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Effect of Squatting on Sprinting Performance and Repeated Exposure to Complex Training in Male Rugby Players

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Abstract

Comyns, TM, Harrison, AJ, and Hennessy, LK. Effect of squatting on sprinting performance and repeated exposure to complex training in male rugby players. *J Strength Cond Res* 24(X): 000–000, 2010—This study was undertaken to examine the effect of a heavy weight training exercise on sprinting performance and on the effect of repeated exposure to a complex training protocol. Eleven male rugby union players (age 20.9 ± 3.1 years) participated in the study, which involved AU2 5 separate testing sessions. Back squat 3RM was established in session 1. Sessions 2–5 were identical and involved the subjects completing a 30-m sprint before and after a 3RM back squat protocol. Four minutes of rest was given between the back squatting and the posttest 30-m sprint. All sprint trials were measured with a laser measurement device (LAVEG, AU3 Jenoptik). Sprint time and instantaneous, average, and maximum velocity were the dependent variables. The criterion for significance was set at an alpha level of $p \geq 0.05$. No significant improvement was evident for any of the testing sessions ($p \geq 0.05$). In session 1, there was a significant increase in 30-m time and a significant reduction in average 30-m velocity and maximum velocity ($p < 0.05$). The expected benefits in sprinting may not have been realized because of intra and intersubject variations in sprint technique. The session × phase interaction revealed a significant improvement in the pre to posttest changes in instantaneous velocity at 20 m ($p = 0.035$) and 30 m ($p = 0.036$) from session 1 to session 4. This indicates that the rugby players may be able to learn to apply the potentiation effects of complex training. From a practical perspective, players may need repeated exposure to this training modality to gain benefit from it, and this should be reflected in program planning.

Key Words leg-spring stiffness, plyometrics, postactivation potentiation, resistance exercise, stretch-shortening cycle

Introduction

The completion of a high-load resistance exercise followed by a biomechanically similar plyometric exercise has been referred to as complex training, and it is thought that the resistance exercise will have a performance-enhancing effect on the plyometric exercise (10). Postactivation potentiation is the physiological rationale for complex training (7). The impetus for this study was the lack of research in 2 specific areas of complex training, namely, the effect of complex training on sprinting and the effect of repeated exposure to a complex training protocol.

The majority of complex training studies have been acute adaptation studies that examined the effect of, for example, lifting load and rest interval on the plyometric performance (5,6,13,17,24,28). Acute changes have been noted, and from this, researchers have attempted to apply the findings to the training programs of athletes. The efficacy, however, of repeated exposure to complex training is unclear. In a review of complex training, Docherty et al. (7) commented that participants need repeated exposure to the complex training protocol to learn to use the potentiated effects produced by heavy preload activities. In addition, Docherty et al. (7) noted that there is a paucity of research examining the effectiveness of a complex training program in producing long-term neuromuscular adaptations.

In response to the lack of complex training studies that examined chronic adaptations, Scott and Docherty (26) investigated if it is possible to learn to apply the potentiation effects of complex training by exposing the subjects to a repeated complex training protocol. Nineteen resistance-trained men underwent 4 identical testing sessions that involved the completion of 4 vertical jumps and 4 horizontal jumps before and after a 5-RM back squat protocol. The study aimed to see if the subjects were able to capitalize on

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Table 1. Physical characteristics of the subjects (mean ± *SD*).

Age (y)	Height (cm)	Mass (kg)	3RM
20.9 ± 3.1	184.3 ± 8.5	90.2 ± 10.7	150.2 ± 32.3

the repeated exposure to the protocol. Jump height was the dependent variable. The results indicated that the jump performance did not benefit from the 5RM lifting and that the subjects were unable to benefit from the repeated exposure to the heavy dynamic preload exercise protocol. The study by Scott and Docherty (26), however, used the outcome measure (jump height) as the only dependent variable and failed to examine the changes that occurred to the biomechanics of the jump performance (process). In addition, Scott and Docherty (26) used slow SSC activities as the plyometric exercise, so the effect of repeated exposure to heavy weight lifting on a fast SSC performance is unknown.

McBride et al. (19) used sprinting as the complex training criterion plyometric exercise. They examined the effect of heavy squatting and loaded CMJs on sprinting performance. Fifteen NCAA Division III football players performed a heavy back squatting (3 repetitions at 90% of 1RM) warm-up, a loaded CMJ (3 repetitions at 30% of 1RM) warm-up, and a control warm-up condition before a 40-m sprint. The order of the 3 conditions was randomly assigned, and the testing took place over a 3-week period. Four minutes was used as the intracomplex rest interval. The performance outcome measures of 10-, 30-, and 40-m time were the dependent variables. These were measured using an infrared timing system. The results indicated that the 40-m time for the sprint that followed the heavy back squatting was significantly faster from the sprint that followed the control warm-up. The percentage difference, however, was only of a magnitude of 0.87%. The authors themselves noted that this change was much smaller than that seen in studies that used vertical jumps as the criterion plyometric exercise. No significant difference was found for the loaded CMJ warm-up compared with the control warm-up. The authors concluded that the data suggest that an acute bout of low-volume heavy squatting may improve 40-m sprint times. Caution should be given to this conclusion because the percentage increase is very small.

The first aim of this study was to investigate if prior contractile activity, in the form of heavy back squatting, provided a stimulus to enhance sprinting performance. Comyns et al. (6) reported that a back squat load of 93% of 1RM provided a potentiation stimulus for drop jumping performed 4 minutes postlifting. There was a significant improvement in leg-spring stiffness (k_{vert}) and a significant reduction in ground contact time (CT), resulting in the drop jump being performed with a stiffer, shorter, and more elastic leg-spring action. Leg-spring stiffness is associated with faster leg cadence in hopping and running (1,11) and effective SSC behavior (12,18). Research has also indicated that sprinters have a higher k_{vert} than endurance runners (16). In addition, minimizing ground CT is an important technical aspect of sprinting (23). Consequently, it is hypothesized that heavy back squatting (3 repetitions at 93% of 1RM) will result in faster sprint times and higher instantaneous, average, and maximum velocity readings over a 30-m sprint distance because of alterations in the biomechanics of performance of the sprinting action. Heavy lifting may alter the sprinting action by increasing leg stiffness and reducing ground CT. It is unknown however if these changes, which have been observed by Comyns et al. (6) in a highly controlled testing environment (sledge and force platform apparatus), will be seen in a more applied testing environment.

Second, the study aimed to investigate if rugby players could learn to apply the

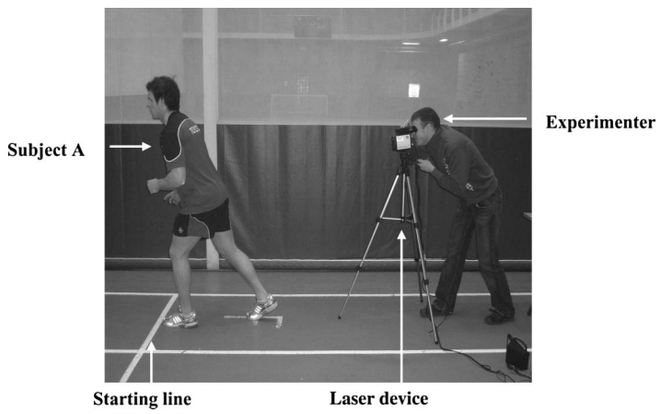

Figure 1. Photograph of the setup of the laser measuring device (LAVEG, Jenoptik). Subject A is seen in starting position about to perform a 30 m sprint.

potentiation effects of complex training. By repeated exposure to the potentiation stimulus, will the pre to posttest changes improve? The subjects were exposed to the training protocol of heavy back squatting followed by 30-m sprinting on 4 different occasions to investigate if they could learn to apply the benefits of such preloading. By conducting such an experiment, it is envisaged that information will be obtained that will provide an insight into the adaptations that occur because of repeated exposure to a complex training protocol. In turn, this may help to assess the efficacy of complex training as an appropriate training strategy in the development of speed for male rugby players.

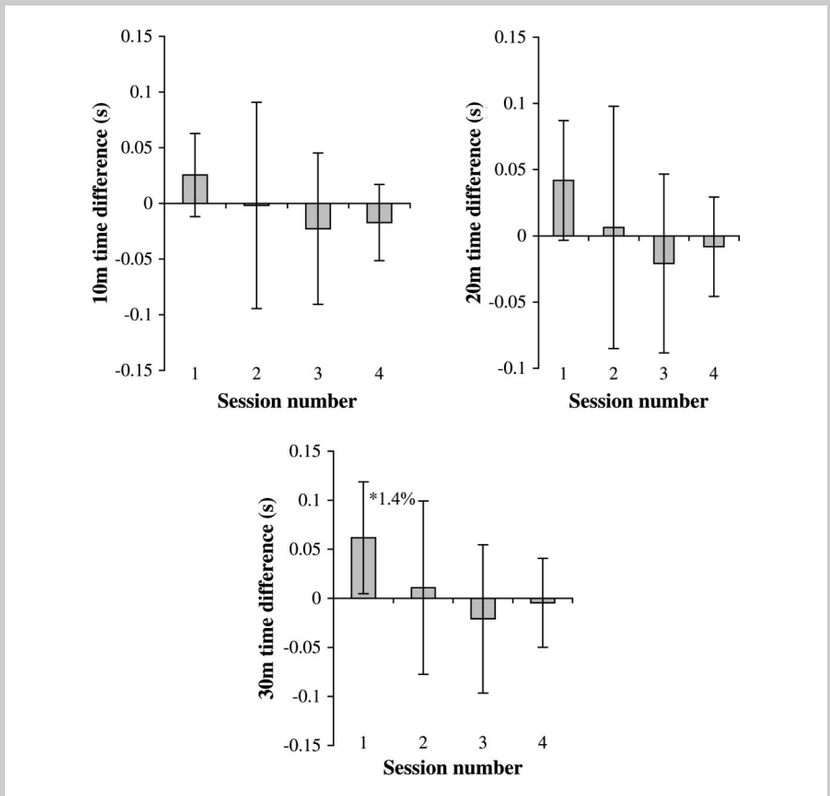

Figure 2. Mean, with 95 % confidence interval, 10 m, 20 m and 30 m time difference for the four testing sessions. Baseline values are represented by the x-axis. *Significant difference between the pre and post-test sprint ($p \geq 0.05$).

Methods

Experimental Approach to the Problem

This study involved the subjects performing a 30-m sprint before and after 3RM back squatting with a 4-minute rest between the lifting and the post 30-m sprint. This procedure was repeated on 4 separate testing sessions. Five testing sessions were involved in the study. The same time of the day was used for reliability reasons and to control for circadian variation (2). No more than 7 days and no less than 3 days separated each intervention session. Güllich and Schmidtbleicher (14) reported that fatigue can negatively affect neural activation; therefore, before each testing session, the subjects were required to refrain from high-intensity exercise, especially strength and plyometric exercises. Session 1 involved the determination of the subjects' 3RM and familiarization trials of the 30-m sprint. Sessions 2–5 involved the subjects performing the test intervention. The dependent variables were time to 10-, 20-, and 30-m sprint; velocity at the 10-, 20-, and 30-m marks; average 10-, 20-, and 30-m velocities; maximum velocity; and time and distance to maximum velocity. These were selected to examine the effect of back squatting on sprinting performance. The variables provided more information than just time alone (outcome measure, product) and gave a greater insight into the effect of back squatting on sprinting. A repeated measures analysis of variance (ANOVA) was used to analyze the effects of lifting on 30-m sprint performance and to assess if there were significant differences between these effects across the 4 intervention sessions.

Subjects

Eleven ($n = 11$) male rugby union players participated in this study (Table 1). Seven of the subjects were backs, and the remaining 4 were forwards. All subjects were proficient with the technique of back squatting and could lift in excess of 1.5 times bodyweight (mean [$\pm SD$] = 1.8 [0.4]). The subjects had 3.5 ± 2.5 years of experience of speed and resistance training. They were full-time professional contracted rugby union players, and 3 had international playing experience. The testing was conducted during the season at a time when the subjects had a 3-week break from playing rugby games. Approval for the use of human subjects was obtained from the University review board of research compliance. Subjects were informed of the experimental risks and signed an informed consent document before the investigation. In addition, a Physical Activity Readiness Questionnaire was completed by the subjects.

Instrumentation

All 30-m sprint trials were measured with a laser measurement device (LAVEG, Jenoptik), refer to Figure 1. The LAVEG laser provides a linear distance measurement at a sampling frequency of 100 Hz. It was connected to a laptop and was placed 2 m behind the starting line and at a height of 1.37 m from the ground to the center of the laser lens. The laser beam was directed at the lower part of the subject's back. The subjects were required to wear a white shirt to facilitate use of the laser. They were instructed to tuck the shirt into their shorts to reduce any potential noise in the raw distance measurements. Once the subject was in the "Set" position, the laser was activated, and it recorded data until the subject was 2–3 m past the finish line.

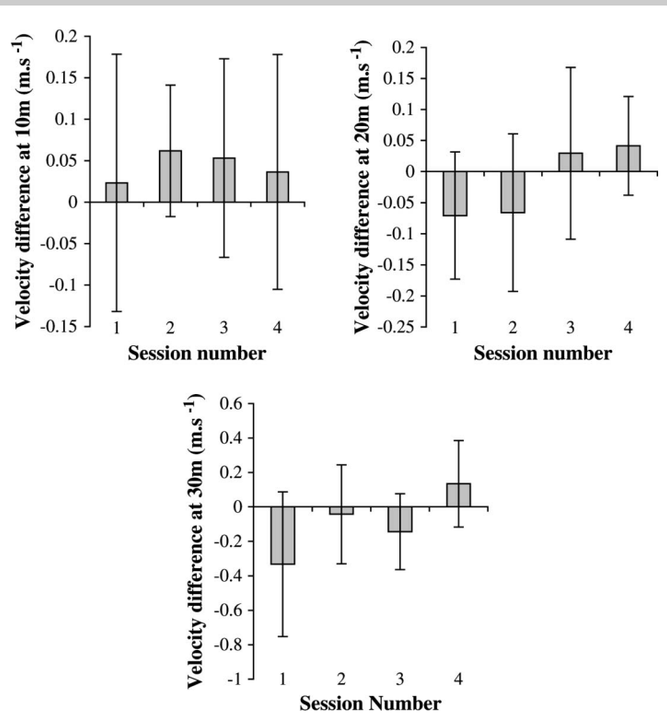

Figure 3. Mean, with 95 % confidence interval, velocity at 10 m, 20 m and 30 m difference for the four testing sessions. Baseline values are represented by the x-axis.

Harrison et al. (15) conducted a study comparing the reliability of this laser system with video-based kinematic analysis in measuring displacement and velocity. To assess the reliability of the system to accurately measure velocity, 10 participants completed 3 running trials at self-determined fast, medium, and slow speeds. Running velocity was measured simultaneously by a laser and 2 video cameras (1 at 50 Hz, 1 at 100 Hz) within a 3-m measurement zone. The test–retest reliability of running velocity measurements in this zone for the laser system was estimated at ICC = 0.986. Both the 50- and 100-Hz cameras' measurement systems reported similar ICCs of 0.984 and 0.981, respectively. Harrison et al. (15) concluded that all 3 devices produced reliable estimates of average velocity within the 3-m measurement zone. The magnitude of the errors in raw displacement data using the laser system was of a similar order to that of video digitizing. The authors advocated applying optimal filtering or smoothing procedures to the raw displacement data to provide valid and reliable measurements of running velocity comparable with video analysis.

Procedures

Testing session 1 began with a warm-up that consisted of 3 minutes of light jogging and static stretching of the major leg muscles, with stretches held for 15 seconds. The subjects' 3RM was then tested using the procedure outlined by Earle (9). This was followed by 2 familiarization trials of the 30- m sprint. The subjects were instructed to begin the sprint from a standing start position and to sprint as fast as they could past the 30-m mark after the command 'Go' was given. They were given 3 commands; 'On your marks,' 'Set,' and 'Go.' For the 'On your marks' command, the subjects walked up to the starting line and on hearing 'Set' they got into the appropriate standing position (Figure 1). The subjects were instructed to stay as steady as possible in this position and on hearing the 'Go' command to sprint as fast as possible past the 30-m mark. It was emphasized to them that they should sprint past the 30-m mark and not to slow down until after this. In addition, it was emphasized that no forward movement or rocking movements were permitted when the subject was in the 'Set' position.

Sessions 2–5 were the testing intervention sessions, and all involved the same procedure. The same track surface (synthetic indoor track surface) and the same track lane were used for each session, and the subjects were instructed to wear the same running clothes and running shoes. The subjects used trainers as opposed to sprinting spikes throughout the experimental procedure.

The warm-up involved 3 minutes of low-intensity jogging followed by static stretches of the major leg muscles. Before

the pretest 30-m sprint, the subjects were involved in a specific warm-up that consisted of 3 × 30 m runs at 50, 75, and 100% effort. Before weight lifting, the subjects did a weights-specific warm-up involving 5 repetitions at 50% of 1RM and 3 repetitions at 75% of 1RM. The subjects' 1RM value was estimated from their 3RM scores attained in session 1. According to the percentage 1RM-repetition relationship outlined by Baechle et al. (3), the load for 3 repetitions is 93% of 1RM. Consequently, the 3RM value was divided by 0.93 to attain a 1RM estimate. Four minutes of rest was given between the lifting and the posttest 30-m sprint. This rest interval was selected because previous complex training research that used such an intracomplex rest interval reported potentiation effects for the plyometric exercise (14,19,24,28). The subjects were allowed to walk or sit during this 4-minute rest interval, but they had to refrain from stretching and from doing any explosive plyometric movements. No feedback was given to the subjects during or after the testing intervention sessions regarding starting and sprinting technique and 30-m sprint performance results. In addition, no encouragement was provided to the subjects. At the end of each testing session, the subjects participated in a cool-down that consisted of 3 minutes of low-intensity jogging and static stretching of the major leg muscles.

Calculation of the Dependent Variables

Raw displacement data for each trial were exported to Microsoft Excel for filtering and calculation of the dependent variables. One second of padding data was included at the beginning and end of each data set to reduce the effects of end-point distortion. The raw displacement data were filtered using a Butterworth fourth order, zero lag filter with a 3-Hz cut-off. This cut-off frequency eliminated the majority of noise while maintaining the most signal. Winter (27) reported that 3 Hz was found to be the optimal cut-off frequency after a residual analysis of several running trials.

The filtered data were converted to instantaneous velocity measurements using the first central difference equation: $v_i = (X_{i+1} - X_{i-1})/2t$, where v is the velocity, i is the frame of interest, and t is the time interval between data points (0.01 seconds) (27).

These instantaneous velocity measurements were then used to determine the point where the subject began the 30-m sprint. The start of the sprint was defined as the point where the subject's velocity readings continuously increased. The cell where this gradual increase in velocity commenced was selected as the start cell. The displacement value corresponding to this cell was noted, and the cell that was 30 m ahead of this value was selected as the finishing cell. This section of filtered displacement and velocity data was then selected as the 30-m sprint section and was analyzed to calculate the dependent variables.

Time to 10, 20, and 30 m was calculated from this filtered 30-m sprint data set. The displacement in the start cell was noted, and the cells that were 10, 20, and 30m ahead of this displacement were located and noted. Velocity at 10, 20, and 30 m was found from the instantaneous velocity data. The cell that corresponded to the 10-, 20-, and 30-m distance was located, and the velocity at that cell was noted. The average

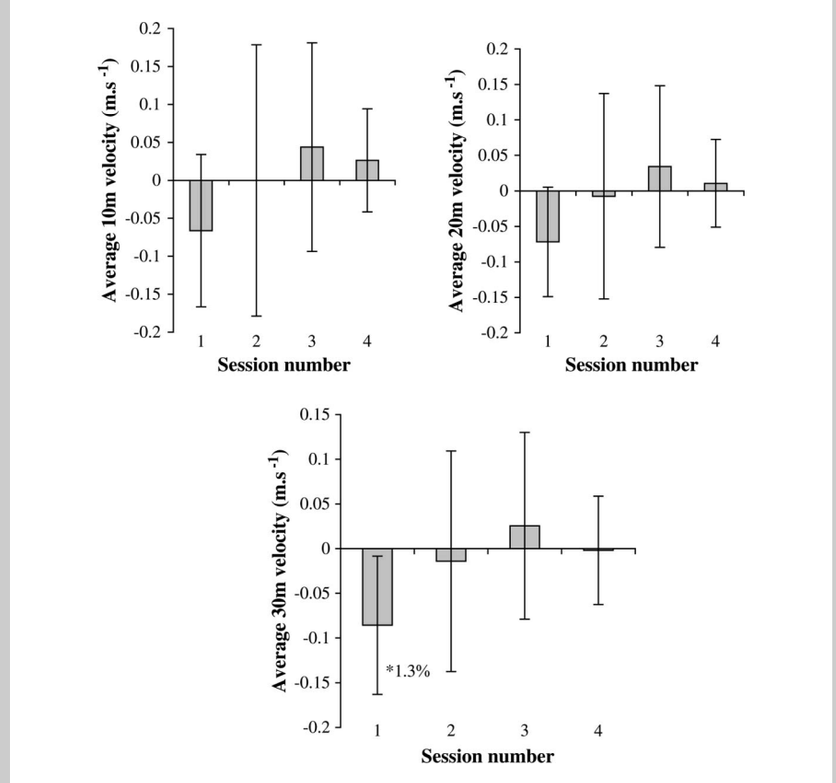

Figure 4. Mean, with 95 % confidence interval, average 10 m, 20 m and 30 m velocity difference for the four testing sessions. Baseline values are represented by the x-axis. *Significant difference between the pre and post-test sprint ($p \geq 0.05$).

velocity for each distance zone was obtained by using the formula: $\bar{v}_{zone} = (X_{last} - X_{first})/(T_{last} - T_{first})$, where $\bar{v}_{zone}$ is the average velocity in the measurement zone, X is the displacement value, and T is the time (15). Maximum velocity was calculated from the 30-m instantaneous velocity data set. Microsoft Excel was used to find the maximum value between the start cell and the cell corresponding to the 30-m mark. Once the value was located, the cell that it was in was noted. This cell was used to determine time and distance to maximum velocity.

Statistical Analyses

AU10 A GLM ANOVA was used to analyze the pre to posttest differences for each testing intervention session. The ANOVA had 1 within-subjects factor, namely, Phase with 2 levels (pre and post). This analysis was done for each dependent variable. The criterion of significance was set at an alpha level of $p \leq 0.05$.

To analyze if there were any differences between the pre to posttest changes from testing intervention session 1 to the second, third, and fourth testing sessions, a second GLM ANOVA was conducted. This time the ANOVA had 2 within-subjects factors, namely, session with 2 levels (session 1 and either session 2, 3, or 4) and phase with 2 levels (pre and post). The analysis was done 3 times to see if there was any difference between the first and second sessions, the first and third sessions, and the first and fourth sessions. This analysis was conducted to investigate if the subjects learned how to apply the potentiation effects of complex training.

Effect sizes using partial eta^2 (η_p^2) were also obtained for each analysis using the formula $\eta_p^2 = SS_{effect}/(SS_{effect} + SS_{error})$, where SS_{effect} = effect variance and SS_{error} = error variance. Interpretation of effect size was based on the scale for effect size AU11 classification (6). This scale is based on f-values for effect size and these were converted to η_p^2 using the formula $f = (\eta_p^2/(1 - \eta_p^2))0.5$. Consequently, the scale for classification of η_p^2 was <0.04 trivial; 0.041–0.249 small; 0.25–0.549 medium; 0.55–0.799 large; and >0.8 very large.

Results

Pre to Posttest Results for the Testing Sessions

The mean baseline scores for each dependent variable were subtracted from their corresponding postlifting scores in each testing session. Thus, in the following figures, the x-axis represents the baseline scores. Figure 2 illustrates the F2 mean differences in the 10-, 20-, and 30-m times for each of the testing sessions. The GLM ANOVA results indicate that the 30-m time postlifting in session 1 was significantly slower than the baseline score ($p = 0.036$; $\eta_p^2 = 0.368$, medium effect). None of the other time variables across the 4 sessions reported any significant differences pre to post ($p \geq 0.05$).

In Figure 3, the results for velocity at 10, 20, and 30 m are F3 presented. There was no significant difference from pre to posttest for any of the variables for the 4 testing sessions ($p \geq 0.05$). The results for the pre to posttest difference in average 10-, 20-, and 30-m velocity are shown in Figure 4. Only F4 average 30-m velocity in session 1 reported a significant change, with a reduction in average velocity ($p = 0.033$; $\eta_p^2 = 0.379$, medium effect). The results for maximum velocity and time and distance to maximum velocity are illustrated in Figure 5. The GLM ANOVA results revealed F5

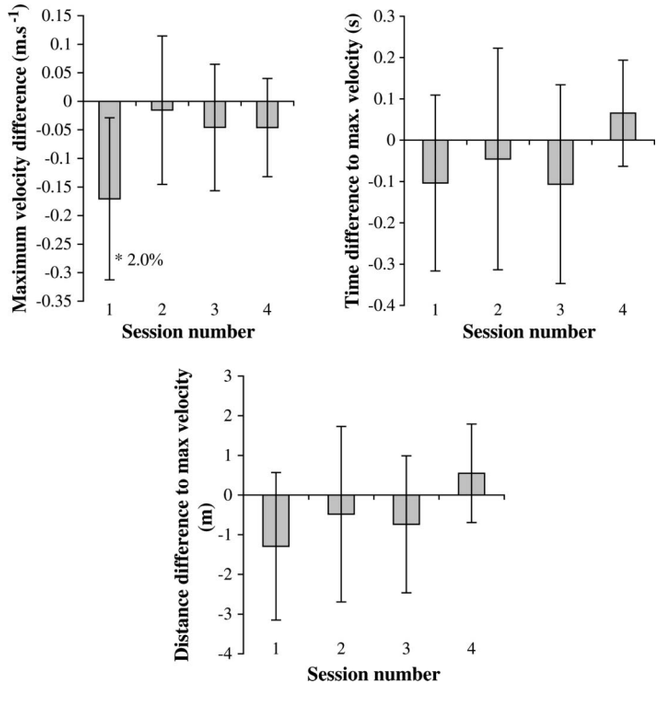

Figure 5. Mean, with 95 % confidence interval, maximum velocity, time and distance to maximum velocity difference for the four testing sessions. Baseline values are represented by the x-axis. *Significant difference between the pre and post-test sprint ($p \geq 0.05$).

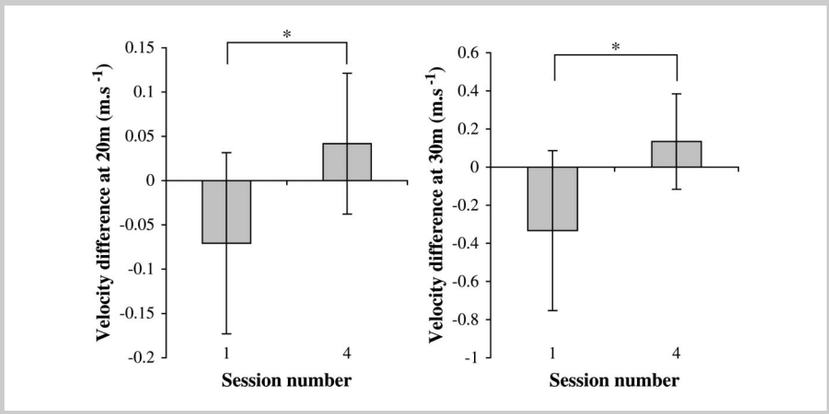

Figure 6. Mean, with 95% confidence interval, velocity at 20 m and 30 m difference for sessions one and four. Baseline values are represented by the x-axis. *Significant difference between the pre and post-test sprint ($p \geq 0.05$).

a significant reduction in maximum velocity in the first session ($p = 0.023$; $\eta_p^2 = 0.418$, medium effect).

Session × Phase Interaction

The session × phase interaction was analyzed to examine if there were any differences between the pre to posttest changes from the first testing intervention session to the second, third, and fourth testing sessions. These results provided information regarding the second aim of this study. Can male rugby players learn to apply the potentiation effects of complex training?

Two variables reported a significant session × phase interaction ($p < 0.05$). When the pre to posttest changes between sessions were compared, there was a significant improvement in the velocity at 20 m ($p = 0.035$; $\eta_p^2 = 0.374$, medium effect) and the velocity at 30-m pre to posttest changes ($p = 0.036$; $\eta_p^2 = 0.319$, $\eta_p^2 = 0.319$, $\eta_p^2 = 0.319$, medium effect) from session 1 to session 4. The results for these 2 variables are presented in Figure 6.

Discussion

Considering the testing sessions separately, no significant potentiation effect was evident for sprinting because of heavy back squatting. In session 1, there was a significant reduction in average 30-m velocity and maximum velocity and a significant increase in 30-m time. For the subsequent sessions, the trend was for an improvement in the mean scores for the variables postlifting, none of which were significant. The session × phase interaction indicated a significant improvement in velocity at 20 and 30 m postlifting. All of these results need to be considered when making a judgment on the efficacy of heavy weight lifting for enhancing sprinting performance in male rugby players.

Although there was deterioration in sprint performance in the first testing session, the percentage changes were small. Time to 30 m was increased by 1.4% (0.06 seconds), and average 30-m velocity and maximum velocity were reduced by 1.3% (0.09 $m \cdot s^{-1}$) and 2.0% (0.17 $m \cdot s^{-1}$), respectively. For the subsequent sessions, no deterioration in performance was evident. In general, for session 2 the mean posttest scores for the dependent variables were similar to the pretest scores, and for sessions 3 and 4, the mean posttest scores were slightly higher. It is important to note that taken separately, no session showed a significant enhancement in sprinting performance. This is in contrast to McBride et al. (19) who reported that 3 repetitions of the back squat at a load of 90% of 1RM caused a significant improvement (0.87%) in 40-m sprint time. This change, however, is of a very small magnitude and represents an improvement of just 0.05 seconds over 40 m. In addition, the subjects in the McBride et al. (19) study sprinted over a 40-m distance, whereas 30 m was the distance used in the current study.

It was hypothesized that the potentiation effects of heavy back squatting on drop jump performance, which were reported by Comyns et al. (6), would be replicated with a similar fast SSC activity, that is, sprinting. Comyns et al. (6) reported that 3 repetitions of the back squat at 93% of 1RM resulted in significant improvements in leg stiffness and ground CT. This resulted in the drop jump being performed with a stiffer, shorter, and more elastic leg-spring action. It was hypothesized that the same potentiation effect could occur for sprinting performed after 3RM back squatting. Although no direct measures of k_{vert} and CT were made in this study, it was felt that improvements in both these variables would result in faster sprint times and higher instantaneous, average and maximum velocities. An increase in leg stiffness is associated with increases in running frequencies (1), and sprinters have been shown to have high leg stiffness values (16). Minimizing ground CT is important for effective sprinting technique and thus increasing speed (4,23). The results of the 4 separate testing sessions, however, revealed that this was not the case, and it could thus be inferred that the potentiation effects evident in Comyns et al. (6) were not elicited for sprinting. It may be, however, that improvements in sprint times and velocities were not evident because of high intra and intersubject variations in sprint technique as opposed to a lack of potentiation. Extraneous factors such as technique were controlled for in Comyns et al. (6) because the drop jumps were performed on a sledge and force platform apparatus, which isolates the leg action and

restricts movement to one plane thus allowing for a valid, reliable, and controlled testing environment. Although the laser device used in this study has been reported to provide reliable measurements of displacement and velocity while running (15), the technique of sprinting could not be controlled in the same way that the drop jump technique was controlled in Comyns et al. (6). In addition, the subjects in this study were rugby players as opposed to track sprinters and did not exhibit a high standard of sprinting proficiency. Correct sprinting technique is central to effective and fast sprinting (4,20,21,23). Cissik (4) and McFarlane (20,21) noted that a major limiting factor in speed is technique. Plisk (23) commented that sound technique is the primary method for developing speed. The importance of technique to sprinting is further emphasized by McFarlane (22), who defined sprinting as *a* "*faultless, perfected series of finely tuned technical and motor coordinated skills*." This lack of proficiency with sprinting technique may have masked the true effects of heavy weight lifting on 30-m sprint performance. It would be of interest to see what changes may occur with athletes who possess a high proficiency of sprinting technique. Future research should address this issue. It is possible that potentiation, similar to that reported by Comyns et al. (6), did occur after the lifting, but the lack of correct technique and high intra and intersubject variation in sprinting technique might have prevented this potentiation being manifested in faster sprint times and higher instantaneous, average and maximum velocities.

After session 1, the trend in the mean postlifting scores was for improvement compared with the mean pretest scores. To assess if the subjects learned how to apply any possible potentiation effects, the session × phase interaction was analyzed. When session 1 was compared with session 4, it was evident that a significant improvement occurred in velocity at 20 and 30 m. Repeated exposure to the protocol caused improvements in instantaneous 20- and 30-m velocity. No significance was evident for the other variables. It appears that the subjects can learn to apply any possible potentiation effects of lifting on sprint performance. There is a trend of improvement from session 1 through to session 4 in applying the potentiation effect of heavy lifting. Initially, the heavy lifting caused deterioration in sprint performance, but repeated exposure resulted in progressive improvements compared with session 1. If this exposure were to continue beyond the existing 4 intervention sessions, this improvement trend might increase to the level where there were significant improvements beyond the baseline. Future research should address this issue by increasing the number of complex training intervention sessions.

Practical Applications

Results from this study have numerous implications for the rugby player and strength and conditioning coach. Although heavy back squatting did not provide a potentiation effect for 30-m sprint performance at any of the 4 testing sessions, there were significant improvement in the pre to posttest changes from session 1 to session 4 for instantaneous 20- and 30-m velocity. This indicates that rugby players can learn to benefit from repeated exposure to a complex training protocol. Consequently, to improve a rugby player's sprinting velocity through the complex training protocol used in this study, a minimum period of 4 sessions is necessary before any potential benefits are realized. Strength and conditioning coaches should consider introducing this training modality before the start of the rugby competitive phase, as players need time to learn to attain any potentiation benefits. It was also noted that a lack of proficiency in sprinting technique may have masked the true effects of heavy lifting on sprint performance. It is recommended, therefore, that before implementing the complex training protocol used in this study, rugby players undergo a training phase where the focus is on improving their sprinting mechanics.

Acknowledgments

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