AUTHOR QUERIES

DATE 12/5/2016
JOB NAME SCJ

ARTICLE SCJ-D-16-00088
QUERIES FOR AUTHORS Brady et al

THIS QUERY FORM MUST BE RETURNED WITH ALL PROOFS FOR CORRECTIONS

Please confirm the given names (pink) and surnames (blue) of authors have been identified correctly.

AU1) Please note that as per style, the running head should contain only 50 characters; the running head introduced exceeds 50 characters. Please check.

AU2) Please note that the affiliation provided has been treated as common for all the authors. Please check. And also provide city name for the affiliation.

AU3) Please confirm if the conflicts of interest and funding statement is accurate.

AU4) Please confirm if the author bios and headshots are accurate.

AU5) Please check and confirm the edits made to the sentence “Several studies have…” and correct if necessary.

AU6) Please check the hierarchy of text section headings, and correct if necessary.

AU7) Please update the references 11 and 27.

AU8) Please note that the references have been renumbered both in text and in list so as to maintain alphabetical order in the reference list, as per the style. Please check.

AU9) Please note that reference 38 is cited in the table body but is not provided in the reference list. Please add this to the list or delete the citation. Also ensure that the references are cited in sequential order.

AU10) Please note that the author names “Wulf and Dufek, Porter, Porter, Wu, Tapley, Porter, and Porter and Sims” cited near references “37, 22, 29, 36, 29, 24, and 23” in the Table body do not match with the author names provided in the reference list. Please check.

Focus of Attention for Diagnostic Testing of the Force-Velocity Curve

Claire Brady, MSc, PhD, Tom Comyns, PhD, Drew Harrison, PhD, and Giles Warrington, PhD
AU2 Biomechanical Research Unit, Department of Physical Education and Sport Sciences, University of Limerick, Ireland

ABSTRACT

DIAGNOSTIC TESTING OF VARIOUS POINTS ON THE FORCE-VELOCITY CURVE, SUCH AS MAXIMUM STRENGTH AND RUNNING SPEED TESTS, IS USED TO IDENTIFY ATHLETES' STRENGTHS AND WEAKNESSES. DURING THE IMPLEMENTATION OF THESE TESTS, COACHES TYPICALLY USE VERBAL INSTRUCTIONS IN AN ATTEMPT TO ENSURE THE ATHLETE ACHIEVES THE HIGHEST RESULT POSSIBLE. RESEARCHERS HAVE SHOWN THAT OPTIMAL MOTOR SKILL PERFORMANCE IS OFTEN ACHIEVED WHEN VERBAL INSTRUCTIONS DIRECT ATTENTION EXTERNALLY. THIS ARTICLE REVIEWS THE CURRENT RESEARCH ON THE APPROPRIATE ATTENTIONAL FOCUS FOR TESTS, WHICH ASSESS ASPECTS OF THE FORCE-VELOCITY CURVE. BASED ON AN ANALYSIS OF THE EXISTING SCIENTIFIC LITERATURE, PRACTICAL APPLICATIONS ARE PROVIDED FOR COACHES.

INTRODUCTION

To improve the specificity and accuracy of strength and conditioning training programs, it is important to undertake an initial needs analysis, where the athlete's strengths and weaknesses are identified. The force-velocity curve illustrates that maximum strength is exerted at low velocities and maximum speed is produced at low resistances; an inverse relationship exists between these 2 variables. The results of force-velocity diagnostic tests can be used by strength and conditioning coaches in the design and implementation of individualized training programs (17). In most circumstances, strength and power training aims to shift the force-velocity curve to the right, in effect this means that the athlete is able to move various resistances at higher velocities and has become more explosive. Shifting the curve to the right represents an improved rate of force development. There are several assessment techniques and methods used to evaluate an athlete's performance on various aspects of the force-velocity curve, such as isometric strength tests (maximum strength), unresisted countermovement jump tests (speed-strength), and 10-m time tests (speed).

Address correspondence to Dr. Claire Brady, claire.brady@ul.ie.

Throughout the implementation of these force-velocity diagnostic tests, verbal communication between the coach and athlete is important to ensure the athlete achieves their optimum result (14). If the correct instruction is given, the optimal outcome will be achieved for the test; however, if the instructions given are incorrect and/or complicated, the performance outcome may be compromised, thereby not providing a true and valid measure of the athlete's strength, power, or speed characteristics (14).

Motor learning research has investigated how motor skill learning and performance are controlled by changing the training environment (32). A key area that has gained considerable interest in the scientific literature is how focusing a learner's attention during training influences motor performance (32). Specifically, to enhance performance, the coach must be aware whether or not to give the athlete an external, internal, or neutral instruction before executing a movement. "External" verbal instruction directs the athlete's attention to the effects of their movement, whereas "internal" verbal instructions direct the athlete's attention to some internal aspects of their own actions (26). For example, when applied during the acceleration phase of sprinting, an external instruction could be "explode off the ground" and an internal instruction could be "explode through your hips" (3). Most studies have demonstrated that an external focus of attention results in a superior performance compared with an internal focus of attention (11,14,16,19,21,34).

Wulf (32) carried out a review of the literature and found that in approximately 80 experiments, significant advantages were found when participants

KEY WORDS:
external focus of attention; internal focus of attention; maximum strength; strength-speed; speed-strength; reactive strength; speed; stretch shortening cycle

were given an external focus of attention compared with an internal focus of attention. Wulf et al. (35) proposed that internally focused instructions promote conscious control that restricts the motor system through greater attentional demands and interferes with automatic control processes. This is known as the "constrained action hypothesis." By comparison, an external focus promotes automatic control processes and allows the motor system to naturally self-organize, which strengthens efficient movements.

Although the review by Wulf (32) addressed some sections of the force-velocity curve such as speed-strength and speed, the review did not report tests for the entire force-velocity curve. A large amount of studies included were on balance and accuracy (e.g., dart throwing, golf shots, basketball shot, and a tennis ball toss). Furthermore, there were no studies included that addressed focus of attention for maximal strength measured by an isometric midthigh pull, reactive strength measured by a drop jump (DJ), or for maximum velocity sprinting. Based on the available scientific literature, the current review article focuses on the comparison between internal and external verbal instructions and an athlete's performance during force-velocity curve diagnostic tests for the lower body, which profile the athlete's force-velocity capabilities. Specifically, testing maximum strength measured through an isometric midthigh pull, strength-speed measured through weighted jumps (jump squat), speed-strength through unweighted jumps (horizontal jumps, vertical jumps), reactive strength (DJs) and speed (acceleration, agility, and maximum velocity) (Figure 1). The summary of the key findings that used internal, external, or neutral instructions to influence performance in these tests, including subject characteristics is outlined in Table 1.

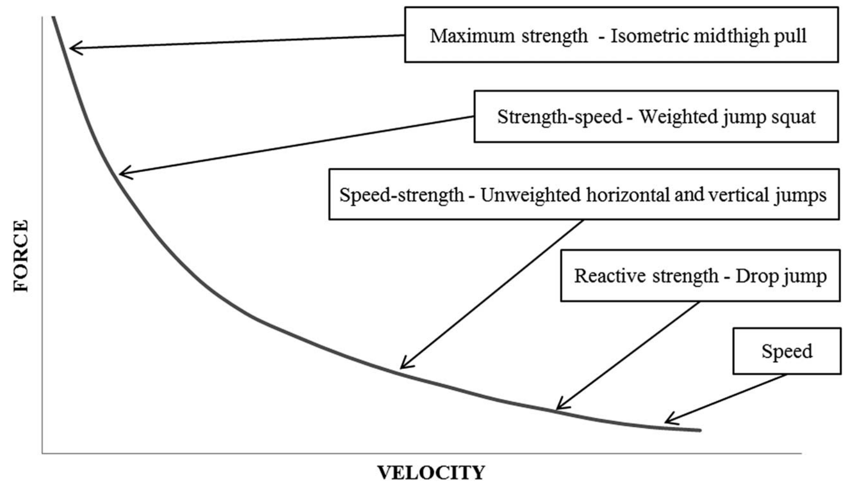

Figure 1. An illustration of the force-velocity relationship with the aspects of the force-velocity spectrum identified, namely strength, strength-speed, speed-strength, reactive strength, and speed.

MAXIMUM STRENGTH

ISOMETRIC MIDTHIGH PULL

Maximal force–generating capabilities are commonly monitored in athletes. This is the section of the curve where force generation requirements are high and the speed of movement is low. The isometric midthigh pull is a frequently used maximal strength exercise where participants are required to isometrically pull a stationary bar located at the midthigh level while standing on a force plate (13). It is regularly used to monitor an athlete's progression and to assist in the design of programs. Research studies examining the effect of attentional focus instructions during maximal effort isometric tests such as the isometric midthigh pull are somewhat lacking in the literature. Of the limited research available, most studies use guideline instructions such as "pull hard and fast" when instructing participants during an isometric midthigh pull (2,10,13,29). Recently, Halperin et al. (11) examined the focus of attention during an isometric midthigh pull in trained athletes. Participants completed trials in 3 different conditions for 3 consecutive days. The first trial was performed with a control instruction. On the second day and third day of testing, athletes repeated the same procedure with the exception that the instructions given (control, internal focus, and external focus) were provided once before each of 3 maximal efforts in a randomized manner. Results showed that peak force production with the externally focused instruction was significantly greater compared with the internally focused instruction and the control instruction. Halperin et al. (11) concluded that an externally focused verbal instruction should be given to athletes when completing an isometric midthigh pull and consistency should be maintained with verbal instructions across testing days.

STRENGTH-SPEED

WEIGHTED JUMP SQUAT

This is the section of the force-velocity curve where the athlete moves a medium to heavy resistance as fast as they possibly can and is sometimes referred to as strength-speed. The weighted jump squat is a common test to assess the strength-speed aspect of the force-velocity curve and is performed with added resistance such as a barbell on the shoulders (26). Although there is a considerable amount of research on the effect of focus of attention on unweighted jumps (speed-strength) (14,33,34,36), there is currently no available research on the effect of focus of attention on a weighted jump such as a jump squat. Therefore, more research studies are needed to determine the type of instruction (external, internal,

Table 1
Depiction of studies that used internal, external, or neutral instruction or cues to influence performance in strength, power, and speed diagnostic tests

Reference	Year	Participants	Sex	Test	Instructions given	Results
Porter et al. (22)	2012	35 recreationally active young adults from a general undergraduate student population	Male	Standing long jump	CON = "jump to the best of your ability"	A significant difference ($P \leq 0.05$) in the distance jumped between the EXT near (207 ± 30.5 cm) and EXT far (212.74 ± 28.9 cm) and the CON (195.92 ± 31.3 cm) and a significant difference between the EXT near and far conditions.
					EXT near ="jump as far past the start line as possible" (white start line was clearly marked and located directly in front of each subject's feet)	
					EXT far = "jump as close to the cone as possible" (cone was placed directly in front of the subject at a distance of 3 m)	
Porter et al. (19)	2010	120 young adults from a general undergraduate student population	72 males; 48 females	Standing long jump	EXT = "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"	A significant difference ($P = 0.003$) in the distance jumped between the EXT (187.4 ± 42.7 cm) group and the INT group (177.3 ± 41 cm)
					INT = "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"	
Wu et al. (36)	2012	21 untrained generally active undergraduate population	10 males; 11 females	Standing long jump	Baseline = "jump as far as you can" INT and EXT focus instructions same as Porter et al. (19)	A significant difference ($P < 0.05$) in the distance jumped between the EXT (153.6 ± 38.6 cm), INT (139.5 ± 46.7 cm), and baseline condition (133.8 ± 35.7 cm)
Wulf et al. (38)	2010	8 healthy physically active undergraduate students	5 females; 3 males	Vertical jump	EXT = participants were instructed to concentrate on the rungs of the Vertec	A significant difference ($P < 0.05$) in the jump and reach height between the EXT (32.4 cm) and INT (31.0 cm) conditions. EMG activity was significantly ($P < 0.05$) lower in the EXT condition compared with the INT condition

(continued)

AU9

Table 1
(continued)

					INT = participants were instructed to concentrate	
					on the tips of their fingers touching the Vertec	
Wulf and Dufek (37) AU10	2009	10 healthy physically active university students	6 females; 4 males	Vertical jump	EXT = concentrate on the rungs of the Vertec, reaching as high as possible.	A significant difference ($P < 0.05$) in the jump and reach height between the EXT (31.9 cm) and INT (30.4 cm) conditions. A significant difference ($P < 0.05$) in the vertical displacement of the COM between the EXT (29.5 cm) and INT (26.2 cm)
					INT = concentrate on the tips of their fingers, reaching as high as possible during the jumps	
Tapley et al. (29)	2014	18 physically active currently/previously participating in recreational sports involving sprinting and jumping	Male	Jump squat	INT = "In this condition, just concentrate on extending the legs as fast as possible to maximise explosive force"	The neutral instruction produced a significantly greater ($P < 0.05$) mean jump height (45.9 cm), peak velocity (2.58 m/s), and downward countermovement distance (54.9 cm) than the INT instruction (mean jump height (44.0 cm), peak velocity (2.43 m/s), and downward countermovement distance (47.5 cm). The INT instruction yielded a significantly greater ($P < 0.05$) peak force (3.7%) compared with the neutral instruction
					NEUTRAL = "In this condition, just concentrate on jumping for maximal height"	

Table 1
(continued)

Halperin et al. (11)	2015	18 trained athletes from various sporting backgrounds	10 males; 8 females	Isometric midthigh clean pull	EXT = "focus on pushing the ground as hard and fast as you possibly can"	Peak force was significantly 9% greater ($P < 0.001$) during the EXT compared with the INT and significantly 3% greater than the CON.
					INT = "focus on contracting your leg muscles as hard and a fast as you possibly can"	
					CON = "focus on going as hard and as fast as you possibly can"	
Porter et al. (24)	2015	84 undergraduate college students, none were former track and field athletes or former collegiate athletes of any sport	42 males; 42 females	Acceleration	EXT = "while you are running the 20-m dash focus on driving forward as powerfully as possible while clawing the floor with your shoe as quickly as possible as you accelerate"	The EXT condition was significantly ($P \leq 0.001$) faster (3.75 s) than the INT (3.87 s) and CON conditions (3.87 s). The INT and CON conditions were not significantly different.
					INT = "while you are running the 20-m dash focus on driving 1 leg forward as powerfully as possible while moving your other leg and foot down and back as quickly as possible as you accelerate"	
					CON = "Please run the 20-m dash as quickly as possible"	
Porter and Sims (23)	2013	9 healthy highly trained collegiate Division 1 football players	Male	Acceleration	EXT = "while you are running the 20 yard dash with maximum effort, focus on gradually raising up. Also, focus on powerfully driving forward while clawing the floor as quickly as possible"	No significant differences between the conditions at the 9.14 m split ($P > 0.971$) and 18.28 m distance ($P > 0.599$). A significant difference ($P < 0.047$) in the second 9.14 split for the CON condition (1.12 s) compared with the INT (1.14 s) and EXT (1.14 s) conditions.

(continued)

Table 1 (continued)

					INT = "while you are running the 20 yard dash with maximum effort, focus on gradually raising your body level. Also focus on powerfully driving one leg forward while moving your other leg and foot down and back as quickly as possible"	
					CON = "run the 20 yard dash with maximum effort"	
Porter et al. (21)	2010	20 undergraduate students with no formal sprint or agility training	14 males; 6 females	Agility "L" test	EXT = "run through the course as quickly as you can with maximum effort. This agility test consists of 2 parts, a running component and a turning component. For each running component, I want you to focus on running toward the cone as rapidly as possible. For the turning component, I want you to focus on pushing off the ground as forcefully as possible"	The EXT (6.10 ± 0.14 s) condition was significantly faster than both the INT ($P < 0.01$) (6.45 ± 0.12 s) and CON ($P < 0.04$) (6.36 ± 0.14 s) conditions. The CON and INT groups were not significantly different.
					INT = "run through the course as quickly as you can with maximum effort. This agility test consists of 2 parts, a running component and a turning component. For each running component, I want you to focus on moving your legs as rapidly as possible. For the turning component, I want you to focus on planting your foot as firmly as possible."	
					CON = "run through the course as quickly as you can with maximum effort"	

CON = control/no focus of attention; EMG = electromyography; EXT = external focus of attention, INT = internal focus of attention.

or neutral) that will improve performance in the strength-speed section of the force-velocity curve.

SPEED-STRENGTH

UNWEIGHTED VERTICAL JUMPS

Speed-strength is the section of the force-velocity curve where the resistance is low and the velocity is high. The athlete is moving a light resistance as fast as they possibly can. An athlete's vertical jump ability is a critical component to success in a number of sport skills such as high jump, a volleyball spike, a basketball block, and a line-out in Rugby. In these cases, the timing and direction of the forces generated needs to be optimal to accelerate the body maximally. Maximum vertical jump depends on the athlete's vertical velocity at take-off. This velocity depends on the mass of the athlete and the impulse developed. Impulse is the product of force multiplied by the time the force acts. A countermovement jump (CMJ) is similar to a jump squat if performed with no added resistance and the hands are kept on the hips (18). The CMJ is a slow stretch shortening cycle (SSC) activity and has been established as a reliable assessment of jumping ability AU5 (5). Several studies have examined how an external focus of attention affects vertical jumping (14,33,34,36).

Talpey et al. (27) performed a study on the effect of instructions on the performance of variables during a CMJ. Two different sets of instructions were given to compare CMJ variables with active males who had a background of jump training. Participants performed the CMJ with a nonweighted dowel across their shoulders. The first instruction was a neutral instruction, and the second instruction was internally focused. The first instruction produced a significantly greater mean jump height, peak velocity, and downward countermovement distance than the second instruction. By comparison, the second instruction resulted in a significantly greater peak force compared with the first instruction. The authors concluded that if greater jump height is preferred, a neutral instruction should be given and if greater peak force is desired, an internally focused instruction should be used. However, no external instruction was given; therefore, it is not known whether an externally focused instruction is superior or inferior from a neutral or internal instruction during CMJ performance from the results of this study.

Wulf et al. (34) examined participants performing a vertical jump and reach task using a Vertec (Sports Imports, Columbus, OH) measurement device. Participants performed 10 trials under each of the internal and external focus conditions, counterbalanced among participants. For the external focus condition, participants were instructed to focus on the rungs of the Vertec, reaching as far as possible. For the internal condition, they were instructed to concentrate on the tips of their fingers reaching as high as possible during the jumps. Results showed that participants reached significantly higher when they adopted an external focus compared with an internal focus. Similarly, Makaruk et al. (14) showed that participants attained a significantly greater jump height when they were instructed to concentrate externally on the rungs of the Vertec compared with an internal focus of their fingers reaching for the rungs.

Wulf et al. (36) also showed that participants' jump and reach heights were significantly higher with an external focus compared with an internal focus or no attentional focus instruction. In addition, the vertical displacement of the center of mass was significantly greater under the external focus condition as opposed to the internal focus or when no focused instructions were given. Furthermore, Wulf and Dufek (33) found that participant's jump height, center of mass displacement, jump impulse, and lower extremity joint moments were all significantly greater with an external focus compared with an internal focus. The authors suggested that participants jumped higher by producing greater forces when they take on an external focus. However, when an athlete applies force to produce a movement, the force is never applied instantly but over a certain period. Therefore, an applied force must be considered in relation to the time length that it is applied, which is known as impulse. Graphically, an impulse can be represented as the area under a force-time curve of a movement. Therefore, the athletes jumped higher because they developed greater impulse rather than produced more force (Figure 2). F2

Wulf et al. (34) found that electromyography activity was significantly lower and jump height was significantly higher with an external focus compared with an internal focus. Jump height increased due to increased force production; these results suggest that impulse increased and neuromuscular coordination was enhanced with the external focus of attention. This proposes that the movement effect might not only enable an effective recruitment of muscle fibers within a muscle ("intramuscular coordination"), but also the effective coordination between agonist and antagonist muscle groups ("intermuscular coordination"). During testing and training sessions, where athletes are aiming to improve their jump height through improved mechanics, the use of external devices and external instructional cues will enhance an athlete's jump performance.

More recently, Walchli et al. (28) found in a general athletic population that providing participants with augmented feedback along with an external focus of attention during a CMJ, participants jumped significantly higher compared with other conditions (control, monetary reward, other combinations such as augmented feedback, and monetary reward). Augmented feedback is defined as feedback from an external source and can be provided as knowledge of performance or knowledge of result (28). Furthermore, participants had significantly lower rectus femoris muscle activity compared with the control condition. This finding is consistent with previous research, which showed that muscular activity was reduced and performance was increased when participants were

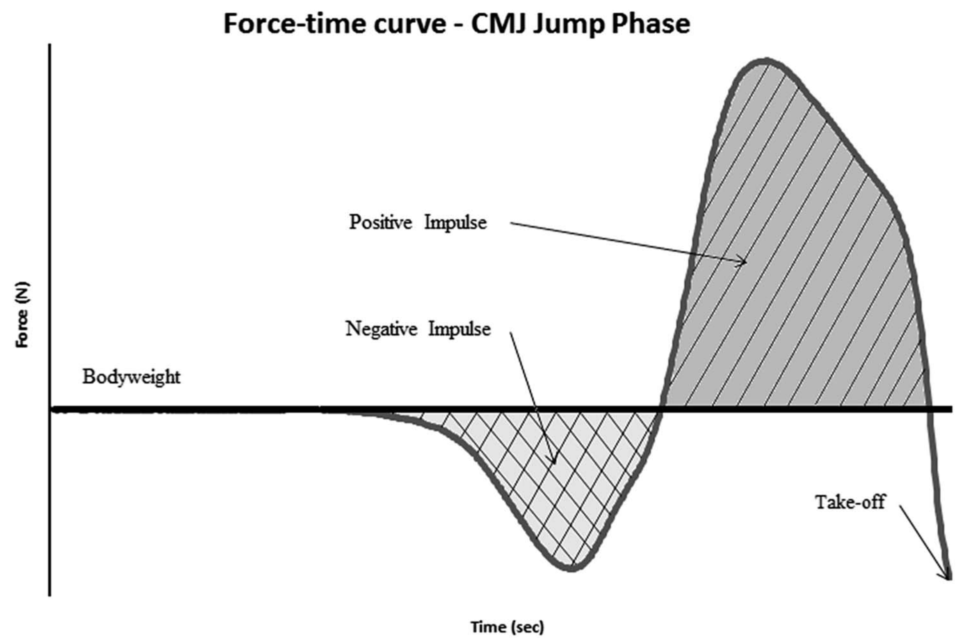

Figure 2. Schematic of the force time curve produced for the jump phase of a CMJ outlining the positive and negative impulses. CMJ = counter-movement jump.

given an external focus of attention (34). In addition, ground reaction forces (GRFs) and joint angles were comparable across all conditions. The authors concluded that augmented feedback improved intrinsic motivation, and the external focus of attention improved movement efficiency.

SPEED-STRENGTH

HORIZONTAL JUMPS

The standing long jump test is a widely used test in various sports (e.g., track and field, soccer, and NFL combine) and is used to assess the speed-strength aspect of the force-velocity curve. Adopting an external focus of attention has been shown to enhance standing long jump performance (19,21,31). Porter et al. (19) established that during the standing long jump, participants performed best when skilled jumpers focused on an external cue (e.g., jumping toward a target). Using a counterbalanced within-participant design, recreationally trained male participants performed 2 standing long jumps following 3 different sets of verbal instructions (total of 6 jumps; each separated by 1 minute of seated rest). One set of instructions was designed to focus attention externally near the body, whereas another set of instructions directed attention externally to a target (cone) farther from the body. The cone was placed directly in front of the participant at a distance of 3 m. The final set of instructions served as a control condition and did not encourage a specific focus of attention. Results showed that the 2 external conditions produced jumping distances that were significantly greater than the control condition. In addition, the jump distances measured for the external near and external far conditions were significantly different. The results from this study indicate that increasing the distance of an external focus of attention relative to the athlete's body will improve standing long jump performance.

Within a general student population, Porter et al. (21) found that participants jumped significantly further when given an external focus of attention compared with an internal focus of attention. Results showed that there was a significant difference in the mean distance jumped between the external and internal group. These results suggest that providing instructions that focus attention externally enhances standing long jump performance when compared with instructions that focus attention internally. The authors suggested that differences in jump performance were possible because the external focus of attention enabled participants to produce greater forces compared with the internal focus condition. However, as previously discussed, the athletes in this instance would have developed greater impulse not just force to jump further.

Wu et al. (31) performed a study to assess peak force and horizontal jump performance between an internal and external focus of attention. Untrained recreationally active participants were assigned to both experimental conditions where they were provided with either an external or internal focus of attention. Participants completed a total of 5 standing long jumps with 2-minute seated rest between jumps. Jump distance and peak forces for both feet were measured throughout each jump. The first jump was a baseline jump where the only instruction given was "jump as far as you can." For the following, 4 jumps participants were given instructions that provoked either an internal or external focus of attention similar to those given by Porter et al. (21). In addition, during the externally focused verbal instructions, an external target (cone) was placed 4.6 cm from the start line. Results showed that during the external focus condition, participants jumped significantly further than the internal and baseline condition. No significant differences in mean peak force were found between the 3 conditions, internal focus, external focus, and baseline. The increase in jump performance during the external focus of attention was not due to an increase in force production compared with the internal condition. This finding conflicts with the assumptions made by Porter et al. (21) that an external focus of attention enabled participants to produce greater forces compared with the internal focus condition. Directing attention externally allows the motor control system to arrange movements, resulting in the movements being subconscious, reflexive, and quick (35).

More recently, an external focus of attention has been shown to produce a projection angle that is closer to optimal (6). Researchers have shown that participants exhibit a mean projection angle of 46° when given an external focus condition compared with an internal (50°) and a baseline (49°) conditions during a standing long jump (6). Therefore, the difference in jump distance among conditions could be explained by the external condition producing a projection angle, which is closer to optimal, which partially supports the "constrained action hypothesis." This hypothesis suggests that when athletes use an internal focus of attention, they may restrict or interfere with automatic control processes, whereas an external focus of attention permits the motor system to self-organize more naturally. Consequently, strength and conditioning coaches should consistently instruct their athletes to use an external focus when performing the standing long jump.

REACTIVE STRENGTH

DROP JUMP

The DJ involves jumping vertically immediately after landing from a predetermined height; a 30-cm height is commonly used. The DJ test usually examines the fast SSC (37). This is the section of the force-velocity curve where movements are high in velocity and the resistance is low. DJs are commonly performed onto a jump mat or force platform to determine contact and flight times as well as vertical jump height (8). In addition, the flight time and contact times obtained during a DJ can be used to estimate the reactive strength index (RSI). This is defined as height jumped (m) divided by contact time (s) (7). The RSI is proposed as an index of an athlete's fast stretch-shortening cycle ability as well as an identifier of optimal drop heights for the performance of DJ training (7). The use of a standardized command such as "jump as high and as fast as possible" is most commonly used to ensure reliable jump performance (37).

Makaruk et al. (14) examined the effect of external, internal, and neutral focus of attention on a 9-week plyometric training program, where participants completed a series of jumps including DJs from a 30-cm box. Participants were randomly assigned to an external focus of attention, internal focus of attention, or a control group. Instruction given throughout the program in the DJ for the externally focused group was "touch the hanging ball," the internally focused instruction was "reach your fingers as high as you can" and the control instruction was "jump as high as you can." Results showed that the control group significantly increased jump height compared with the internally focused group, but there were no differences between the external and control group and the external and internally focused groups. However, the only instructions given here were jump height related and not on ground contact time. For example, an instruction of "imagine the ground as a hot surface" is an externally focused instruction, which may help an athlete reduce their ground contact time and thus improve their RSI.

In contrast, Ford et al. (9) found that an external focus of attention concentrating on an overhead target produced a significantly greater jump height and maximum take-off external knee flexion moment compared with a control group that did not have an overhead target when testing performance in the DJ. It must be noted that in the Makaruk et al. (14) study, all 3 groups (internal, external and control) improved their DJ height and all increases were achieved through different movement strategies. The externally focused group increased mean contact time and knee flexion and produced greater force. However, a longer contact time may decrease the efficiency of the SSC, losing stored elastic energy (1). For the DJ test to be used as a measure of an athlete's reactive strength, the SSC must remain fast and ground contact time needs to be minimized. This study did not give an instruction, which focused on minimizing ground contact time. In comparison, the internal and control focus groups decreased contact time. The control group significantly reduced the range of knee flexion, and this change was significantly different than the externally focused group. The effectiveness of the fast SSC could be improved by increasing leg stiffness, which is achieved by decreasing range of knee flexion, therefore improving jumping ability (30). Thus, the control group produced a more effective SSC. The authors concluded that more research is needed to fully understand how focus of attention and the SSC interact with each other during the DJ. Further research should examine using external instructions that relate to effective fast SSC performance, that is short ground contact time and maximum jump height.

The effect of instructions related to both contact time and height on fast SSC is evident in research by Young et al. (37). These researchers examined the effect of instructions related to jumping for maximum height and minimum contact time on DJ performance. They reported that an instruction to jump for both maximum height and minimum ground contact time compared with an instruction of jumping for height resulted in the jump height being reduced by 17.7% and the RSI being increased by 89%. Both sets of instructions ("jump for height" and "jump for height and minimum ground contact time") were a neutral focus with neither being internally or externally focused. However, the results indicate that a reference to both height and contact time in an instruction can result in the fast SSC being performed in a manner that increases reactive strength. Research seems to indicate that an external or neutral instruction of "jump as high and as fast as possible" should be used for DJ testing. However, research is still needed to identify the most appropriate instruction to optimize DJ performance as past research has generally not examined the effect of external, internal, and neutral instructions that relate to both maximizing height and minimizing contact time.

SPEED

ACCELERATION

Linear sprinting is one of the most important motor skills in sport. Being able to sprint faster and more efficiently gives an athlete a substantial competitive edge (24). To date, only a few studies have explored the effect of verbal communication on sprinting speed (12,17,22,23). Of interest, the skill level of the athlete may be a factor determining how the athlete responds to the instructions given. In support of this, Ille et al. (12) found that novice and expert athletes both performed faster 10-m sprints when given an external focus of attention compared with an internal or control condition. Similarly, Porter et al. (23) established that low-skilled sprinters completed a 20-m sprint significantly faster when they were instructed to focus externally compared with an internally focused or control condition. However, Porter and Sims (22) found that high-skilled athletes performed better when given a control instruction compared with an internal or external focus of attention instruction. From the current available literature, no evidence exists showing an internal focus results in superior sprint performance compared with an external or neutral focus (12,22,23). Therefore, both novice and expert performers seem to benefit equally from an external focus of attention compared with an internal focus of attention. However, experts with high motor skill abilities may not require any obvious instruction; a neutral instruction will suffice.

MAXIMUM VELOCITY

Despite the dearth of scientific evidence on the effects of various attentional foci strategies on biomechanical sprint variables, Benz et al. (3) carried out a review on the available literature and made several suggestions based on motor behavior and biomechanics literature. Skilled sprinters attain higher maximal velocities compared with nonsprinters (10.4 $\pm$ 0.3 versus 8.7 $\pm$ 0.3 m/s) by applying larger vertical GRFs during the first half of the stance phase (4). Also, during the stance phase of sprinting, sprint velocity can be increased by applying large GRFs over a minimal amount of time (0.083–0.101 seconds) (15). Based on mechanical determinants of maximum velocity sprinting, Benz et al. (3) suggested that coaches could use external focus of attention cues to enhance sprint performance by getting an athlete to "step down hard" or "accelerate into the ground with maximum effort," potentially enhancing the athletes relative GRF and consequently their sprint velocity.

AGILITY

Agility is defined as the ability to change the direction of the body rapidly using a combination of speed, balance, strength, and coordination (25), and is a common element of speed in many field and court sports. Porter et al. (20) examined whether focusing attention externally produced faster agility task times when compared with instructions that focused attention internally or a neutral set of instructions. Participants completed 15 trials of an agility "L" run following instructions designed to encourage an external or internal focus of attention or a neutral set of instructions (20). Participants completed one experimental condition per day over 3 nonconsecutive days. Results showed that the external condition was significantly faster than both the internal and neutral conditions (20). Agility tests are commonly used by coaches to evaluate performance and measure skill development. Verbal instructions that induce an external focus of attention should be used to improve performance in such movement-related tasks.

PRACTICAL APPLICATIONS

This review of the scientific literature has demonstrated the potential advantages of using focus of attention to improve performance during force-velocity diagnostic tests. Specifically, the tests used to assess the force-velocity curve include maximum force production measured through an isometric midthigh pull, dynamic strength through horizontal jumps and vertical jumps, reactive strength with DJs and speed elements of acceleration, maximum velocity, and agility. Studies have shown that an external focus of attention improves performance in the standing long jump, vertical jump, isometric midthigh pull, acceleration, maximum velocity, and agility. However, in sprinting, nonelite sprinters should be given an external instruction whereas a neutral or external cue has been shown to improve performance in elite level athletes (22,23). More research is needed for vertical jumps such as the weighted jump squat and DJ. Studies have shown that athletes alter their jump technique when given a different focus of attention and this may alter the effectiveness of the SSC. It is important that the external instructions selected for such jumps pertain to the technique requirements of the jump. For example, for effective fast SSC performance, such as the DJ, the athlete is aiming to minimize ground contact time and maximize jump height. External verbal instructions in this case should focus

Table 2
Verbal instructions for enhancing performance during diagnostic tests of various aspects of the force-velocity curve

Section of force-velocity curve	Test	Focus of attention	Example instruction/cue	
Maximum strength	Isometric midthigh pull	External	"Focus on pushing the ground as hard and as fast as you possibly can"	
Speed-strength	Standing long jump	External	"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"	
			"Explode as far as you can away from the start line"	
			Use of an external target (e.g. cone)	
Speed-strength	Vertical jump	External	"Focus on the rungs, reaching as far as possible" when using an external target on a Vertec.	
			"When you jump, focus on jumping up and reaching the ceiling" when using an external target	
			"Explode off the ground and try and reach the ceiling"	
Reactive strength	Drop jump	External or neutral	"Jump as high as you can"	
			"Imagine the ground as a hot surface"	
			"Touch the hanging ball" when using an external target	
			Note: more research is needed in this area	
Speed	Acceleration	Novice—external, elite—external or neutral	External:	Neutral:
			"Push the ground away"	"Sprint with maximum effort"
			"Drive away from the start"	"Run as fast as you can"
			"Explode off the ground"	"Run as quickly as possible"
			"Powerfully drive forward while clawing the ground back"	"Sprint as if you're being chased"
			"Drive out like you're sprinting up a hill and come up gradually"	"Just sprint"
			"Push into the ground"	
Speed	Maximum velocity	Novice—external, elite—external or neutral	External:	Neutral:
			"Run tall"	"Sprint as fast as you can"
			"Step over"	"Relax"
			"Step down"	"Sprint past the finishing line"
			"Hit the ground hard"	"Just run as fast as you can"

(continued)

Table 2 (continued)

			"Accelerate into the ground"	
			"Explode through the ground"	
Speed	Agility	External	"Run through the course as quickly as you can with maximum effort. For each running component, I want you to focus on driving away from the start. For the turning component, focus on pushing off the ground as forcefully as possible."	
			"Push the ground away when you change direction"	
			"Drive out hard and push when you turn"	
			"Explode away when you change direction"	

on both aspects to optimize fast SSC performance. Finding the appropriate instructions for the strategy of the task is important. Evidence-based verbal instructions that can be quickly adopted and immediately implemented into testing sessions have been provided in this review.

A summary of verbal instructions for enhancing performance during force-velocity diagnostic tests is detailed in Table 2. T2 When communicating with athletes, coaches should always be aware of the words they are using and should avoid verbal instructions that refer to the movement of the body or specific body parts. The current body of evidence suggests that these internally focused instructions will most likely result in a decrease in performance in most of the tests. Coaches should provide augmented feedback along with the external focus of attention as this has been shown to produce superior results compared with an external focus of attention on its own (28). In the weighted jump squat and DJ, more research is needed to determine the instructions that should be given to athletes to enhance their performance during testing as the literature is lacking and contradictory in some instances. In addition, coaches should consider using analogies and metaphors to provoke an external focus of attention. These can be an effective way to encourage the athlete to think about the desired outcome rather than thinking about moving their body parts. For example, during sprinting, telling the athlete to imagine the ground is a "hot surface" will result in the athlete minimizing their ground contact time. This type of instruction will limit the amount of instruction needed and reduce the likelihood of the athlete becoming overwhelmed with the amount of information given, which could decrease performance by cognitive overload. Although it may be a challenge for coaches to change the way they have always instructed their athletes, they should try to be inventive and imaginative to get the most out of their athletes during force-velocity diagnostic testing as well as regular training.

From a practical perspective, coaches should standardize the verbal instructions that they give to athletes when they are conducting force-velocity diagnostic testing sessions. Such standardized instructions are provided in Table 2. The external, neutral, or internal instructions that are used to maximize performance in a testing session should be repeated for subsequent testing sessions. Such an approach will ensure that results from one testing session can be compared with previous or subsequent testing sessions to assess if any worthwhile change has occurred. It is advisable that coaches document the exact instructions that they will use in each testing session to ensure a standardized and comparable testing environment is created.

SUMMARY

The use of tests to assess an athlete's force-velocity capabilities is central to effective program planning. To ensure that a program is specific to an athlete's needs, the coach should have an accurate overview of an athlete's current strength, power, and/or speed levels. Verbal instructions play a role in ensuring that the athlete performs to the highest level possible in these diagnostic tests that target various elements of the force-velocity curve. In general, research indicates that verbal instructions that focus an athlete's attentional externally as opposed to internally are more effective in enhancing performance during the performance of force-velocity diagnostic testing. The coach should consider what they say during any testing sessions and refer to instructions such as the ones provided in Table 2. For each testing session, the coach should standardize their instructions to ensure a maximal performance by the athlete that can be compared with previous testing results. AU6

Conflicts of Interest and Source of Funding: The authors report no conflicts of interest and no source of funding. AU3

Claire Brady *is a PhD researcher in the Physical Education and Sport Sciences department in the University of Limerick.*

Dr. Tom Comyns *is a lecturer in the Physical Education and Sport Sciences department in the University of Limerick.*

AU4

Drew Harrison *is Professor of Biomechanics in the Physical Education and Sport Sciences Department in the University of Limerick. He has extensive experience in Track and Field and Strength & Conditioning Coaching of international athletes and is a fellow of the International Society of Biomechanics in Sport (FISBS).*

Dr Giles Warrington *is a senior lecturer in Sport and Exercise Physiology in the Physical Education and Sport Sciences Department of the University of Limerick.*

REFERENCES

1. Anderson T. Biomechanics and running economy. *Sports Med* 22: 76–89, 1996.
2. Beckham G, Mizuguchi S, Carter C, Sato K, Ramsey M, Lamont H, Hornsby G, Haff G, and Stone M. Relationships of isometric mid-thigh pull variables to weightlifting performance. *J Sports Med Phys Fitness* 53: 573–581, 2013.
3. Benz A, Winkelman N, Porter J, and Nimphius S. Coaching instructions and cues for enhancing sprint performance. *Strength Cond J* 38: 2–11, 2016.
4. Clark KP and Weyand PG. Are running speeds maximized with simple-spring stance mechanics? *J Appl Physiol (1985)* 117: 604–615, 2014.
5. Cormack SJ, Newton RU, McGuigan MR, and Doyle T. Reliability of measures obtained during single and repeated countermovement jumps. *Int J Sports Physiol Perform* 3: 131–144, 2008.
6. Ducharme SW, Wu WFW, Porter JM, and Geraldo F. Standing long jump performance with an external focus of attention is improved as a result of a more effective projection angle. *J Strength Cond Res* 34: 276–281, 2016.
7. Flanagan EP and Comyns TM. The use of contact time and the reactive strength index to optimize fast stretch shortening cycle training. *Strength Cond J* 30: 33–38, 2008.
8. Flanagan EP, Ebben WP, and Jensen RL. Reliability of the reactive strength index and time to stabilization during depth jumps. *J Strength Cond Res* 22: 1677–1682, 2008.
9. Ford KR, Myer GD, Smith RL, Byrnes RN, Dopirak SE, and Hewett TE. Use of an overhead goal alters vertical jump performance and biomechanics. *J Strength Cond Res* 19: 394–399, 2005.
10. Haff GG, Carlock JM, Hartman MJ, Kilgore JL, Kawamori N, Jackson JR, and Stone MH. Force-time curve characteristics of dynamic and isometric muscle actions of elite women Olympic weightlifters. *J Strength Cond Res* 19: 741–748, 2005.
11. Halperin I, Williams K, Martin DT, and Chapman DW. The effects of attentional focusing instructions on force production during the isometric mid-thigh pull. *J Strength Cond Res* 2015 [Epub ahead of print].
12. Ille A, Selin I, Do MC, and Thon B. Attentional focus effects on sprint start performance as a function of skill level. *J Sports Sci* 31: 1705–1712, 2013.
13. Kawamori N, Rossi SJ, Justice BD, Haff EE, Pistilli EE, O'Bryant HS, Stone MH, and Haff GG. Peak force and rate of force development during isometric and dynamic mid-thigh clean pulls performed at various intensities. *J Strength Cond Res* 20: 483–491, 2006.
14. Makaruk H, Porter JM, Czaplicki A, Sadowski J, and Sacewicz T. The role of attentional focus in plyometric training. *J Sports Med Phys Fitness* 52: 319–327, 2012.
15. Mann RV. *The Mechanics of Sprinting and Hurdling*. Lexington, KY: CreateSpace Independent Publishing Platform, 2013.
16. Marchant DC, Greig M, and Scott C. Attentional focusing instructions influence force production and muscular activity during isokinetic elbow flexion. *J Strength Cond Res* 23: 2358–2366, 2009.
17. McGuigan MR, Cormack SJ, and Gill ND. Strength and power profiling of athletes: Selecting tests and how to use the information to program design. *Strength Cond J* 35: 7–14, 2013.
18. McGuigan MR, Cormack S, and Newton RU. Long-term power performance of elite Australian rules football players. *J Strength Cond Res* 23: 26–32, 2009.
19. Porter JM, Anton PM, and Wu WFW. Increasing the distance of an external focus of attention enhances standing long jump performance. *J Strength Cond Res* 26: 2389–2393, 2012.
20. Porter JM, Nolan RP, Ostrowski EJ, and Wulf G. Directing attention externally enhances agility performance: A qualitative and quantitative analysis of the efficacy of using verbal instructions to focus attention. *Front Psychol* 1: 1–7, 2010.
21. Porter JM, Ostrowski EJ, Nolan RP, and Wu WFW. Standing long jump performance is enhanced when using an external focus of attention. *J Strength Cond Res* 24: 1746–1750, 2010.
22. Porter JM and Sims B. Altering focus of attention influences elite athletes sprinting performance. *Int J Coach Sci* 8: 22–27, 2013.
23. Porter JM, Wu WFW, Crossley RM, Knopp SW, and Campbell OC. Adopting an external focus of attention improves sprinting performance in low-skilled sprinters. *J Strength Cond Res* 29: 947–953, 2015.
24. Ross A and Leveritt M. Long-term metabolic and skeletal muscle adaptations to short-sprint training: Implications for sprint training and tapering. *Sports Med* 31: 1063–1082, 2001.
25. Sayers A, Sayers BE, and Binkley H. Preseason fitness testing in national collegiate athletic association. *Strength Cond J* 30: 70–75, 2008.
26. Sheppard JM, Cormack S, Taylor K, McGuigan MR, and Newton RU. Assessing the force-velocity characteristics of the leg

extensors in well-trained athletes: The incremental load power profile. *J Strength Cond Res* 22: 1320–1326, 2008.

27. Talpey S, Young W, and Beseler B. Effect of instructions on selected jump squat variables. *J Strength Cond Res* 2014 [Epub ahead of print]. AU7

28. Wälchli M, Ruffieux J, Bourquin Y, Keller M, and Taube W. Maximizing performance: Augmented feedback, focus of attention, and/or reward? *Med Sci Sports Exerc* 48: 714–719, 2016.

29. West DJ, Owen NJ, Jones MR, Bracken RM, Cook CJ, Cunningham DJ, Shearer DA, Finn CV, Newton RU, and Crewther BT. Relationships between force–time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. *J Strength Cond Res* 25: 3070–3075, 2011.

30. Wilson JM and Flanagan EP. The role of elastic energy in activities with high force and power requirements: A brief review. *J Strength Cond Res* 22: 705–715, 2008.

31. Wu WFW, Porter JM, and Brown LE. Effect of attentional focus strategies on peak force and performance in the standing long jump. *J Strength Cond Res* 26: 1226–1231, 2012.

32. Wulf G. Attentional focus and motor learning: A review of 15 years. *Int Rev Sport Exerc Psychol* 6: 77–104, 2013.

33. Wulf G and Dufek JS. Increased jump height with an external attentional focus due to enhanced lower extremity joint kinetics. *J Mot Behav* 41: 401–409, 2009.

34. Wulf G, Dufek JS, Lozano L, and Pettigrew C. Increased jump height and reduced EMG activity with an external focus of attention. *Hum Mov Sci* 29: 440–448, 2010.

35. Wulf G, McNevin NH, and Shea CH. The automaticity of complex motor skill learning as a function of attentional focus. *Q J Exp Psychol A* 54: 1143–1154, 2001.

36. Wulf G, Zachry T, Granados C, and Dufek J. Increases in jump-and-reach height through an external focus of attention. *Int J Sports Sci Coach* 2: 275–284, 2007.

37. Young WB, Pryor JF, and Wilson GJ. Effect of instructions on characteristics of countermovement and drop jump performance. *J Strength Cond Res* 9: 232–236, 1995. AU8