Title: External cueing influences drop jump performance in trained young soccer players.

Running Head: External cueing effects young soccer players drop jump performance.

Authors:

Jon L. Oliver[1, 2*], Saldiam R. Barillas[1], Rhodri S. Lloyd[1, 2, 3], Isabel Moore[1], Jason Pedly[1]

Affiliations:

[1]Youth Physical Development Centre, Cardiff School of Sport and Health Sciences, Cardiff Metropolitan University, Cyncoed Campus, Cardiff Wales, UK.

[2]Sport Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand.

[3]Centre for Sport Science and Human Performance, Waikato Institute of Technology, Hamilton, New Zealand.

***Corresponding Author:**

Jon L. Oliver, Ph.D.
Youth Physical Development Centre
Cardiff School of Sport and Health Sciences
Cardiff Metropolitan University
Cardiff, UK CF23 6XD
Phone: +44 29 2041 7276
E-mail: joliver@cardiffmet.ac.uk

Title: External cueing influences drop jump performance in trained young soccer players.

Running Head: External cueing effects young soccer players drop jump performance.

Key Words: young athlete; plyometric; ground contact time; jump height; impact peak; impulse; relative strength index

ABSTRACT

Drop jump (DJ) characteristics provide insight on power production and injury risk. The purpose of this study was to investigate the effect of external cueing on drop jump characteristics in young male soccer players. Fourteen academy soccer players performed DJs with four different conditions, control (CONT), contact cue (CC), height cue (HC), and quiet cue (QC). Performance measures were reactive strength index (RSI), jump height, ground contact time (GCT), and take-off impulse, with injury risk reflected by impact peak, impact timing and landing impulse. CC showed a very large significant reduction in GCT (ES > 2.0, $p<0.05$), and moderate to large increase in RSI, landing impulse, and push off impulse (ES 0.70-1.55, $p<0.05$) compared to all other conditions. CC also moderately increased impact peak when compared to HC and QC (ES ≥ 0.78, $p<0.05$). HC led to a significant increase in jump height that was moderately greater than other external cues (ES ≥ 0.87, $p<0.05$), but with only a small non-significant increase compared (ES 0.54, $p >0.05$) to CONT. The data showed that all cues provided a specific response; CC reduced GCT and increased RSI, HC increased jump height and QC reduced outcomes associated with injury risk. HC may be advantageous for young soccer players with a low training age as it shows a small to moderate increase in jump height without increasing injury risk. Young players may need to be safely progressed to be able to use a CC to facilitate high reactive strength without being exposed to undue injury risk.

INTRODUCTION

Jumping is a useful training tool for many sports and the ability to jump high is a distinguishing characteristic of success in adult and young soccer players (2, 12, 13, 22, 25). Therefore, developing a soccer players' ability to quickly generate vertical power is likely to be advantageous for competition. Rebound jumping, in the form of plyometric training, is also known to provide an effective chronic training stimulus, improving jump height and transferring gains to other motor skills such as sprinting and change of direction speed in young soccer players (12, 13, 25). The positive transference of plyometric training to sports performance is likely attributed to the fact that many athletic movements require a rapid stretch-shortening cycle action, with athletes required to rebound against the ground with short ground contact periods (1, 13). Reflecting the need to utilize an effective stretch-shortening cycle, the drop jump (DJ) has been advocated as a useful training tool to enhance the performance of young soccer players (22). As a result, practitioners may target briefer contact periods and increased jump heights as desirable performance outcomes, both of which would increase the reactive strength index (RSI). Unfortunately, increased DJ performance may also expose athletes to increased injury risk due to increased landing forces (5, 14), with research demonstrating that the drop jump is also an effective tool for determining injury risk in young athletes (14, 25, 29). This means there is a need for practitioners to develop training strategies that allow young soccer players to improve DJ performance without increasing the risk of injury.

Increasing RSI during training is a desirable outcome, with DJ training that optimizes RSI leading to improvements in the jump, squat and sprint performance of young soccer players (22). This finding suggests there is merit in not only trying to maximize jump height during a DJ, but also an increased RSI via a reduction in ground contact time. However, reductions in ground contact time may also increase peak impact force, reducing the time to impact and increase landing impulse, all of which have been associated with increased ACL injury risk (1, 8). Attenuating landing impact peak force requires adequate levels of eccentric knee flexion strength, rate of force development, stretch-shortening cycle function, and leg stiffness (27), qualities that may not yet be fully developed in young soccer players. A lack of neuromuscular control and eccentric strength may predispose young athletes to greater risk of injury (5), and cues that promote a short ground contact time may further elevate this risk. However, research is needed to confirm whether or not this is the case.

Cueing is the use of verbal instructions by a coach to direct an athlete's attentional focus to a particular feature of a movement and plays a vital role in motor learning and performance outcomes (28, 29). Cues are classified as internal or external, with the former reflecting instructions that focus attention towards how the body and its segments should move and the latter focus attention towards the environment and an external outcome. External cues have been consistently shown to lead to improvements in performance outcomes (4, 29, 31). In adults, it has been reported that DJs using external cues focused on increasing jump height or reducing ground contact time had specific and differential effects on peak vGRF, RSI, rate of force development, leg stiffness, and jump kinematics (7, 15, 30). However, in terms of performance it is not known whether children would respond in a similar way given that the neuromuscular system and cognitive abilities are still developing. With regards to injury risk, it has been shown that children reduce DJ landing forces in similar way to adults when given specific cues and feedback (11, 18, 21), but to the authors knowledge no previous research in youth has examined whether cuing to reduce landing forces negatively influences performance or vice-versa. An understanding of the interaction of physical and cognitive development is needed to design training strategies to optimize training outcomes in youth (14), and this would include the need for practitioners to better understand how young athletes respond to cueing. The primary hypothesis is that during a DJ young soccer players will exhibit responses that are specific to the type of external cue given. A secondary hypothesis is that cueing would result in an interaction between performance and injury risk; cues that improved performance would increase injury risk and cues which reduced injury risk would impair performance. Thus, the current study examines the effects of different types of external cues on drop jump characteristics in young male soccer players.

METHODS

Experimental Approach to the Problem

A within-group, repeated-measures design was used to examine the acute effects of external cueing on DJ characteristics in young elite soccer players. Participants performed three DJs in each of four different conditions; control, contact cue, height cue, and quiet cue, with trials randomized and counterbalanced. The DJ is performed by stepping off a box, contacting the floor and immediately jumping as high as possible with restriction on the amount of knee and hip flexion (19).

Participants

Fourteen male, young (age:11.6±0.5 yrs; height: 148.4±8.3 cm; mass: 39.3±5.5 kg) academy soccer players volunteered to participate in the study. The academy was part of a club in the second tier of English soccer. All participants had been at the club for at least one year and had received movement competency and strength training at least three times a week for a minimum of one year. Participants were required to be able to perform DJs competently to participate in the study, this included the absence of any obvious knee valgus. All participants signed an assent form and their parents signed a consent form prior to any data collection. The project was approved by the institutional ethics committee.

Protocol

All data was collected at the training ground of the soccer club in a quiet room by the same investigator to avoid influence of external audience and noise. Each participant was requested to avoid any form of training on the day of testing and to avoid heavy meals one hour prior to data collection. Testing began with familiarization with equipment and collection of anthropometric data, however, the participants were already familiar with the DJ from prior training. The warm-up was standardized for each participant and was administered by the same investigator prior to performing the CONT condition. The dynamic warm up consisted of a 3-minute cycle on low resistance at 50 rpm, followed by a series of dynamic stretches of lower body major muscle groups, a set of 10 body weight squats, 10 jump squats and 10 lateral jumps. Post warm-up, a rest period of 30 seconds was given before the completion of three trials under the control instruction, 15 seconds rest was given between each trial with a 3-minute rest between the next set of trials. Each condition consisted of the participant stepping off a 30-cm high box onto two Pasco force plates (Pasco, Scientific, USA), landing with one foot on each plate with force then summed from both plates.

For the CONT condition the standard instructions were “with hands on hips, step off the box with one foot, land on both feet and jump as high as possible”. This instruction was selected as the only information given on how to perform the exercise without any feedback, which is typical of instructions used in previous research (7). The importance of maximal effort in each trial and maintaining a straight gaze ahead was emphasized. For the subsequent cueing conditions, the control instruction was given first and then additional cues provided in a randomized order. The cueing conditions were randomly allocated in a counter-balanced design. Other than the instructions given by the same investigator, no other guidelines or encouragement were provided. The specific instructions for each cueing condition were as follows: Contact cue (CC) used the instruction “Whilst performing the drop vertical jump, focus on spending as little amount of time on the floor as possible”. Height cue (HC) used the instruction “Whilst performing the drop vertical jump, focus on getting as close to the ceiling as possible”, this is different to the control condition as it provides an external focus of attention. Quiet cue (QC) used, the instruction “whilst performing the drop vertical jump, focus on being as quiet as possible when landing, then jump as high as possible”.

Data Processing

Data was sampled at 1000 Hz and the trials with the best jump height were taken forward for further analysis. The sensitivity of the analysis to determine contact on or off the force plates was >10 N for more than 0.05 seconds. Raw data were imported to MATLAB (MATLAB version 7.10.0. Natick, Massachusetts: The MathWorks Inc., 2010) filtered using a fourth order Butterworth filter with a cut-off frequency of 30 Hz, and then following variables were calculated: Ground contact time (ms) was determined by time from initial contact to take off. Jump height (cm) was calculated from flight time. Reactive strength index was determined by dividing the jump height (m) by the ground contact time (s) prior to take-off. Landing impulse (Ns) was determined as the time integral of the vGRF during the landing phase. Push-off impulse (Ns) was determined as the time integral of the vGRF during the take-off phase. Impact peak (N) was the peak force reached during the initial part of the ground contact period and was expressed relative to body weight (BW). Impact timing (ms) was determined as the time from landing to impact peak. Figure 1 illustrates the location of the variables on a DJ force-velocity profile.

[Figure 1 About Here]

Statistical Analysis

Data were analyzed using a 1 (time) x 4 (condition) repeated measures analysis of variance (ANOVA) to examine the main effects of condition for each dependent variable. Sphericity was examined using Maulchy's test and where violated, a Greenhouse-Geisser adjustment was applied. Condition main effects were further examined with Bonferroni post-hoc pairwise comparisons. An alpha level of $p < 0.05$ was used to determine statistical significance and SPSS v. 23 (SPSS, Inc., Chicago, IL, USA) was used to conduct the ANOVA. Given that significance and practical importance are different outcomes, percentage differences and effect sizes were calculated to describe the magnitude of differences between conditions. Effect sizes were calculated in Microsoft Excel® using Cohen's D and were interpreted as; < 0.20 trivial, ≥ 0.20-0.59 small, ≥ 0.60-1.19 moderate, ≥ 1.20-1.99 large, ≥ 2.00 very large.

RESULTS

Results for all variables are shown in Table 1, with the percentage difference for each condition to the control group displayed in Figure 2. Participants achieved the greatest jump height with the HC (23.5±5.7 cm), the shortest GCT with the CC (326±66 ms) and the lowest impact peak with the QC (3.36±1.06 BW).

The analyses revealed main effects of condition for all dependent variables ($p<0.05$). Bonferroni post-hoc comparisons revealed when using a HC participants jumped 4.6±0.8 cm and 4.1±0.7 cm higher than when using a CC ($p<0.05$, ES=0.98) and QC ($p<0.05$, ES=0.87), respectively. When using a CC participants spent 175±508 ms, 183±24 ms, and 235±13 ms less time on the ground when compared to CONT ($p<0.05$, ES=2.37), HC ($p<0.05$, ES=2.01), and QC ($p<0.05$, ES=2.97), respectively. Reactive strength index was also greater when using a CC by 0.19±0.05, 0.14±0.06, and 0.27±0.11 compared to CONT ($p<0.05$, ES=0.95), HC ($p<0.05$, ES=0.70), and QC ($p<0.05$, ES=1.35), respectively. Furthermore, when using a HC RSI was greater by 0.13±0.05 than when using a QC ($p<0.05$, ES=0.93). When using a CC participants experienced 0.35±0.13 BWs, 0.34±0.13 BWs, and 0.44±0.13 BWs greater landing impulse than CONT ($p<0.05$, ES=1.23), HC ($p<0.05$, ES= 1.17), QC ($p<0.05$, ES= 1.55). Additionally, when using a HC participants experienced 0.1 BWs greater landing impulse than QC ($p<0.05$, ES=0.86). When pushing off using CC participants experienced 0.4±0.28 BWs, 0.39±0.26 BWs, and 0.55±0.28 BWs greater push off impulse than CONT ($p<0.05$, ES=0.87), HC ($p<0.05$, ES=0.84), and QC ($p<0.05$, ES=1.19). When using a HC, push off impulse was 0.16±0.02 BWs greater when compared to QC ($p<0.05$, ES=0.77). When using a CC participants experienced 1.31±0.78 BW and 1.63±0.63 BW greater impact peak than HC ($p<0.05$, ES=0.78) and QC ($p<0.05$, ES=0.96). Finally, when using a QC impact timing was 17±4 ms greater when compared CC ($p<0.05$, ES=1.13)

[Table 1 about here]

[Figure 2 about here]

DISCUSSION

Different external cues elicited different responses related to performance and injury risk. It was consistently shown that positive responses were specific to the cue, for example, the highest jump height was achieved with the HC, the shortest GCT with the CC and the lowest impact peak with the QC. As well as positive responses being specific to the cues there were also associated changes in rebounding performance; CC markedly reduced jump height but increased RSI, impact peak and push-off impulse, QC increased GCT and reduced jump height, while HC increased jump height and RSI without simultaneously increasing impact peak.

Findings in the present study agree with prior investigations in adults that the acute responses in DJ performance are altered specifically in accordance with the nature of the external cue (7, 11, 21). When performance is the goal of the exercise, QC is the least effective external cue as it impairs GCT, RSI, jump height, and push-off impulse. Rather, CC and HC offer specific advantages over the other external cue. HC provided small to moderate increases in jump height over all external cues, while RSI, landing and push-off impulse forces were only greater than QC. When aiming to develop an explosive rebound rather than maximizing height, the CC was most effective. Although the CC reduced jump height by 6% when compared to CON this was accompanied by a 34% reduction in ground contact time, creating the condition that maximized RSI. Thus, ground contact time appears to be a variable that is particularly responsive to cueing in young soccer players and this facilitates much greater increases in RSI (+45%) than a height cue (+14%). This may mean that chronic adaptations to DJ training will be affected by the type of cue used, but more research is needed to confirm this.

The CC improved markers of performance but also increased impact peak force to an average of 5 times body weight, with some individual values considerably greater than this. Newton et al. (15) reported that a CC (7.59-9.37 BW) increased peak force compared to a HC (3.31-5.68 BW) in adults performing a DJ. The authors speculated that the increase in force may have been responsible for injuries observed during a DJ CC training intervention, with injuries also associated with lower strength. The authors also suggested that individuals with lower relative strength may not possess the neuromuscular qualities to safely engage in DJ training that includes a CC; identifying a leg strength index (DJ height/ relative maximum force) > 15 was associated with lower limb pain and drop out. As immature children (10) and individuals with a low training age (6) are known to have lower relative strength it may be prudent to use a CC cautiously with untrained young soccer players.

As landing forces during rebounding activities are associated with non-contact lower limb injuries (1, 8), researchers have been interested in identifying how DJ training can be safely coached with children and adults (11, 18, 21). The QC may be the most appropriate cue to attenuate impact force and landing impulse compared to other external cues, but this occurs at the expense of push-off impulse, jump height, GCT, and RSI. More investigation is needed to determine if this decrement in impact peak with QC coincides with increased lower limb joint displacement during landing. Noyes et al. (16) reported that after 6 weeks of neuromuscular training with both a verbal and physical component, young female athletes landed from a DJ with greater knee separation and less valgus. Young soccer players often display abhorrent mechanics during jump landings; this is most apparent in younger less mature players, with over 60% of pre-pubertal players demonstrating moderate or severe knee valgus during jump landings (23). Greater valgus during jump landings has also been shown to be related to non-contact injury incidence in elite young soccer players aged 11-12 years old (24). Therefore, it may be beneficial for practitioners to use a QC with young soccer players who demonstrate poor landing mechanics to help focus on safe landing technique and negate their already increased risk of injury.

Changes in DJ kinematics using a CC or HC have been reported in adults; when instructed with a CC smaller joint angles paired with no heel contact were observed, whereas larger joint angles and heel contact with HC (15, 30). In the current study the use of CC reduced contact time, which increased RSI but this also came at the expense of an increased impact peak and reduced time to impact. In fact, the CC was the only condition that decreased the time to peak impact force to <50 ms, which may be a concern as ACL injuries are reported to occur in the first 50 ms of ground contact during landing (8). Landing impulse was also increased by 37% compared to the control with the CC and this is also suggested to be an ACL injury risk factor (1). The results of the current study demonstrate that while external cues provide a specific response in young soccer players, practitioners must be cognizant of associated changes that may either impair performance or increase injury risk.

The ground contact times and RSI scores of the young soccer players in the present study show that participants were only able to utilize a slow stretch-shortening cycle during the DJ task. The RSI scores in the present study are similar to a modified RSI reported for adolescent athletes performing a CMJ (20). However, it is worth noting the contact times in the present study are much shorter than the ~0.8 s contraction times reported for adolescent athletes and soccer players performing a CMJ (17, 20) and similar to the ~0.4 s ground contact times reported for 16 year old soccer players and 17 year old basketball players performing a DJ from a height of 30 cm without a CC (17, 26). The relatively long contact times observed in most instances in the present study suggest participants were predominantly utilizing a countermovement drop jump technique. As per the suggestions of Struzik et al. (26), the inclusion of a cue focused on movement speed reduces contact time and will promote a shift to a bounce drop jump technique.

While the current study provides some insight into the effect of cueing in young athletes more research is needed to better understand how different types of cues, different types of jumps and other tasks, maturity, sex and training age interact to influence the response to cueing. In that regard, more cueing research is needed with larger populations of youth athletes with a range of different characteristics. For example, a limitation of the current study is that only immature players were included. As maturity status changes a relearning process happens with athletes who have gone through the growth spurt (9) and cueing may have a different response between athletes of varying maturity.

In agreement with our primary hypothesis this study shows that young male soccer players exhibit responses specific to the type of external cue used during a drop jump; a HC increased jump height, a CC decreased contact time, and a QC reduced impact force and timing as well as landing impulse. Of all the observed changes ground contact time appears to be particularly responsive to specific external cueing, with the CC reducing contact times by ~34% compared to CON. This reduction in ground contact time provided an additional performance benefit of increasing RSI by 45%. The secondary hypothesis is partly accepted, with findings demonstrating unwanted interactions when comparing some conditions; a CC dramatically improved some measures of performance but with increased risk of injury, while a QC reduced measures of injury risk but with impaired contact times and RSI compared to a CC. However, a HC was able to improve jump height without increasing injury risk when compared to the control condition. It seems possible that the repeated use of a given cue would influence the chronic training adaptations and risk of injury in young soccer players, but further research is needed to confirm this.

PRACTICAL APPLICATIONS

Practitioners should consider the type of cue used when young soccer players perform the drop jump as different cues have been shown to elicit different responses. A QC will be appropriate with young players returning from lower-limb injury and those who can be observed to have abhorrent landing mechanics (e.g. knee valgus), where it is desirable to reduce impact forces and the immediate focus is not on performance. Ground contact time is particularly sensitive to specific cueing. However, practitioners should use a CC with caution as although this will shorten contact times, increase RSI and increase push-off impulse it will also increase impact force, reduce time to impact force and increase landing impulse; all factors associated with increased injury risk. Reduced ground contact time during a DJ should be progressively developed alongside other strategies (such as integrative neuromuscular training) to help young players tolerate rapid impact forces. Importantly a CC should only be encouraged when a young athlete can produce short ground contact times in the absence of a potentially injurious impact peak (3). A HC is likely to be the most appropriate introductory cue for injury free, young soccer players performing DJs as it can maximize jump height without increasing injury risk.

REFERENCES

1. Bates NA, Ford KR, Myer GD, and Hewett TE. Timing differences in the generation of ground reaction forces between the initial and secondary landing phases of the drop vertical jump. *Clin Biomech (Bristol, Avon)* 28: 796-799, 2013.

2. Chelly MS, Ghenem MA, Abid K, Hermassi S, Tabka Z, and Shephard RJ. Effects of in-season short-term plyometric training program on leg power, jump-and sprint performance of soccer players. *J Strength Cond Res* 24: 2670-2676, 2010.

3. 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: 32-38, 2008.

4. 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.

5. Hewett TE, Myer GD, Ford KR, Heidt RS, Jr., Colosimo AJ, McLean SG, van den Bogert AJ, Paterno MV, and Succop P. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med* 33: 492-501, 2005.

6. Hoeger WWK, Hopkins DR, Barette SL, and Hale DF. Relationship between Repetitions and Selected percentages of One Repetition Maximum: A Comparison between Untrained and Trained Males and Females. *J Strength Cond Res* 4: 47-54, 1990.

7. Khuu S, Musalem LL, and Beach TAC. Verbal Instructions Acutely Affect Drop Vertical Jump Biomechanics--Implications for Athletic Performance and Injury Risk Assessments. *J Strength Cond Res* 29: 2816-2826, 2015.

8. Krosshaug T, Nakamae A, Boden BP, Engebretsen L, Smith G, Slauterbeck JR, Hewett TE, and Bahr R. Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. *Am J Sports Med* 35: 359-367, 2007.

9. Lloyd RS, Cronin JB, Faigenbaum AD, Haff GG, Howard R, Kraemer WJ, Micheli LJ, Myer GD, and Oliver JL. National Strength and Conditioning Association Position Statement of Long-Term Athletic Development. *J Strength Cond Res* 30: 1491-1509, 2016.

10. Malina RM, Eisenmann JC, Cumming SP, Ribeiro B, and Aroso J. Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *Eur J Appl Physiol* 91: 555-562, 2004.

11. McNair PJ, Prapavessis H, and Callender K. Decreasing landing forces: effect of instruction. *B J Sports Med* 34: 293-296, 2000.

12. Meylan C and Malatesta D. Effects on In-Season Plyometric Training Within Soccer Practice on Explosive Actions of Young Players. *J Strength Cond Res* 23: 2605-2613, 2009.

13. Michailidis Y. Effect of plyometric training on athletic performance in preadolescent soccer players. *Journal of Human Sport and Exercise* 10, 2015.

14. Myer GD, Kushner AM, Faigenbaum AD, Kiefer A, Kashikar-Zuck S, and Clark JF. Training the Developing Brain, Part I: Cognitive Developmental Considerations for Training Youth. *Curr Sports Med Rep* 12: 304-310, 2013.

15. Newton RU, Young WB, Kraemer WJ, and Byrne C. Effects of drop jump height and technique on ground reaction force with possible implication for injury. *Res Sports Med* 10: 83-93, 2001.

16. Noyes FR, Barber-Westin SD, Fleckenstein C, Walsh C, and West J. The drop-jump screening test: difference in lower limb control by gender and effect of neuromuscular training in female athletes. *Am J Sports Med* 33: 197-207, 2005.

17. Oliver J, Armstrong N, and Williams C. Changes in jump performance and muscle activity following soccer-specific exercise. *J Sports Sci* 26: 141-148, 2008.

18. Onate JA, Guskiewicz KM, Marshall SW, Giuliani C, Yu B, and Garrett WE. Instruction of jump-landing technique using videotape feedback: altering lower extremity motion patterns. *Am J Sports Med* 33: 831-842, 2005.

19. Pedley JS, Lloyd RS, Read P, Moore IS, and Oliver JL. Drop Jump: A technical Model for Scientific Application. *Strength Cond J* 39: 36-44, 2017.

20. Petridis L, Tróznai Z, Pálinkás G, Kalabiska I, and Szabó T. Modified Reactive Strength Index in Adolescent Athletes Competing in Different Sports and Its Relationship with Force Production. *American Journal of Sports Science and Medicine* 5: 21-26, 2017.

21. Prapavessis H, McNair PJ, Anderson K, and Hohepa M. Decreasing Landing Forces in Children: The Effect of Instructions. *J Orthop Sports Phys Ther* 33: 204-207, 2003.

22. Ramirez-Campillo R, Alvarez C, Garcia-Pinillos F, Sanchez-Sanchez J, Yanci J, Castillo D, Loturco I, Chaabene H, Moran J, and Izquierdo M. Optimal Reactive Strength Index: Is It an Accurate Variable to Optimize Plyometric Training Effects on Measures of Physical Fitness in Young Soccer Players? *J Strength Cond Res* 32: 885-893, 2018.

23. Read PJ, Oliver JL, De Ste Croix MBA, Myer GD, and Lloyd RS. Landing Kinematics in Elite Male Youth Soccer Players of Different Chronologic Age and Stage of Maturation. *J Athl Train*, 2018.

24. Read PJ, Oliver JL, De Ste Croix MBA, Myer GD, and Lloyd RS. A prospective investigation to evaluate risk factors for lower extremity injury risk in male youth soccer players. *Scand J Med Sci Sports* 28: 1244-1251, 2018.

25. Sohnlein Q, Muller E, and Stoggl TL. The Effect of 16-Week Plyometric Training on Explosive Action in Early to Mid-Puberty Elite Soccer Players. *J Strength Cond Res* 28: 2105-2114, 2014.

26. Struzik A, Juras G, Pietraszewski B, and Rokita A. Effect of drop jump technique on the reactive strength index. *J Hum Kinet* 52: 157-164, 2016.

27. 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: 1705-1715, 2008.

28. Winkelman NC. Attentional Focus and Cueing for Speed Development. *Strength and Conditioning Journal* 40: 13-25, 2018.

29. Wulf G, Zachry T, Granados C, and Dufek JS. Increases in Jump-and-Reach Height Through and External Focus of Attention. *Int J Sports Sci Coach* 2: 275-284, 2006.

30. Young WB, Pryor JF, and Wilson G, J. Effect of Instructions on Characteristics of Countermovement and Drop Jump Performance. *J Strength Cond Res* 9: 232-236, 1995.

31. Zarghami M, Saemi E, and Fathi I. External focus of attention enhances discus throwing performance. *Kinesiology (Zagreb)* 44: 47-51, 2012.

FIGURE LEGENDS

Figure 1. DJ force-velocity profile with labeled kinetic dependent variables.

Figure 2. Jump height (JH), ground contact time (GCT), reactive strength index (RSI), landing impulse (LI), push off impulse (POI), impact peak (IP), and impact timing (IT), percentage difference from CONT for each condition.

Table 1. Mean±SD of jump measures for CONT, CC, HC, & QC conditions.

Performance Measures	CONT	CC	HC	QC
Jump Height (cm)	23.5±5.7	21.4±5.5	26.0±4.7[a]	21.9±4.0
Ground Contact Time (ms)	501±74	326±66†	509±90	561±79
Reactive Strength Index	0.48±0.15	0.67±0.20*	0.53±0.14[b]	0.40±0.09
Landing Impulse (BWs)	0.98±0.15	1.33±0.28*	0.99±0.15[b]	0.89±0.15
Push Off Impulse (BWs)	1.92±0.19	2.32±0.47*	1.93±0.21[b]	1.77±0.19
Impact Peak (BW)	4.42±1.69	4.99±1.69[d]	3.68±0.91	3.36±1.06
Impact Timing (ms)	51±14	44±11	51±14	61±15[c]

* = Significantly greater than all other conditions ($p<0.05$)

† = Significantly lesser than all other conditions ($p<0.05$)

[a] = Significantly greater than CC & QC ($p<0.05$)

[b] = Significantly greater than QC ($p<0.05$)

[c] = Significantly greater than CC ($p<0.05$)

[d] = Significantly greater than HC & QC ($p<0.05$)