Jump Training in Rugby Union Players: Barbell or Hexagonal Bar?

Weakley, JJS, Till, K, Read, DB, Leduc, C, Roe, GAB, Phibbs, PJ, Darrall-Jones, J, and Jones, B

ABSTRACT

The countermovement jump (CMJ) is an exercise that can develop athletic performance. By using the conventional barbell (BAR) and hexagonal barbell (HEX) while jumping, the intensity can be increased. However, the bar that provides greater adaptations is unknown. Therefore, this study aimed to assess changes in loaded and unloaded CMJ with either a BAR or HEX across a four-week mesocycle in rugby union players. Twenty-nine subjects were strength-matched and randomised into two groups. Subjects completed three sets of CMJ at 20% of one repetition maximum back squat, three times per week for four weeks, using either a BAR or HEX. Subjects completed an unloaded CMJ upon a force plate pre and post, while the highest peak concentric velocity during the jump squat was recorded in the first and last training session using a linear position transducer. Magnitude based inferences assessed meaningful changes within- and between-groups. *Possibly* greater improvements in unloaded CMJ were found in the HEX group in jump height (Effect size±90%confidence intervals: 0.27±0.27), relative peak (0.21±0.23) and mean power (0.32±0.36). Additionally, *likely* to *very likely* greater improvements were observed in the HEX group in peak velocity (0.33±0.27), relative mean power (0.53±0.30), mean force (0.47±0.27) and 100ms impulse (0.60±0.48). Similar raw changes in jump squat peak velocity occurred (0.20-0.25m·s^{-1}), despite the *likely* greater ES occurring with the BAR (0.32±0.26). These results indicate that training with the HEX leads to superior unloaded CMJ adaptations. Additionally, practitioners should utilise either the HEX or BAR when aiming to enhance loaded jump ability.

KEY WORDS: Force; Power; Velocity; Impulse; Jump Squat; Hexagonal Barbell

INTRODUCTION

The vertical countermovement jump (CMJ) is often incorporated within exercise routines and fitness testing batteries that are aimed at developing and assessing muscular power and athletic performance (8, 15). To increase the intensity of the CMJ, additional resistance can be added via external load (e.g. barbells, dumbbells, weighted vests) (26, 27). The most common method of increasing external load during a CMJ is through the placement of a conventional barbell (BAR) over the posterior aspect of the shoulder (26). This variation of the CMJ is often referred to as the jump squat and has been recommended to be implemented within training programmes for the development of lower body power (7). By using this exercise within a resistance training programme, large improvements in physical performance have been observed (8).

An alternative to the BAR jump squat is the use of a hexagonal barbell (HEX) with recent research suggesting this may be a safer and more effective alternative (26). The HEX allows individuals to stand within its frame and hold the external load at arms length (i.e. so that resistance is held approximately parallel to the hip or upper thigh, depending on make and subject arm length) (26, 27). Recent research has demonstrated that when completing the jump squat with the HEX, athletes are able to produce greater force (effect size (ES) = 0.47), power (ES = 1.08), and velocity (ES = 0.62) at the same relative intensity (e.g. 20% of 1 repetition maximum (1RM) of the back squat) compared to the BAR jump squat (26). These greater kinetic and kinematic outputs have been attributed to the external load being positioned closer to the athletes centre of mass which can result in favourable changes to the resistance moment arms of individual joints (e.g. hips). Correspondingly, due to the increases in acute kinetic and kinematic outputs, it has been suggested that the HEX may promote

superior physical adaptations (26). However, changes from training with these different barbells have not been examined.

When performing the jump squat with a BAR or HEX, the load that optimizes power output has been subject to considerable debate (10, 26, 27). When entire system mass (i.e. external load and body mass) is accounted for, it has been suggested that 0% of 1RM (i.e. body mass alone) maximizes power output (10). However, these conclusions were made despite the lack of statistical difference between peak power outputs at both 0 and 20% of 1RM (10). Additionally, Turner et al. (27) found that peak power output in professional rugby union players in the HEX jump squat is optimized at a load of 10-20% 1RM. Nevertheless, while the load that maximizes acute peak power output in the BAR and HEX jump squat is established to be 0-20% of 1RM dependent upon individual variations (e.g. body mass, training status) (10, 26, 27), the effects of training at these intensities with these two different types of barbell has not been established.

While the HEX has demonstrated greater acute force, power, and velocity production compared to the BAR at the same relative intensities (26), training adaptations utilising these different training apparatus have not been investigated. It is feasible that exposure to greater kinetic and kinematic outputs when training could promote greater changes in physical capacity. To this end, the aim of this study was to compare the effects of training with either a BAR or HEX on CMJ performance across a four-week mesocyle within semi-professional rugby union players. Additionally, this study assessed changes in peak velocity in the BAR and HEX jump squat between the first and final training session of the four-week mesocycle.

METHODS

Experimental Approach to the Problem

To assess the effects of completing jump squats with either a BAR or HEX on jump performance, 29 semi-professional rugby union players were randomly allocated into a BAR or HEX training group during a resistance training mesocycle (refer to Table 1). All subjects completed three sets of three jump squat repetitions at the beginning of each resistance training session across the four-week mesocycle. Groups used either a conventional 20kg barbell or a 20kg hexagonal barbell that were both loaded to 20% of estimated 1RM back squat (26, 27). Subjects trained three times per week and were provided feedback on their peak concentric velocity after each repetition during all training sessions (22). Pre and post the training programme, all participants completed a body weight CMJ upon a force platform that recorded kinetic and kinematic variables. Additionally, each subject's highest peak concentric velocity value in the jump squat in the first and final (12th) training session was recorded.

Subjects

Twenty-nine male subjects (BAR group: 16 subjects; HEX group: 13 subjects) completed the training and testing protocols. Thirty-three semi-professional rugby players were initially recruited to take part in this study. However, four subjects were not included during the final analysis as they did not attend 100% of the training sessions. All subjects had at least two years of resistance training experience (3.6 ± 1.1 years) and were recruited from a British University and Colleges Super Rugby squad in the United Kingdom. The training and testing took place across the months of August and September (which is during the pre-season period of the rugby union playing calendar). Recruited subjects confirmed that they did not have any current injuries, do not consume any medications or supplements that could influence

performance and adaptations, and were not suffering from any diseases. Prior to the study, all subjects had completed a six-week standardised preparatory phase where all resistance training exercises and intensities were specified. Furthermore, all subjects had previous experience of training that involved jump squats with both the BAR and HEX. Subjects were explained the design of the study, were provided an opportunity to ask questions, and then provided informed written consent. All experimental procedures were approved by Leeds Beckett University's ethics committee and written assent was provided by all subjects.

Insert Table 1 here

Experimental Procedures

Preceding the initial testing session, all subjects were provided 72 hours active rest and then were required to complete 1) an unloaded CMJ upon a force platform (NMP Technologies Ltd., ForceDecks Model FD4000a, London, UK) and 2) a 3RM barbell back squat. Subjects were then strength matched (using maximal back squat strength) and randomly assigned into one of two groups (i.e. BAR or HEX). During the following four weeks all subjects completed 100% of the resistance (three sessions per week; refer to Table 2 for resistance training sessions) and field training sessions (three sessions per week). Each session was initiated with the subject completing a dynamic warm up and then completing three sets of three jump squats using either the BAR or HEX. Previous research (22) has utilised the same protocols (i.e. number of sessions, sets, repetitions, and intensity) to assess the effect of jump squat training on physical development. The external load for each subject in both the BAR and HEX group was prescribed at 20% of estimated back squat 1RM and adjusted to the nearest whole kilogram (3). All subjects were required to be as "explosive and as forceful" as possible during all repetitions. After every repetition of the jump squat exercise, visual

kinematic feedback of peak concentric velocity was provided by a GymAware (Kinetic Performance Technology, Canberra, Australia) linear position transducer to assist motivation and competitiveness (32). In the first and last (i.e. the 12th) resistance training session, the highest peak concentric velocity reported by the linear position transducer was recorded by the lead researcher. At the end of the four week mesocycle and 48 hours after the final training session, subjects completed another CMJ (using the same procedures that were completed during pre-testing) upon a force plate.

Countermovement Jump

Analysis of CMJ was completed pre and post the training mesocycle using a force platform (NMP Technologies Ltd., ForceDecks Model FD4000a, London, UK) which sampled at a rate of 1,000 Hz. All participants performed three CMJ's with feet placed approximately shoulder width apart and with hands placed on hips (24, 31). Participants lowered themselves to a self-selected depth and jumped as high as possible. Between each maximal exertion at least 60 seconds' rest was provided (24, 31). We chose the following CMJ variables for analysis based on previously published between-day reliability statistics in a similar cohort (25). These were CMJ height (jump height), peak velocity, relative peak and mean power, mean power and force, and impulse at 100ms. These variables were also selected due to their close relationship with physical performance (14, 33) and previous use in rugby union players (24, 30, 31).

3RM Strength Assessment

Assessment of the 3RM back squat was chosen as this is regularly completed in rugby union players of a similar standard (9, 30, 31) and is commonly used for exercise prescription (29, 31, 32). Additionally, all subjects within this cohort were familiar with the 3RM testing protocol. Players first completed a dynamic warm up which has previously been completed prior to maximal 3RM attempts (31). Maximal back squat strength was completed with a barbell (Eleiko Sport AB, Halmstad, Sweden) resting on the upper trapezium with participants grasping the bar with a pronated grip. Participants were required to lower themselves so that the top of the thigh was observed (by the lead researcher) to be parallel with the floor, while the chest was required to remain upright. Heels were to remain in contact with the ground throughout the movement, and the participant was to return to the initial standing position.

Exercise Training Routine

Table 2 outlines the resistance training protocols that all subjects undertook across the four-week mesocycle. The resistance training exercises and sessions prescribed were part of the regular preseason training routine and were based upon previous research by Randell et al. (22). There were two different training routines (session one and session two) and these were completed in an alternating order (e.g. session one during resistance training session one; session two during resistance training session two) so that each individual session was completed six times. At the beginning of each resistance training workout, a dynamic warm up would be undertaken followed by three sets of three repetitions of jump squat. Subjects within the BAR jump squat group completed the jump squat with a BAR that rested across the posterior aspect of the shoulder, while subjects within the HEX jump squat group held the HEX parallel to the hip/thigh. Both groups completed the same number of repetitions at the

same intensity across all training sessions. Following on from the jump squat, a high intensity (~85-93% of 1RM back squat) bilateral lower body movement was completed (refer to Table 2). During the back squat, depth was monitored by ensuring that all subjects touched a box so that the upper thigh was parallel to the ground. In the HEX deadlift the weight started on the ground and was raised until the participant was standing fully upright. Both movements were required to be completed with maximal intent. All other movements (e.g. 10 metre accelerations and upper body movements) were also completed with maximal intent but using methodology previously detailed within literature pertaining to resistance training in rugby union (22, 30, 31). All field sessions involved a rugby union skill emphasis with all subjects taking part in each session.

Insert Table 2 Here

Kinematic feedback and collection of peak concentric velocity

Across the training mesocycle, subjects were provided feedback of peak concentric velocity during each repetition of the jump squat. All repetitions were recorded with a GymAware linear position transducer which sampled at 50 Hz. The optical encoder, which was placed directly below the BAR or HEX during the jump squat exercise, contains a retractable cord that was attached to the barbell during each set for each subject. Velocity and displacement were calculated from the rotation of a pulley system within the optical encoder upon the movement of the barbell during the exercise (23). The encoder, which has previously been assessed as highly valid for reporting of velocity, power, and force (4), provides approximately one electrical impulse every three millimetres of barbell displacement with each value time stamped with a one-millisecond resolution. This velocity information was then transmitted to an iPad (iPad Pro, Apple Inc., Cupertino, California, USA) which was placed directly in front of subjects at standing eye level.

Statistical analysis

Data are presented as either mean ± SD or percentage/effect size (ES) ± 90% confidence intervals (90% CI) where specified. Prior to analysis, all data were log-transformed to reduce bias arising from non-uniformity error, and then analysed for practical significance using magnitude-based inferences (5). The chance of the CMJ variables or peak concentric velocity across the mesocycle being lower, similar, or greater than the smallest worthwhile change/difference (SWC/D) (i.e. 0.2 x between subject difference) was calculated using an online spreadsheet (11), with all between group comparisons of effects being further analysed using a separate spreadsheet (13). The probability that the magnitude of change was greater than the SWC/D was rated as <0.5%, *almost certainly* not; 0.5-5%, very un*likely*; 5-25%, un*likely*; 25-75%, possibly; 75-95%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly*

(12). Where the 90% Confidence Interval (CI) crossed both the upper and lower boundaries of the SWC (ES±0.2), the magnitude of change was described as *unclear* (5). ES thresholds were set at <0.2 (*trivial*), 0.2-0.6 (*small*), 0.6-1.2 (*moderate*), and 1.2-2.0 (*large*) (12).

Results

Pre and post CMJ values and corresponding within-group inferences are shown in Table 3. Standardised ES (±90%CI) and inferences comparing between group differences are presented in Figure 1. Individual subject and group mean (±SD) peak concentric velocity values reported in session one and 12 of the four week mesocycle are presented in Figure 2. Mean peak concentric velocity in session one of the BAR jump squat was 2.28 ± 0.14 m·s^{-1}. By session 12 this had increased to 2.49 ± 0.17 m·s^{-1} (ES ± 90%CI: 1.28 ± 0.25). Mean peak concentric velocity in session one of the HEX jump squat was 2.55 ± 0.20 m·s^{-1}. By session 12 this had increased to 2.78 ± 0.23 m·s^{-1} (ES ± 90%CI: 0.96 ± 0.10). Between group comparison of ES (±90%CI) changes show *likely* greater improvements in the BAR condition (0.32 ± 0.26).

Insert Table 3 Here

Insert Figure 1 Here

Insert Figure 2 Here

DISCUSSION

The aim of this study was to present and compare the effects of completing jump squat with either the BAR or HEX across a training mesocycle. After four weeks, the HEX group showed *possibly* greater improvements in CMJ height, relative peak power, and mean power. Additionally, the HEX group showed *likely* greater improvements in peak velocity and impulse at 100ms, and *very likely* greater improvements in relative mean power and mean force. Conversely, the BAR group showed *likely* greater improvements in loaded jump squat peak velocity, despite similar raw changes, due to lower initial training velocities in the jump squat. These outcomes indicate that, while both forms of jump squat training promote improvements in peak velocity at 20% of 1RM, the HEX jump squat may be a superior alternative to the BAR jump squat due to greater improvements in the unloaded CMJ power, velocity, and jump height. These findings suggest that performing HEX jump squats can promote greater adaptations in physical capacity.

Changes across the training mesocycle showed subjects within the HEX condition had *possible* improvements in jump height (ES ± 90%CI: 0.20 ± 0.25) and peak velocity (0.24 ± 0.25). Conversely, the BAR condition showed *very likely* (-0.07 ± 0.12) and *likely trivial* (-0.09 ± 0.11) changes, respectively. These findings may partially be explained by acute differences in kinematic outputs when using the BAR and HEX for jump squat (26). Swinton et al. (26) has previously shown that when these different types of bar are loaded with 20% of 1RM, the HEX allows for greater jump heights to be achieved. However, these differences were only shown to occur at 20% of 1RM. These disparities were attributed to the

12

significantly lower peak velocities that are produced when performing the jump squat with the BAR (compared to the HEX), and the close relationship this variable has with ballistic performance (17, 19). Consequently, it is possible that continued exposure to higher training velocities when using the HEX may have provided a greater stimulus for the development of jump height and peak velocity.

While *trivial* changes in peak velocity and jump height occurred within the BAR condition, *trivial* to *likely* negative changes in mean (ES $\pm$ 90%CI: -0.11 $\pm$ 0.29) and relative mean (-0.28 $\pm$ 0.16) power output were reported. Conversely, the HEX condition showed *possible* improvements in mean (0.21 $\pm$ 0.23) and relative mean (0.25 $\pm$ 0.26) power output. These differences may be explained by differences in changes in force related variables (e.g. mean force and 100ms impulse) (refer to Figure 1). Within the BAR condition, *very likely* and *likely* negative changes in mean force and impulse were reported, respectively. Conversely, these variables remained relatively stable within the HEX condition. Consequently, it is theorized that reductions in force related variables and maintenance of peak concentric velocity within the BAR condition may have caused possible decreases in power. However, it should also be noted that in the BAR group, *small* negative changes were only reported in relative power measures (e.g. relative peak and mean concentric power), while mean power reported *possibly trivial* changes. Therefore, fluctuations in body mass could also be attributed to these outcomes. Irrespectively, subjects within the HEX condition showed *possible small* positive changes in both mean and relative mean power output production. Consequently, it is suggested that the HEX be used preferentially to promote the development of power output in athletes.

Within group changes that were reported in force and impulse at 100ms demonstrate an interesting aspect of this study. While *likely* and *possibly trivial* changes in mean force (ES ± 90%CI: 0.00 ± 0.19) and impulse at 100ms (0.18 ± 0.27) occurred within the HEX group, *very likely* (-0.47 ± 0.20) and *likely* (-0.42 ± 0.41) decreases occurred within the BAR group, respectively. These reported changes suggest that training with a BAR at 20% of 1RM did not promote positive adaptations in acceleration of body mass. This loss may be particularly pertinent during initial stages of the CMJ (i.e. the first 100ms). It is thought that these changes may have occurred due to the differences in bar placement during training. Previous research has stated that the placement of the BAR upon the posterior aspect of the shoulder during the jump squat can limit forward inclination of the trunk at the bottom of the countermovement (2, 20, 28) and cause larger moment arms around the knee and reduced recruitment of the hip extensor muscles (28). These changes are known to reduce jump height and power output (28). Additionally, it has been stated that by using the HEX during the jump squat, unloaded jump performance is more closely resembled (26, 27). Consequently, these differences in jump technique and muscle recruitment may have impacted upon force generating adaptations. Considering this, the HEX may promote or maintain mean concentric and early phase force development (i.e. during the first 100ms of a CMJ) to a greater extent when compared to the barbell jump squat.

When completing jump squat with 20% of 1RM, *almost certain* improvements in peak velocity were observed in both groups across the mesocycle. While similar raw changes were reported, greater effects (± 90%CI) were observed in the BAR condition (1.42 ± 0.27 vs. 0.96 ± 0.10). This suggests that, irrespective of chosen apparatus, *moderate* to *large* improvements in peak velocity occur at the intensity that is trained. This corroborates with Cormie et al. (8) who demonstrated that athletes show the largest adaptations at the intensities that are trained.

However, these improvements in loaded jump squat performance may not have similar transference to body mass only performance (e.g. the HEX condition showed *possible* improvements in unloaded CMJ peak velocity, while the BAR condition showed *likely trivial*). This may occur for a number of reasons, but it is hypothesised that velocities completed during the HEX condition more closely replicated the velocities that were achieved when performing an unloaded jump (26, 27). Additionally, by transitioning the barbell closer to the centre of mass (i.e. during the HEX condition) athletes can more closely replicate their unloaded vertical jump technique (26).

While this study is the first to examine the physical adaptations of utilising either the BAR or HEX when performing the jump squat, it is not without its limitations. First, any potential differences in on-field training was unable to be accounted for. While all subjects within this study were from the same training squad and took part in the exact same training exercises, slight differences in rugby training loads cannot be dismissed. To counter this, the authors ensured a range of playing positions were included within each condition and that all sessions (i.e. resistance training and field) were completed. Second, due to the lack of a control group we cannot definitively state that outcomes from these two different training methods are a result of the intervention or random error when assessing within-group changes. However, as there were substantial differences between the two training groups we can make inferences about the efficacy of the HEX over the BAR for improving CMJ variables. Third, the training routine that was completed was across a four week mesocycle. While longer exposure to the training routine may have caused greater training effects, this mesocycle length was chosen as it mimics actual training practice and has ecological validity for the athletes involved (6, 22). Finally, the intensity selected for the HEX was derived from the back squat exercise. This methodology has previously been used to investigate the acute kinetic and kinematic

outputs of completing the jump squat with both the BAR and HEX (26, 27). Moreover, it was decided necessary to control for intensity utilising the back squat as the HEX jump squat utilises an explosive stretch shortening cycle action (similar to the back squat and BAR jump squat), while the HEX deadlift starts from the floor without a preceding lowering phase.

In conclusion, the HEX jump squat appears to promote greater physical adaptation in the unloaded CMJ when compared to the BAR jump squat. These results may be of benefit for athletes aiming to improve velocity, power and force characteristics. Additionally, *almost certain* improvements in peak velocity occur in the jump squat, irrespective of the type of bar that subjects use when training at 20% of 1RM of back squat. However, the greater training velocities and similarities in movement between the HEX jump squat and the unloaded CMJ may encourage greater adaptations in unloaded performance. With these findings, the practitioner is advised to utilise the HEX when programming jump squat into a training mesocycle.

PRACTICAL APPLICATION

The jump squat is a commonly used exercise that can promote lower body power and can be completed with a range of different apparatus (e.g. barbells, dumbbells, weighted vests). Findings from this study suggest that the HEX jump squat could be a superior alternative for the development of jump height, velocity, power, and force when compared to the BAR jump squat. Within this study, subjects completed three sets of three repetitions, with 2-3 minutes rest between each set at the beginning of each training session. Additionally, subjects completed this exercise with relatively light loads (i.e. 20% of 1RM back squat) as this has been reported to maintain high concentric kinetic and kinematic outputs when performing

loaded jumps. Consequently, it is suggested that practitioners utilise a similar loading

protocol that includes the HEX bar.

REFERENCES

1.   Aagaard P, Simonsen E, Trolle M, Bangsbo J, and Klausen K. Specificity of training velocity and training load on gains in isokinetic knee joint strength. *Acta Physiologica* 156: 123-129, 1996.
2.   Argus CK, Gill ND, Keogh JW, and Hopkins WG. Assessing lower-body peak power in elite rugby-union players. *J Strength Cond Res* 25: 1616-1621, 2011.
3.   Baechle TR and Earle RW. *Essentials of Strength Training and Conditioning.* Champaign, IL: Human Kinetics, 2008.
4.   Banyard HG, Nosaka K, Sato K, and Haff GG. Validity of Various Methods for Determining Velocity, Force and Power in the Back Squat. *Int J Sports Physiol Perform* Publish Ahead of Print, 2017.
5.   Batterham AM and Hopkins WG. Making meaningful inferences about magnitudes. *Int J Sports Physiol Perform* 1: 50-57, 2006.
6.   Bompa TO and Haff GG. *Periodization: Theory and methodology of training.* Champaign, IL: Human Kinetics Publishers, 2009.
7.   Cormie P, McCaulley GO, Triplett NT, and McBride JM. Optimal loading for maximal power output during lower-body resistance exercises. *Med Sci Sports Exerc* 39: 340-349, 2007.
8.   Cormie P, McGuigan MR, and Newton RU. Adaptations in athletic performance after ballistic power versus strength training. *Med Sci Sports Exerc* 42: 1582-1598, 2010.
9.   Darrall-Jones JD, Jones B, and Till K. Anthropometric and Physical Profiles of English Academy Rugby Union Players. *J Strength Cond Res* 29: 2086-2096, 2015.
10.   Dayne AM, McBride JM, Nuzzo JL, Triplett NT, Skinner J, and Burr A. Power output in the jump squat in adolescent male athletes. *J Strength Cond Res* 25: 585-589, 2011.
11.   Hopkins W. Reliability from consecutive pairs of trials (Excel Spreadsheet). *Sportsci* 10: 50-53, 2006.
12.   Hopkins W, Marshall S, Batterham A, and Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc* 41: 3, 2009.
13.   Hopkins WG. A spreadsheet for combining outcomes from several subject groups. *Sportsci* 10: 50-53 2006.
14.   Hori N, Newton RU, Andrews WA, Kawamori N, McGuigan MR, and Nosaka K. Does performance of hang power clean differentiate performance of jumping, sprinting, and changing of direction? *J Strength Cond Res* 22: 412-418, 2008.
15.   Laffaye G, Wagner PP, and Tombleson TIL. Countermovement Jump Height: Gender and Sport-Specific Differences in the Force-Time Variables. *J Strength Cond Res* 28: 1096-1105, 2014.
16.   Linthorne NP. Analysis of standing vertical jumps using a force platform. *Am J of Physics* 69: 1198-1204, 2001.
17.   Mann JB, Ivey PA, and Sayers SP. Velocity-based training in football. *Strength Cond J* 37: 52-57, 2015.
18.   McBride JM, Triplett-McBride T, Davie A, and Newton RU. The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res* 16: 75-82, 2002.
19.   Moir GL. Three different methods of calculating vertical jump height from force platform data in men and women. *Meas Phys Educ Exerc Sci* 12: 207-218, 2008.
20.   Mundy PD, Smith NA, Lauder MA, and Lake JP. The effects of barbell load on countermovement vertical jump power and net impulse. *J of Sports Sci* 35: 1-7, 2017.
21.   Pareja-Blanco F, Rodriguez-Rosell D, Sanchez-Medina L, Gorostiaga EM, and Gonzalez-Badillo JJ. Effect of movement velocity during resistance training on neuromuscular performance. *Int J Sports Med* 35: 916-924, 2014.

22. Randell AD, Cronin JB, Keogh JW, Gill ND, and Pedersen MC. Effect of instantaneous performance feedback during 6 weeks of velocity-based resistance training on sport-specific performance tests. *J Strength Cond Res* 25: 87-93, 2011.

23. Randell AD, Cronin JB, Keogh JW, Gill ND, and Pedersen MC. Reliability of Performance Velocity for Jump Squats under Feedback and Nonfeedback Conditions. *J Strength Cond Res* 25: 3514-3518, 2011.

24. Roe G, Till K, Darrall-Jones J, Phibbs P, Weakley J, Read D, and Jones B. Changes in markers of fatigue following a competitive match in elite academy rugby union players. *S Afr J Sports Med* 28: 1-4, 2016.

25. Roe, G., Darrall-Jones, J., Till, K., Phibbs, P., Read, D., Weakley, J., & Jones, B. (2016). Between-Day Reliability and Sensitivity of Common Fatigue Measures in Rugby Players. *Int J Sports Physiol Perform, 11*, 581-586.

26. Swinton PA, Stewart AD, Lloyd R, Agouris I, and Keogh JW. Effect of load positioning on the kinematics and kinetics of weighted vertical jumps. *J Strength Cond Res* 26: 906-913, 2012.

27. Turner TS, Tobin DP, and Delahunt E. Optimal loading range for the development of peak power output in the hexagonal barbell jump squat. *J Strength Cond Res* 29: 1627-1632, 2015.

28. Vanrenterghem J, Lees A, and Clercq DD. Effect of Forward Trunk Inclination on Joint Power Output in Vertical Jumping. *J Strength Cond Res* 22: 708-714, 2008.

29. Weakley JJ, Till K, Read DB, Phibbs PJ, Roe G, Darrall-Jones J, and Jones BL. The Effects of Superset Configuration on Kinetic, Kinematic, and Perceived Exertion in the Barbell Bench Press. *J Strength Cond Res* Publish Ahead of Print, 2017.

30. Weakley JJS, Till K, Darrall-Jones J, Roe GAB, Phibbs PJ, Read D, and Jones BL. Strength and Conditioning Practices in Adolescent Rugby Players: Relationship with Changes in Physical Qualities. *J Strength Cond Res* Ahead of Print, 2017.

31. Weakley JJS, Till K, Read DB, Roe GAB, Darrall-Jones J, Phibbs PJ, and Jones B. The effects of traditional, superset, and tri-set resistance training structures on perceived intensity and physiological responses. *Euro J App Physiol* 117: 1877-1889, 2017.

32. Weakley JJS, Wilson KM, Till K, Read DB, Darrall-Jones J, Roe GA, Phibbs PJ, and Jones BL. Visual feedback attenuates mean concentric barbell velocity loss, and improves motivation, competitiveness, and perceived workload in male adolescent athletes. *J Strength Cond Res* Ahead of pre ss, 2017.

33. Winter EM, Abt G, Brookes FB, Challis JH, Fowler NE, Knudson DV, Knuttgen HG, Kraemer WJ, Lane AM, van Mechelen W, Morton RH, Newton RU, Williams C, and Yeadon MR. Misuse of "Power" and Other Mechanical Terms in Sport and Exercise Science Research. *J Strength Cond Res* 30: 292-300, 2016.

Table 1. Mean ± SD descriptive data of BAR and HEX groups.

Table 2. Resistance training sessions completed in an alternating order across the mesocycle.

1   **Table 3.** Mean ± SD pre and post countermovement jump variable outputs and corresponding
2   inferences.
3

1 **Figure 1.** Standardised effect size (±90%CI) change in countermovement jump variables and
2 corresponding inference and effect size of between group differences. ES = Effect size.

3

1   **Figure 2.** Individual and group mean (±SD) changes in peak concentric velocity in sessions
2   one and 12.
3

Table 1

Table 1. Mean ± SD descriptive data of BAR and HEX groups.

	BAR	HEX
Age (years)	20.8 ± 1.0	21.4 ± 1.6
Height (cm)	184.2 ± 6.1	186.1 ± 6.6
Body mass (kg)	95.8 ± 11.0	94.9 ± 9.7
3RM back squat (kg)	153.9 ± 19.7	154.8 ± 20.3
Estimated 1RM back squat (kg)	165.5 ± 21.2	166.5 ± 21.8
Prescribed jump squat load (kg)	33.1 ± 4.2	33.3 ± 4.4

Table 2

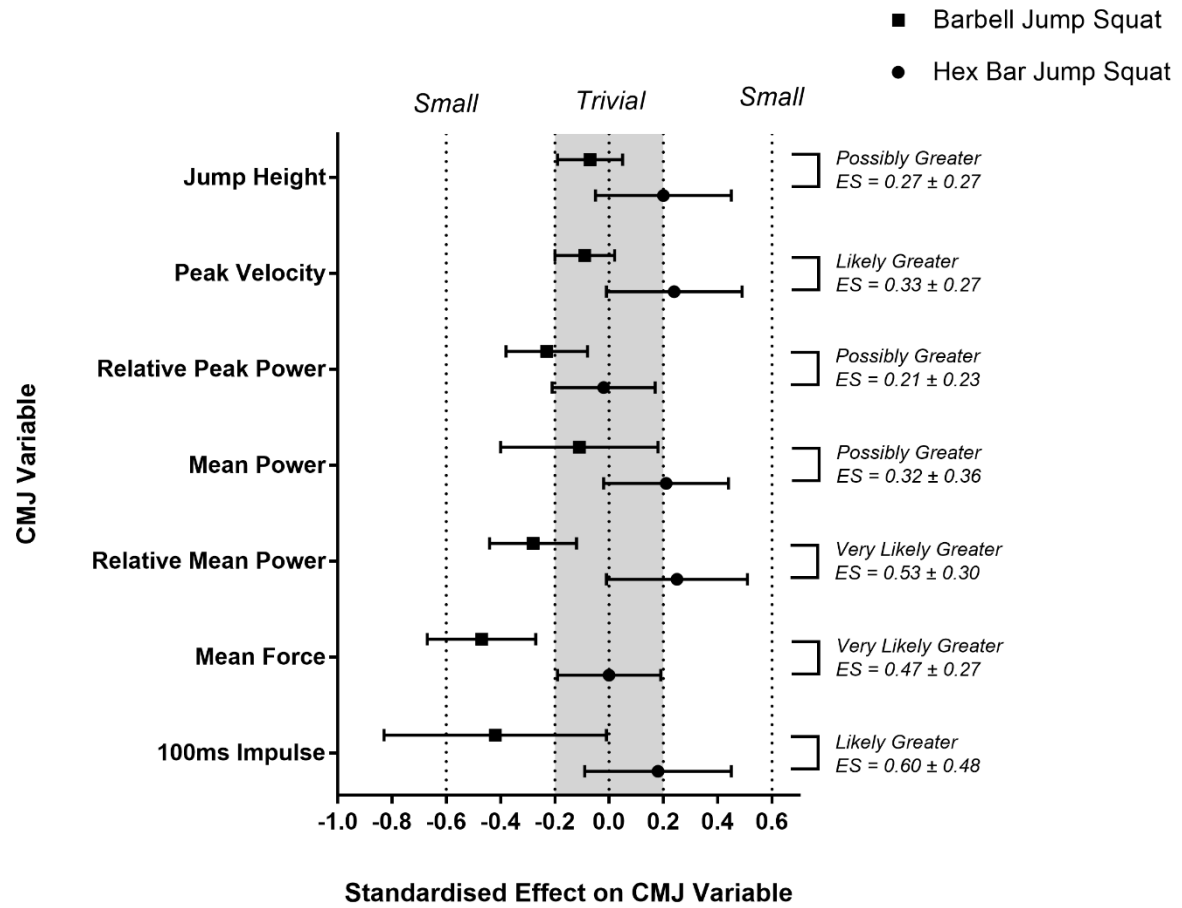**Table 2.** Resistance training sessions completed in an alternating order across the mesocycle.

	Session 1	*Session 2*	**Sets x repetitions (week 1,2,3,4)**
Squat Jump	*Bar or Hex Jump Squat**	*Bar or Hex Jump Squat**	Weeks 1-4: 3 sets of 3 repetitions at 20%
Bilateral Lower body	*Back Squat**	*Hex Bar Deadlift**	Week 1: 3 sets of 5 repetitions at 85% Week 2: 3 sets of 4 repetitions at 87% Week 3: 3 sets of 3 repetitions at 90% Week 4: 3 sets of 2 repetitions at 93%
Upper body push/pull	*Bench Press*	*Bent Over Row#*	Week 1: 3 sets of 5 repetitions at 85% Week 2: 3 sets of 4 repetitions at 87% Week 3: 3 sets of 3 repetitions at 90% Week 4: 3 sets of 2 repetitions at 93%
Horizontal Jump	*Standing Broad Jump*	*Standing Broad Jump*	Weeks 1-4: 3 sets of 2 repetitions with body mass
Acceleration	*15 m Acceleration*	*15 m Acceleration*	Weeks 1-4: 2 sets of 2 repetitions with body mass
Hip/Hamstring	*Single Leg Glute Bridge*	*Nordic Drops*	Weeks 1-4 3 sets of 4 repetitions with body weight (Nordic drops) 3 sets of 10 repetitions with body weight (single leg glute bridge)
Abdominal	*Side Plank*	*Front Plank*	Weeks 1-4: 3 sets of 1 minute repetitions with body weight

* = intensity based as a percentage of estimated 1RM back squat. # = intensity based as a percentage of bench press estimated 1RM.
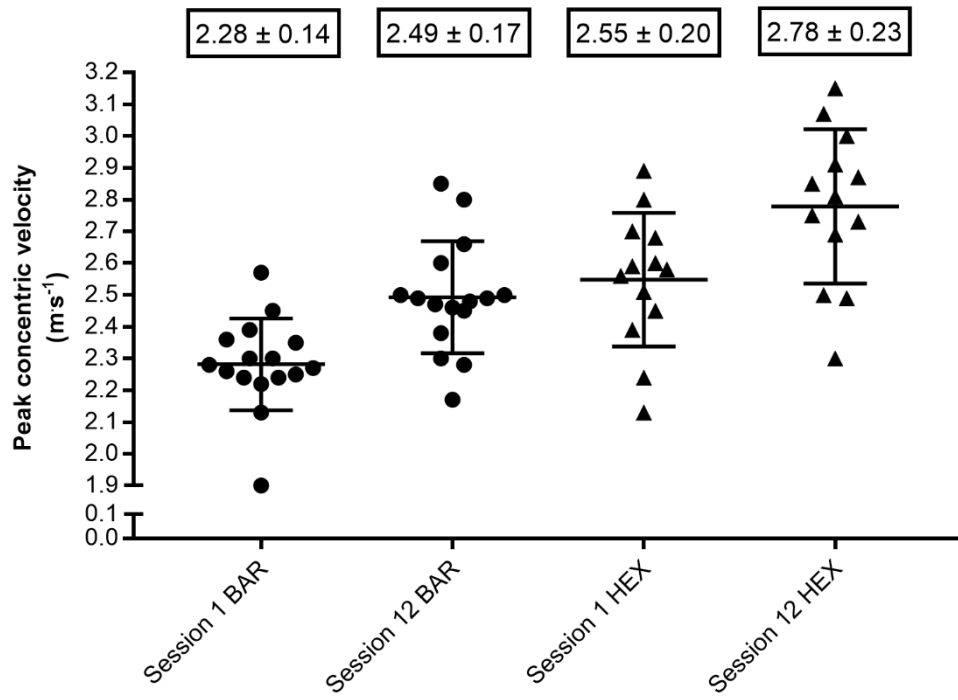
Table 3

Table 3. Mean ± SD pre and post countermovement jump variable outputs and corresponding inferences.

	BAR			HEX		
	Pre	**Post**	**ES ± 90%CI** **Inference**	**Pre**	**Post**	**ES ± 90%CI** **Inference**
Jump height (cm)	40.4 ± 11.8	39.5 ± 11.2	-0.07 ± 0.12 Very likely ↔	40.4 ± 5.1	41.4 ± 6.2	0.20 ± 0.25 Possible ↑
Peak velocity (m·s⁻¹)	2.85 ± 0.32	2.82 ± 0.33	-0.09 ± 0.11 Likely ↔	2.88 ± 0.20	2.93 ± 0.21	0.24 ± 0.25 Possible ↑
Relative peak power output (W·kg⁻¹)	52.85 ± 9.67	50.73 ± 9.54	-0.23 ± 0.15 Possible ↓	54.1 ± 7.6	54.0 ± 7.2	-0.02 ± 0.19 Likely ↔
Mean power output (W)	2999.6 ± 288.0	2839.0 ± 278.2	-0.11 ± 0.29 Possibly ↔	2795.9 ± 529.7	2905.2 ± 397.8	0.21 ± 0.23 Possible ↑
Relative mean power output (W·kg⁻¹)	30.2 ± 6.2	28.6 ± 5.8	-0.28 ± 0.16 Likely ↓	28.6 ± 4.3	29.7 ± 3.3	0.25 ± 0.26 Possible ↑
Mean force (N)	1990.6 ± 211.0	1893.2 ± 183.6	-0.47 ± 0.20 Very likely ↓	1905.6 ± 287.6	1906.4 ± 237.4	0.00 ± 0.19 Likely ↔
Impulse - 100ms (Ns)	132.0 ± 17.9	124.7 ± 14.5	-0.42 ± 0.41 Likely ↓	114.5 ± 41.6	121.4 ± 26.5	0.18 ± 0.27 Possibly ↔

ES ± 90%CI = Effect size ± 90% confidence interval; ↓ = decrease; ↑ = increase; ↔ = trivial.

Figure 1. Standardised effect size (±90%CI) change in countermovement jump variables and corresponding inference and effect size of between group differences. ES = Effect size.

Figure 2. Individual and group mean (±SD) changes in peak concentric velocity in sessions one and 12.