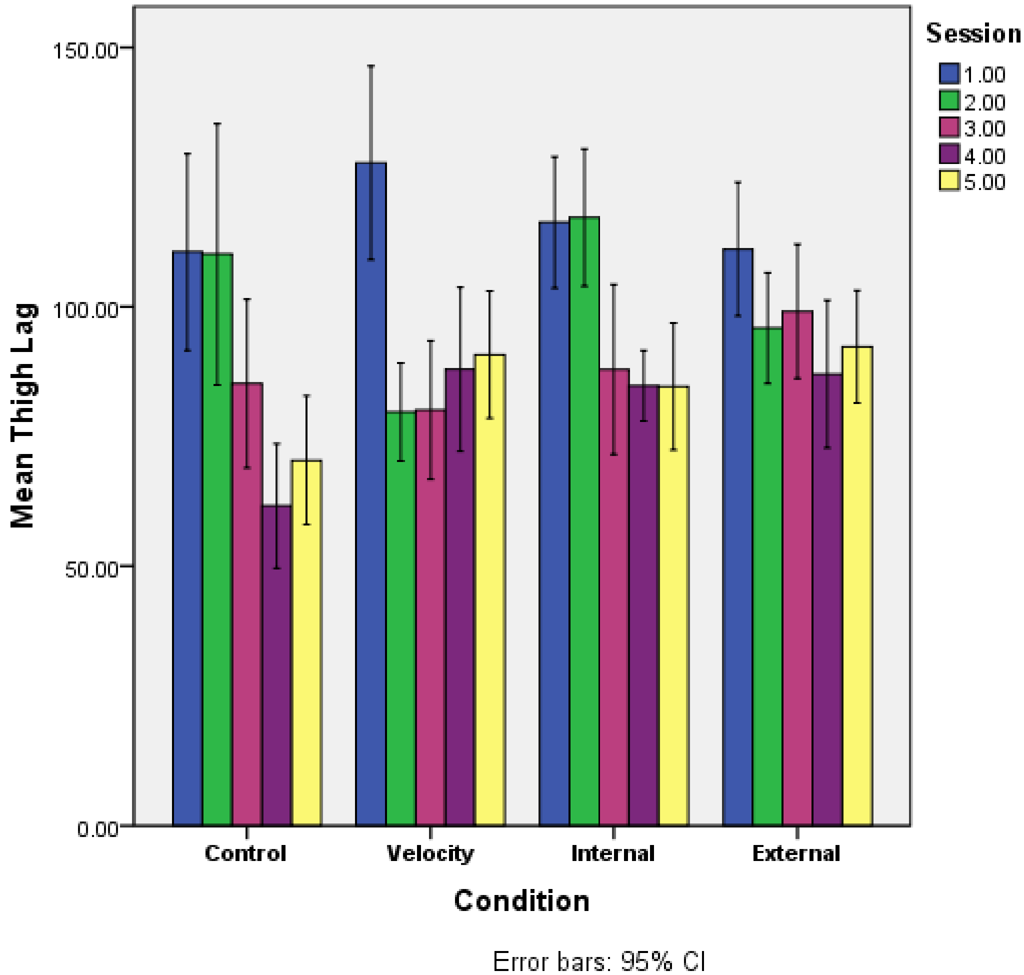

Figure 1.

Figure 2

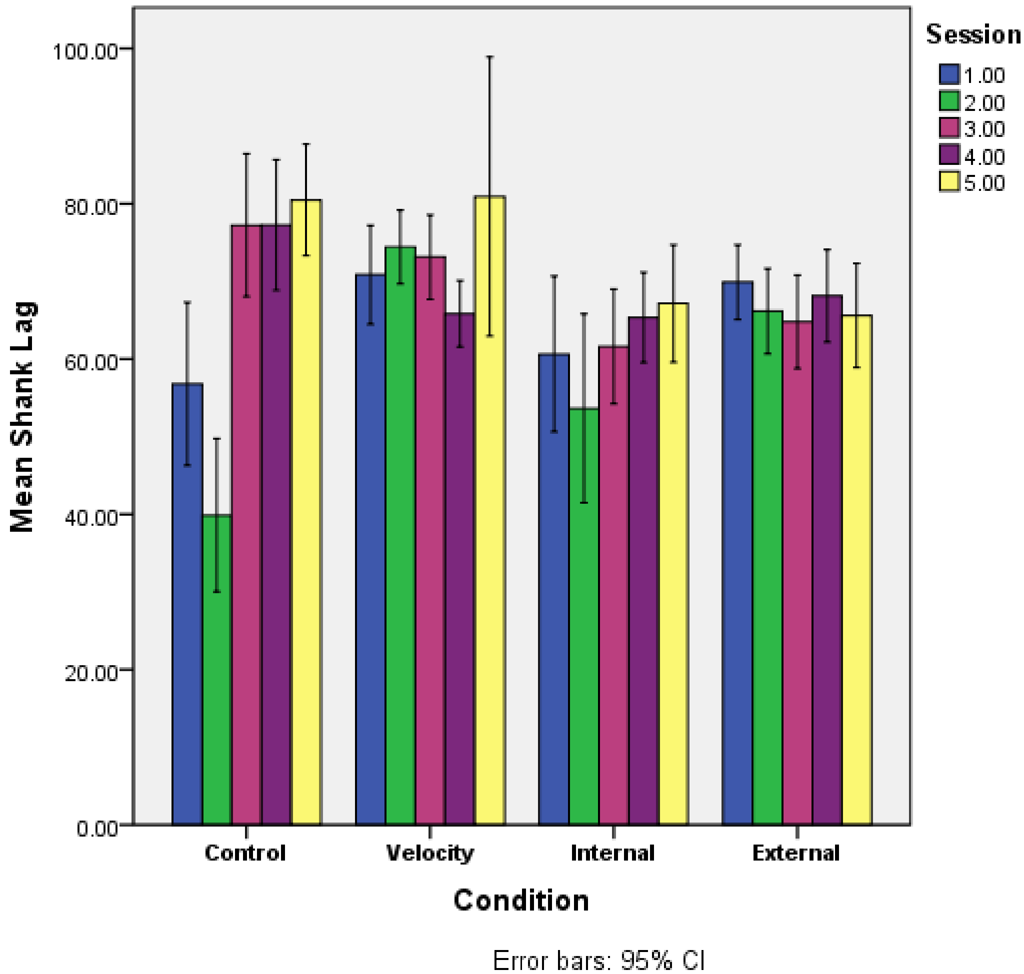

Figure 2.

Figure 3

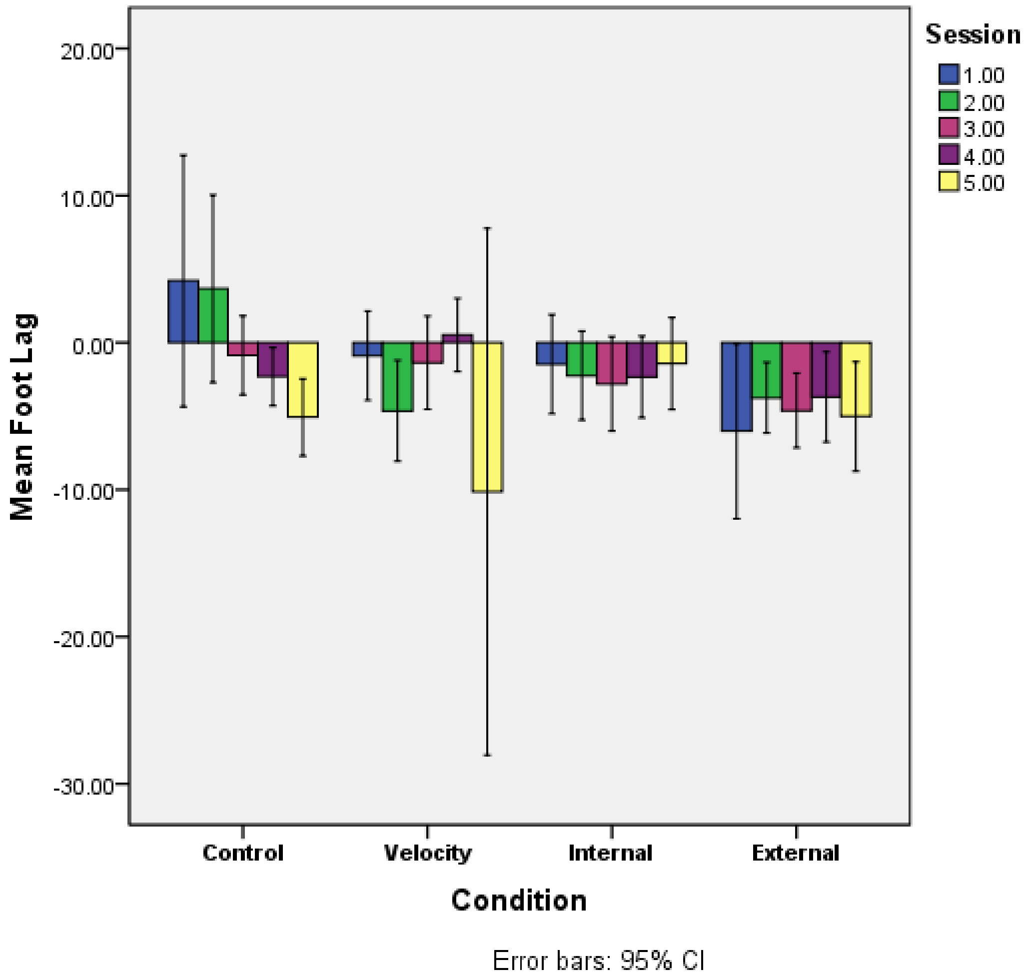

Figure 3.

APPENDIX

Consent Form

Texas Christian University
Fort Worth, Texas

CONSENT TO PARTICIPATE IN RESEARCH

Title of Research: Effect of Internal Focus, External Focus, and Constraints on Kicking Pattern

Funding Agency/Sponsor: N/A

Study Investigators: Ariana Sheridan- primary investigator
Dr. Dan Southard- primary department supervisor

What is the purpose of the research?
To compare different methods of instruction and their effect on kicking pattern.

How many people will participate in this study?
Twenty –four TCU students. Twelve males and 12 females.

What is my involvement for participating in this study?
You will be required to kick a standard size soccer ball into a padded mat for five different sessions in the Motor Behavior Laboratory. The sessions will require you to kick the ball 12 times to a padded mat located 5 meters to your front. You will be randomly placed in one of four different conditions. Conditions vary by the type of instruction and feedback you receive while kicking the ball. For each session, you will have harmless reflective markers attached to your kicking leg and torso with double-back adhesive tape. The markers will serve as data collection points for a motion analysis system. The system will track your movement and create graphs that represent your kicking motion. Prior to beginning each session, you will be required to warm-up using stretching exercises and five practice kicks.

How long am I expected to be in this study for and how much of my time is required?

This study will require you to visit the lab on five different days. A different day is required for each session. The first session will be used to assess your kicking pattern. Sessions 2, 3, and 4 will be practice sessions. The last session will be one week after your fourth session. The sessions will take approximately 20 minutes of your time. It will take about 5 minutes to apply the markers and about 15 minutes to collect data. Your total time is estimated to be about 100 minutes. Sessions will be scheduled at your convenience.

What are the risks of participating in this study and how will they be minimized?
There is some risk of muscle strain from kicking the soccer ball. Risk is minimized by requiring that you warm-up adequately before participating in each session. If you should experience pain while participating, I will stop data collection.

What are the benefits for participating in this study?
At the end of the study, you will be afforded the opportunity to view your data and discuss your data with the researchers. The study also allows you to experience an important part of the research process (data collection) in the area of Biomechanics.

Will I be compensated for participating in this study?
If you are a participant from the primary supervising professor's class, you will be awarded 10 points extra credit for your participation. The 10 points will be added to the total points that you earn at the end of class.

What is an alternate procedure(s) that I can choose instead of participating in this study?
If you choose not to participate, you can choose to earn extra credit by reporting on three Biomechanics articles from kinesiology journals.

How will my confidentiality be protected?
There will be no way for anyone other than the primary investigator to match your data with your name. The only people that will be present during data collection are the primary investigator and supervising professor. Data will be stored in a locked computer. The only people with access to the data are the primary investigator and supervising professor. Following the study, data will be stored in a locked cabinet in the Motor Behavior Laboratory. Only the principle investigator and supervising professors will have access to the data

Is my participation voluntary?
Yes.

Can I stop taking part in this research?
Yes, you may withdraw from the study at any time without penalty

What are the procedures for withdrawal?

You should contact Ariana Sheridan in person, by email (ariana.sheridan@tcu.edu), or by phone 360.633.6474. You can also contact Dr. Southard in person, by email (d.southard@tcu.edu), or by phone 817.257.6869.

Will I be given a copy of the consent document to keep?
Yes.

Whom should I contact if I have questions regarding the study?
You should contact Ariana Sheridan in person, by email (ariana.sheridan@tcu.edu), or by phone 360.633.6474 and express your desire to withdraw. You can also contact Dr. Southard in person, by email (d.southard@tcu.edu), or by phone 817.257.6869 and express your desire to withdraw

Whom should I contact if I have concerns regarding my rights as a study participant?
Dr. Sally Fortenberry, Chair of University IRB Committee, Telephone 817.257.6752
email: s.fortenberyy@tcu.edu.
Dr. Gloria Solomon, 817.257.6868 g.solomon@tcu.edu

Your signature below indicates that you have been read the information provided above, you have received answers to all of your questions and have been told who to call if you have any more questions, you have freely decided to participate in this research, and you understand that you are not giving up any of your legal rights.

Participant Name (please print):
____

Participant's Signature: ______________________________ Date: _____________

Investigator's Signature: ______________________________ Date: _____________

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