Fast-Speed Compared to Slow-Speed Eccentric Muscle Actions are Detrimental to Jump Performance in Elite Soccer Players In-Season

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ABSTRACT

Purpose: To examine the effect of fast-speed vs. slow-speed eccentric muscle actions resistance training on lower-body strength, vertical jump height, sprint speed and COD performance in elite soccer players during a competitive season. **Methods:** Twenty-two elite soccer players, from a single team, were randomly selected to groups that undertook either 1 s (fast speed [1S]) or 4 s (slow speed [4S]) eccentric resistance training during the in-season period. A five-week programme was conducted during an elite top division European League soccer season. Performance measures, including predicted one repetition maximum (1RM) back squat, countermovement jump (CMJ), 20 m sprint and change of direction (COD) were tested before and after the intervention period. Total match and training running distance and muscle soreness were also recorded during each week of the intervention. **Results:** An ANCOVA showed significant group effects (P = 0.01) for CMJ with a greater jump height in the 1S group post-intervention (95% CI [1.1 to 6.9 cm]). Despite an overall increase in 1RM pre- to post-training (95% CI [10.0 kg to 15.3 Kg], ES: 0.69), there were no significant differences (P > 0.05) between groups after the intervention. Similarly, there were no differences between groups for COD, 20 m sprint or muscle soreness. **Conclusion:** Faster eccentric muscle actions may be superior for increasing jumping movements in elite soccer players in-season.

Keywords

Football, Lengthening Contractions, Strength, Speed, Change of Direction, Jumping

INTRODUCTION

Soccer is a highly demanding team sport, requiring high levels of aerobic and anaerobic capacity, speed, agility, strength, and power to underpin proficient performance [1]. Physical activities, such as sprinting and rapid change of direction (COD), occur during critical moments of the game, potentially being decisive in determining the result [2]. Resistance training has consistently shown to enhance physical performance in soccer players [3]. However, incorporating regular resistance training sessions during the in-season period is challenging for practitioners at the elite level due to frequent fixture congestion and minimal recovery time (>72 hours) to optimise match-play performance [4]. Recent evidence has also suggested that elite soccer players may experience increased fatigue across a season, resulting in reduced physical performance [5]. Consequently, it is essential that the optimal resistance training load is prescribed to soccer players to manage this fatigue whilst also striving for positive adaptations to the applied stimuli.

Resistance training generally consists of dynamic muscle actions that can be classified into two fundamental types: concentric and eccentric [6]. When comparing force production between concentric and eccentric muscle actions, it is proposed that eccentric actions produce from 20 to 60% more force [7] whilst eliciting greater improvements in total concentric and eccentric strength [6]. The superiority of eccentric actions is possibly due to greater increases in volitional drive [8] and unique structural adaptions, such as increased fascicle length [9], greater increases in muscle mass [6] and specifically greater increases in type II fibre area [10]. It is well-established that developing eccentric strength is important for enhancing athletic movements, such as COD, speed and vertical jump height [11]. However, high load eccentric muscle actions are associated with exercise-induced muscle damage [12] and may lead to excessive fatigue in soccer players in-season. Moreover, only a limited amount of research has focused on increasing the time under (TUT) tension during submaximal eccentric intensities [13-16].

Due to the increased metabolic demand from reduced blood flow, greater hypertrophic adaptions have been reported during sustained compared to intermittent muscle actions [17]. Performing slower, as opposed to faster, submaximal eccentric actions may attenuate exercise-induced muscle damage and further enhance muscle strength during traditional resistance training programmes (where the load is prescribed from the concentric one repetition max) [13]. Pereira et al. [13] examined the effects of fast-speed (1 s) vs. slow-speed (4 s) eccentric phase with a 1 s concentric phase in well-trained adults. Their results indicated that slow-speed eccentric contractions enhanced muscle hypertrophy and strength compared to fast-speed eccentric training. However, other researchers have suggested that increasing the eccentric duration of the muscle action has limited additional benefit on performance in tasks [14,15] or may even be attenuate adaptations in some cases [16]. Furthermore, as increased TUT leads to an increase in metabolic demand [18] with a resultant increase in peripheral fatigue [19], the suitability of increasing contraction time needs to be further investigated in team sports.

With the decrease in match running output and associated fatigue in professional soccer across a season [5], slow eccentric muscle actions [18] may provide an additional metabolic stimulus that could be detrimental for short-term performance. Compared to slower, quicker submaximal contractions have been shown to elicit greater eccentric overload, even at lower eccentric loads [20]. In addition, to maximise changes in fast eccentric strength, it has been demonstrated that fast eccentric resistance training may be more appropriate at improving fast eccentric strength [21,22]. Soccer activity consists of rapidly lengthening eccentric actions that are executed through repeated decelerations and rapid changes of direction [23]. Accordingly, it seems logical that the incorporation of fast lengthening muscle actions may be superior to slow muscle actions in improving dynamic tasks on the field of play. Consequently, it is currently unclear if manipulating the eccentric muscle actions duration during a resistance training programme could further enhance or, indeed, have a detrimental effect on athletic ability in professional soccer players.

Therefore, the purpose of this study was to implement a short, in-season resistance training intervention and to examine the effect of fast-speed vs. slow-speed eccentric muscle actions on lower-body strength, vertical jump height, sprint speed and COD performance in elite soccer players during a competitive season. It is hypothesised that fast-speed eccentric muscle actions will elicit a greater increase in lower-body strength, vertical jump height, sprint speed and COD performance.

Methods

Participants

A sample of 22 elite-level professional soccer players (age = 22 $\pm$ 3 years, stature = 1.82 $\pm$ 0.06 m, 76.8 $\pm$ 6.3 kg) from the top division of a European League took part in the study. All participants had a minimum of 2 years resistance training experience. Fitness testing was conducted in the middle of the season (across February and March) where there was a period of four competitive matches. Across the 5-week period, players participated in 18 soccer-specific team training sessions and four matches and one 11-Vs-11 non-competitive match. During the 18 team training sessions, three conditioning sessions were implemented focusing on soccer-specific aerobic conditioning through small-sided games. All the participants provided informed consent prior to the study and completed a minimum of two weeks of full first team squad training preceding the intervention and were injury free. Ethical approval was gained through the institutional ethics committee.

Procedures

Fitness testing was conducted in the middle of the season (across February and March) where there was a period of four competitive matches. All testing was completed on a single day, at least 48 h after a match and was preceded with a dynamic warm-up that lasted approximately ten minutes. The warm-up included three minutes of low-intensity jogging followed by two minutes of bodyweight activation exercises (including squats, lunges, and single-leg Romanian deadlifts). The last five minute consisted of dynamic stretching exercises, (quadriceps, adductor, abductor, gluteal, hamstring, and gastrocnemius muscle groups). During the sprint and COD tests, two submaximal efforts were performed to prepare the participant for the subsequent maximal efforts. The countermovement jump (CMJ) was performed first, followed but the sprint, COD and finally the maximal strength test.

One Repetition-Max (1RM)

Maximal strength was analysed using the barbell back squat exercise. Participants were instructed to place their feet shoulder-width apart with the Olympic barbell placed on top of the shoulders. Participants descended into the squat position until their quadriceps were parallel with the floor, which was verified by the strength and conditioning coach. The warm-up protocol consisted of two sets of five repetitions with an Olympic barbell, followed by five repetitions of 40-60% of participants' perceived five-repetition-max. Subsequently, after three minutes of full recovery after each set, the participants were instructed to increase the load incrementally until they were unable to perform five complete repetitions. From this information, the athlete's one repetition-max (1RM) was calculated using the Epley formula [24].

Countermovement Jump

CMJ was measured using a contact platform (Chrono Jump, Bosco System, Barcelona, Spain) and analysed with the software (ChronoJump 1.5.0). The participants were informed to place their hands on their hips throughout the duration of the jumps. Participants performed two jumps with three minutes rest between each effort [15]. The participants were cued to jump as high as possible, maintaining in the air for a long as possible. The best attempt was recorded. An intraclass correlation coefficient (ICC) of 0.94 has been reported for 20 m sprint test [25].

20 m Sprint Test

Sprint time was measured by analysing 20 m sprint times from a standing start using two pairs of timing gates (Witty Timing System, Microgate, Bolzano, Italy) placed at 0 m and 20 m. All testing was conducted on synthetic grass. The front foot was placed 0.5 m behind the first timing gate. The participants performed two sprints with 3 min recovery between each sprint. The same footwear was used across all sprints. The fastest time was used for the analysis. An ICC of 0.98 has been reported for the CMJ test [26].

505-Agility

Participants performed the 505-agility test to evaluate COD ability [27]. The players adopted the same standing start position as in the 20 m sprint test (0.5 m behind the start line). A single timing gate was set up at the start line. Participants were instructed to sprint forward from the 15 m line. The timing began once crossed the 5 m timing gate at start line. They then performed a 180° turn at the 5 m mark and ran 5 m back through the timing gate. A total of four attempts were executed (two with the right foot and two with the left) with three minutes of recovery between each attempt. The fastest attempt on each side was recorded for analysis, with the mean then reported across both sides. An ICC of 0.97 has been reported for the 505-agility test [28].

Resistance Training Intervention

The participants were semi-randomly allocated into two resistance training groups, that were balanced for position and 'starters' Vs 'non-starters' with eleven participants in each. Groups were defined first and then randomly allocated their training intervention. The fast-speed eccentric duration group (1S) executed exercises with a one second eccentric phase, followed by a maximal intent concentric contraction. The slow-speed eccentric duration group (4S) performed a four second eccentric contraction, with a maximal intent concentric contraction. Each resistance training session was performed at the same time of day with the same recovery duration between the previous soccer-specific session. Implementing a training protocol of two strength sessions per week, across a four-week period, the participants participated in eight individual strength sessions (higher volume; n = 4 and lower volume; n = 4). Table 1 shows a full breakdown of the resistance training programme. A progressive increase in load (kg) of approximately 2-5% per micro-cycle (two training sessions) was used across the eight resistance training sessions (over five weeks). During the low volume sessions, the participants performed one main core exercise with one supplementary power-based exercise. Both strength sessions were separated by 48 h to allow for sufficient recovery. During every strength session, experienced strength and conditioning coaches were present and timed every repetition using a standardised stopwatch. The coaches provided verbal and visual cues to the participants when deemed necessary, specifically around controlling the movement through the eccentric phase. When a participant was unable to perform the repetitions at the prescribed speed, the load was reduced by approximately 10% to ensure all the remaining repetitions were completed in line with the study protocol.

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Perceived Muscle Soreness

Muscle soreness was collected as part of the clubs internal monitoring process. Data was collected after 48 hours after the "higher volume" resistance training session. Participants were asked to rate their perceived muscle soreness on a scale of that ranged from one (unbearable soreness pain) to 10 (completely fresh).

Global Positioning Systems

During all on-field training sessions and matches, players wore a tightly-fitted vest, with a Global Positioning Systems (GPS) device (STATSports Apex, Ireland) secured inside, positioned between the shoulder blades [29]. The GPS devices sampled at 10 Hz and housed a 100 Hz tri-axial accelerometer. Devices were switched on 15 min before the start of training or a match. Total distance and sprint distance (> 7 m/s) were recorded across each week and used to quantify external on-field training load [30].

Statistical Analysis

Data were screened visually for normality using Q-Q plots. All data are presented as mean ± standard deviation. For maximal strength, 20 m sprint COD and CMJ, a One-way Analysis of Covariance (ANCOVA) was used to analyse between-group differences, with baseline measures as the covariate. Confidence intervals (CI: 95%) and Cohen's *d* effect sizes (ES) [31] were used to describe changes across time. Average muscle soreness, total distance and sprint distance across each week were analysed with a five (week) by two (group) repeated measures Analysis of Variance (ANOVA). Where significant differences were observed, pairwise comparisons were followed-up with Bonferroni post hoc tests, 95% confidence intervals and Cohen's *d* ES to interpret the magnitude of the difference. ES were set as trivial (<0.25), small (0.25–0.50), moderate (0.50–1.0), or large (>1.0). All statistical analysis was performed using SPSS Statistics 24 (IBM, USA) and statistical significance was set at 0.05

RESULTS

Changes in 1 RM Squat, CMJ, 20 m sprint and COD are presented in Figure 1. The ANCOVA revealed no significant differences between groups for predicated 1RM (P = 0.57). However, there was a *moderate* overall increase in 1RM (ES: 0.69; 95% CI [10.0 kg to 15.3 kg]). The ANCOVA showed no significant difference between groups for 20 m sprint but there was a *small* overall increase across both groups pre- to post-intervention (ES: 0.34; 95% CI [0.01 to 0.08 s]). CMJ showed significant group effects ($F_{(1,19)}$ = 8.2, P = 0.01), with a greater jump height for the 1S group post-intervention (95% CI [1.1 to 6.9 cm]). There were also no significant difference between groups for COD (P = 0.44).

INSERT FIGURE ONE ABOUT HERE

Figure 2 shows muscle soreness, on-pitch total distance, and sprint distance across the four weeks for the 1S and 4S groups. There was no significant difference between groups for muscle soreness (P = 0.08); however, there was a significant main effect ($F_{(3,60)}$ = 8.5, P < 0.001) across time. Muscle soreness was significantly lower (P < 0.05) on weeks 2, 3, and 4 compared to week 1. Total distance across the week also had a significant effect across time ($F_{(3,51)}$ = 11.9, P < 0.001) but no significant difference between groups (P = 0.17). Participants covered significantly (P < 0.05) greater distance in weeks 2 and 4 compared to 1 and 3. No significant differences across weeks (P = 0.11) or between groups (P = 0.67) were found for sprint distance.

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DISCUSSION

The aim of this study was to assess the effects of increasing TUT during eccentric muscle actions on physical performance during the season in elite soccer players. This is the first study to manipulate TUT during the eccentric phase of a resistance training programme and evaluate the impact on physical performance within elite soccer players. The main findings from the study suggest that increasing TUT during the eccentric phase of a resistance training programme, provides no additional benefits to strength adaptions and may even be detrimental to jumping movements in professional soccer players in a short resistance training intervention.

Despite the overall *moderate* increase in maximal strength observed after the resistance training programme, there were no differences between the 1S and 4S group. Literature has reported mixed findings around the effect of the eccentric phase length on 1RM. A greater changes in strength following 4 s eccentric muscle action when compared to 1 s has previously been shown [13], though these changes are largely based on differences in effect sizes. Our findings oppose previous results in amateur soccer, showing prolonging the eccentric phase is detrimental for enhancing strength [14], with our results showing that eccentric duration length has no effect on strength changes. The reason for the differences may be related to the higher training status of our athletes and thus may not respond to the increase metabolic demand associated with longer duration muscle actions.

Overall *Moderate* group increases in strength were still evident in our study from only five weeks of resistance training, in elite soccer players. It should be noted that whilst the improvement in strength from resistance training is unsurprising, ours is one of only a limited number of studies investigating changes in strength in elite soccer players during the in-season period [32]. One strength session per week in-season has been suggested to maintain strength, whilst two sessions per week have demonstrated improvements [3]. Our results add to these data, showing as little as one high- and one low-volume resistance training session per week can increase lower-body strength in professional soccer players in-season, though dose-response studies should be conducted to test our observational finding.

Similar to 1RM, there were no differences in 20 m sprint time after the resistance training programme. The result from the current study supports O'Brien et al. [15], who found no improvements in shorter sprint performance after conducting a similar four week slow speed eccentric (4-seconds) strength intervention in well-trained female basketball players. Furthermore, an investigation by Cook et al. [33] measured the effects of controlled tempo (3 s) eccentric resistance training (80% 1RM) on 40 m sprint performance with semi-professional rugby players over a three-week period. The authors demonstrated controlled (3 s) eccentric muscle actions alone induced no changes in sprint speed; however, once additional overspeed exercises (i.e., downhill running) were combined with controlled eccentric strength training, an increase in sprint speed was evident. It therefore appears that modifying eccentric speed during a resistance training programme has no impact on sprint times.

There was an overall decline in sprint times across the intervention. This was a little surprising given the increase in predicted 1RM found in our study and previously reported relationship between strength and 20 m sprint times (i.e. stronger individuals have a quicker 20 m sprint time [34]). Increases in sprint times have previously been reported following two-thirds of a season [35] and reductions in sprinting match output (> 7 m/s) have also been found towards the end of the season [5]. As our study took place during a five-week period, with only four competitive matches, it is unlikely that chronic neuromuscular fatigue contributed to the increase in sprint times. Even though the players in our study were accustomed to resistance training, the rigid nature of a training intervention within a professional football club may have increased neuromuscular fatigue. Half of the participants were also performing 4 s eccentrics which may have also contributed to the overall group change. Finally, post experimental testing is only a single point and thus training within the days before the sprint test may have affected the results.

Countermovement jump height was lower in the 4S group compared to the 1S group following the five-week period. Interestingly, across a four-week squat resistance training programme, Mike et al. (2017) also reported that longer eccentric muscle actions (6 s) caused a reduction in peak take off jump squat velocity compared to 2 s and 4 s actions. The 2 s group also showed an increase in vertical jump height. Although TUT tension is an important factor for maximising hypertrophic adaptations and strength [17], it appears that to maximise ballistic movements in the short term, faster eccentric muscle actions are superior. The longer eccentric muscle actions may attenuate any potential adaptations from the stretch-shortening reflex associated with quicker eccentric muscle actions, though further research is needed in this area. A greater amount of eccentric overload has also been shown in faster speed eccentric muscle actions, due to the quick speed of the muscle actions [20]. Therefore, the larger adaptive response seen here in the CMJ could also be explained by a greater eccentric overload in the 1S group.

There was no difference in the COD between the 1S and the 4S group post-resistance training. As CODs demand than an athlete execute both fast and slow eccentric muscle actions in quick succession, it may be logical to suggest that a periodised programme containing varying muscle action velocities is optimal, though it is beyond the scope of these findings. Change of direction is recognised as a complex skill that requires several important components (i.e., technical efficiency, speed, and specific leg muscle qualities) to be successful [36]. No technical coaching in relation to COD was provided in this study and this could, therefore, have contributed to lack of overall change and between groups.

Despite the four times higher TUT in the 4S group there were no differences in muscle soreness between the two groups. Mike et al.[16] showed a reduction in muscle soreness in week four compared to week one, in the six second compared to the two second resistance training group. The participants within our study were trained elite soccer players so any difference in soreness between the two interventions are likely to have been smaller and potentially undetectable. Despite no difference between the on-field demands between our two groups, the on-field training may have also influenced the findings of the muscle soreness results.

A potential limitation of the current study is the short duration of the training intervention. It may be unrealistic to obtain meaningful improvements in sport-specific performance measures with elite level athletes in this short time period. Elite athletes require a long-term training development plan to elicit meaningful adaptations when compared to well-trained or recreational athletes. A further limitation is that there was only one post-intervention testing session. Because increased TUT induces greater acute fatigue and potentially prolongs the neuromuscular adaptation phase [19], it may be plausible the 4S group may have improved performance if the tests were conducted some weeks after the intervention when the participants had sufficiently recovered from the rigours of the training stimulus.

CONCLUSION

The findings from this study suggest that shorter duration eccentric muscle actions are superior for increasing lower-body jumping movements in-season, within elite soccer players. The increased TUT of the eccentric muscle action may be detrimental to jumping performance and potentially not recommended for elite soccer players in-season. A final observation from the study is that notable increases in lower-body strength were found across the short resistance training period from only a single high-volume and low-volume resistance training session.

PRACTICAL IMPLICATIONS

- Eccentric contraction duration during resistance training programmes has no influence on changes in strength.
- Longer eccentric contractions attenuate CMJ height and should be avoided during a professional soccer season.
- Both sprint speed and COD is not limited by eccentric contraction duration during resistance training programmes.

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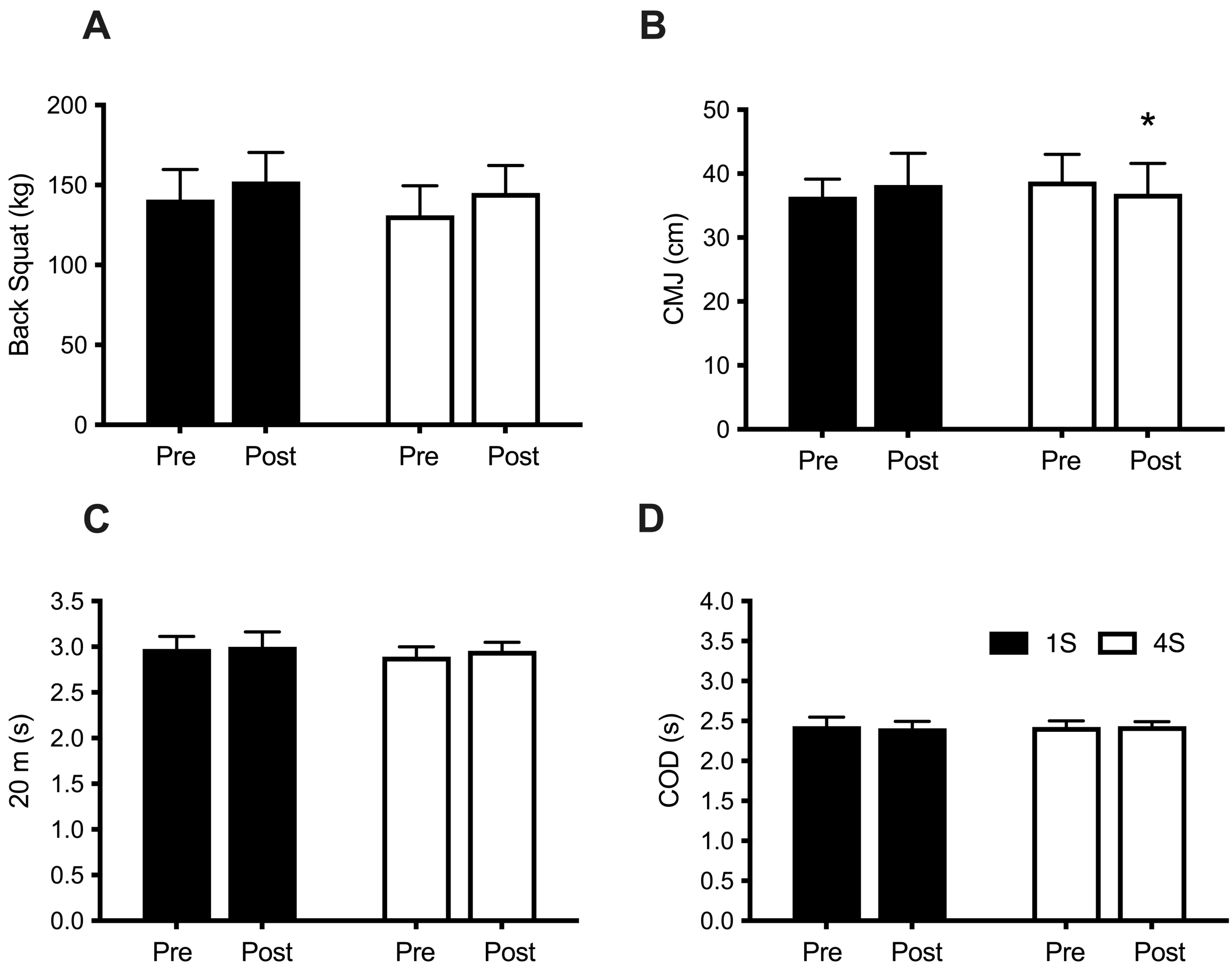

Figure 1. Mean changes in predicted one-repetition-max (A), counter movement jump (B), 20 m sprint times (C), change of direction (D). *Denotes significant difference between groups post-intervention ($P < 0.05$).

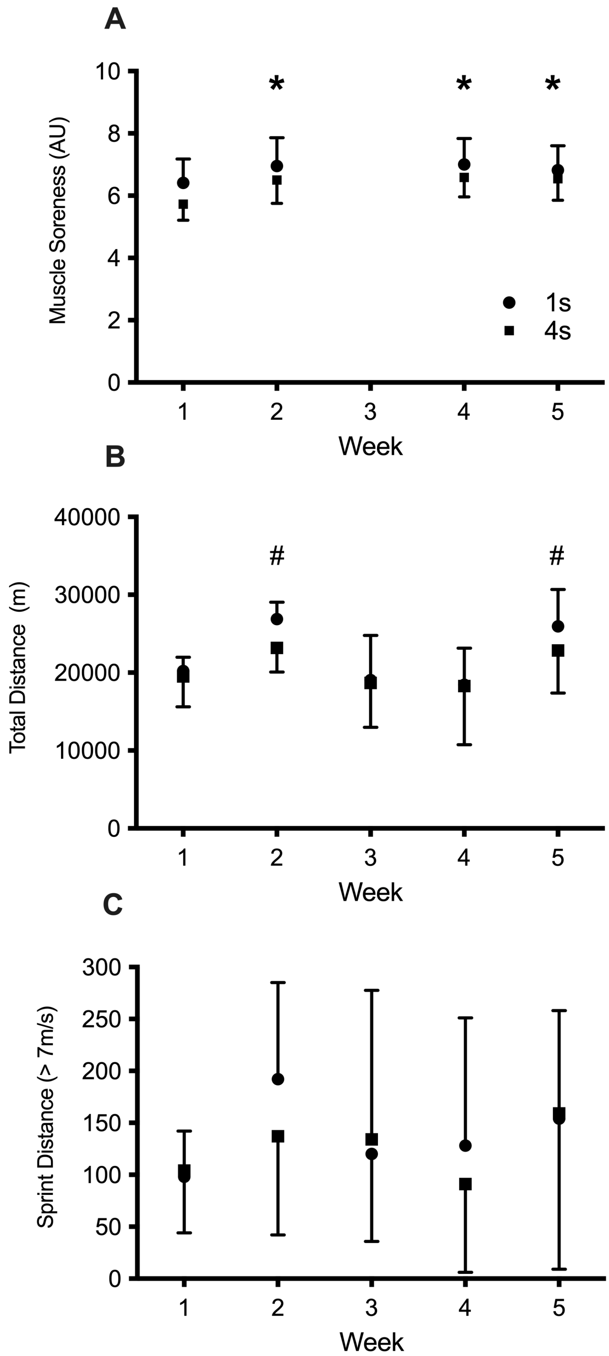

Figure 2. Changes in muscle soreness (A), total distance covered (B) and sprint distance (C) across the training intervention. *Denotes significant main effect difference from Week 1 ($P < 0.05$); #Denotes significant difference from Weeks 1, 3 and 4 ($P < 0.05$). *Note muscle soreness (A) ranges from 1 (unbearable soreness pain) to 10 (completely fresh).*

Table 1. Resistance training programme.

Exercise	High Volume (sets | repetitions)	Low Volume (sets | repetitions)	Week 1 (load)	Week 2 (load)	Week 3 (load)	Week 4 (load)
Barbell back squat*	4 | 4	3 | 3	70% 1RM	75% 1RM	77.5% 1RM	80% 1RM
Hexagonal bar deadlift*	4 | 4		70% 1RM	75% 1RM	77.5% 1RM	80% 1RM
Hexagonal bar jump squat	5 | 3	3 | 3	70% 1RM	75% 1RM	77.5% 1RM	80% 1RM
Hang power clean	4 | 3		60-80% 1RM	60-80% 1RM	60-80% 1RM	60-80% 1RM
Barbell bent over row	4 | 6	3 | 6	80% 1RM	80% 1RM	82.5% 1RM	82.5% 1RM
Dumbell bench press	4 | 6	3 | 6	70% 1RM	72.5% 1RM	75% 1RM	75% 1RM
Wide pull ups	3 | 8	3 | 8	Body Mass	Body Mass	Body Mass	Body Mass

*Modified eccentric duration.