THE EFFECT OF BACK SQUAT RESISTIVE LOADS ON THE BIOMECHANICAL PERFORMANCE OF DROP JUMPS IN MALE RUGBY PLAYERS.

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This study examined the effect of three different resistive loads (65%, 80%, & 93% of 1 RM) for the back squat on the biomechanical performance of the drop jump (DJ) in male rugby players. Twelve elite level rugby players participated in the study. Drop jumps were done prior to and after the back squat lifting at the different loads. All jumps were performed on a specially constructed sledge and force plate apparatus. Time in the air (flight time) and leg spring stiffness were the dependent variables. The results indicated that lifting at all loads significantly ($p < 0.01$) reduced flight time but lifting the 93% load caused a significant improvement ($p < 0.05$) in leg spring stiffness. From a practical viewpoint, the results support the use of a heavy back squatting prior to performing a fast SSC activity, such as drop jumping.

KEY WORDS: leg spring stiffness, complex training, stretch-shortening cycle

INTRODUCTION: Combining weight lifting with plyometrics has been referred to as complex training (Ebben et al., 1998). The majority of complex training research studies have used a 5 RM protocol where the subject lifted 85% of their 1 RM for 5 repetitions prior to performing a drop jump (DJ) or counter-movement jump (CMJ). The results using this protocol have differed. Some found this load to have a significant effect on plyometric performance (Radcliffe & Radcliffe, 1999; Young et al., 1998), while others found no such change (Jones & Lees, 2003; Scott & Docherty, 2004). Only a few studies have used an alternative resistive load (Baker, 2003, Gourgoulis et al., 2003). Baker (2003) found that a 65% load for the bench press enhanced the performance of an explosive bench-press style throw. Gourgoulis et al. (2003) had the subjects perform a series of sets of half squats of 2 repetitions at 20%, 40%, 60%, 80% and 90% of 1 RM. They found a 2.39% improvement in jump height for the CMJ post-lifting. In addition, only a small number of complex training studies used the DJ, which is a fast stretch-shortening cycle (SSC) activity, as the criterion jump (French et al., 2003; Güllick & Schmidtbleicher, 1996; Jones & Lees, 2003). French et al. (2003) and Güllick & Schmidtbleicher (1996) used maximum voluntary contractions (MVCs) as opposed to weight lifting. Both studies found a significant increase in DJ performance variables after the MVC protocol. MVCs, however, are not generally used in the training environment and the stimulus obtained from them may not be the same as from weight training exercises. Jones & Lees (2003) used a 5 RM back squat protocol prior to the performance of DJ and CMJ. There were no significant main effects of the 5 RM lifting on any of the DJ performance variables, which included jump height. Ambiguity exists on the effect of different loads on fast SSC performance. The aim of this study was to examine the effect of three resistive loads on the biomechanical performance of the DJ. In particular, the effect of resistive load on jumping performance, i.e. flight time (FT), and vertical leg-spring stiffness (k_{vert}) was examined.

METHODS: Twelve elite male rugby players participated in this study. All subjects were proficient with the technique of the back squat exercise and drop jumping and could squat in excess of 1.5 times bodyweight (Mean ± SD: 2.0 ± 0.3). The study had obtained ethical approval from the University of Limerick research ethics committee and written informed consent was obtained from all subjects prior to their participation in the study.

Table 1 Physical Characteristics of the Subjects.

Age (years)	Height (cm)	Mass (kg)	1 RM (kg)
23.3 ± 2.5	182.2 ± 6.0	94.6 ± 11.5	191.7 ± 35.4

Procedures: Resistive load was the independent variable. FT and k_{vert} were the dependent variables. Three different loads were selected, 65%, 80% and 93% of 1 RM, for the back squat. Three repetitions of each load were performed. Drop jumps were performed prior to and after the back squatting at each resistive load. A one-legged drop jump from a 30 cm height was used as the test jump. The subjects were asked to use their dominant leg. The jumps were performed on a sledge apparatus inclined at 30° as described by Harrison et al. (2004). An AMTI OR6-5 force platform was mounted at right angles to the sledge apparatus and sampled at 1000 Hz. The FT for each jump was calculated by inspecting the AMTI force platform data. It was obtained by finding the time difference between the take-off and landing points. A spring-mass model was used to analyse the control of k_{vert}, which has been defined as the ratio of the peak force in the spring, GRF, to the displacement of the spring, ΔL, at the instant that the leg spring was maximally compressed. Due to the spring-like nature of the leg during drop jumps, the peak ground reaction force and the peak leg-spring displacement both occur simultaneously at the middle of the ground contact phase (Ferris & Farley, 1997). Stiffness measures were calculated by dividing the peak force by the displacement of the chair from landing to full crouch for each DJ. The SVHS video recordings (50 Hz) were digitised using Peak Motus® (Peak Performance Technologies, Colorado, USA) to calculate the displacement of the sledge.
The testing took place over two sessions with 7 days between each session. The subjects were instructed to refrain from weight and plyometric training on the day preceding each of the testing days. Session one involved the determination of the subjects' 1 RM. Three familiarisation sets of 3 drop jumps were performed on the sledge following an explanation and demonstration of the technique of the drop jumps. The subjects were instructed to minimise their contact time on the force platform and maximise their subsequent jump height. Session two began with a warm-up (3 minutes of low-intensity jogging and static stretching of major leg muscles with stretches held for 15 seconds) followed by the completion of three baseline drop jumps. These jumps acted as a control to compare all subsequent jumps with. Next the subjects completed a specific weight-lifting warm-up of 5 repetitions of the back squat at 50% of 1 RM and then 3 repetitions at 60% of 1 RM. Following three minutes rest the subjects performed 3 repetitions of one of the resistive loads (65%, 80% or 93% of 1 RM) of the back squat and after 4 minutes rest performed 3 drop jumps. This was one complex pair. Four minutes was chosen as the rest interval between the weight lifting and the drop jumps as pervious research that used such a rest interval found an ergogenic advantage for the plyometric exercise (Güllich & Schmidtbleicher, 1996; Radcliffe & Radcliffe, 1996; Young et al., 1998). Six minutes rest was given before the start of the next complex pair. This resulted in a minimum of 10 minutes rest between back squat lifts. Three complex pairs were completed in total to cater for the 3 resistive loads. The order of the resistive loads was randomly assigned for each subject. A cool-down (light jogging and static stretching) was completed at the end of the testing session.
Statistical Analysis: All statistical analysis was conducted using a software package (SPSS for Windows, Release 11.0.1). Differences between the baseline scores and the scores after the different resistive loads for each dependent variable were evaluated using a 2-way analysis of variance (ANOVA) with repeated measures. The GLM ANOVA had 2 within-subjects factors. Factor 1 was Condition with 4 levels (baseline, 65%, 80% and 93% load). Factor 2 was Trials with 3 levels (trial 1, trial 2 and trial 3).

RESULTS AND DISCUSSION: The mean FT and k_{vert} scores for the baseline jumps were subtracted from the FT and k_{vert} scores for the jumps done after the different loads and the results can be seen in Figure 1 (FT differences) and Figure 2 (k_{vert} differences). In both figures, the x-axis represents the baseline. The GLM ANOVA results ($p < 0.01$) indicated a significant reduction in FT between the baseline jumps and the jumps done after all resistive loads. For k_{vert}, the difference between the baseline jumps and the jumps done after the 93% load only was significant ($p = 0.023$).

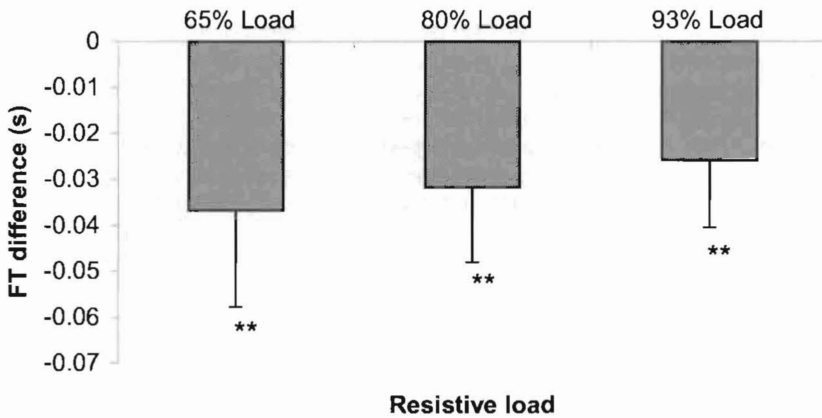

Figure 1 Mean ± 95% confidence interval FT difference between the baseline jumps and the jumps done after the 65%, 80% and 93% resistive loads. (indicates a significant difference between base and load, $p < 0.01$).**

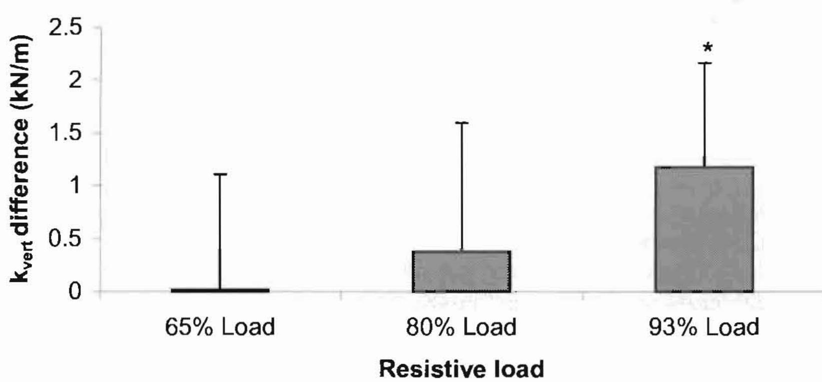

Figure 2 Mean ± 95% confidence interval k_{vert} difference between the baseline jumps and jumps done after the 65, 80 and 93% resistive loads. (*indicates a significant difference between base and load, $p < 0.05$).

The flight time data suggests that performing back squat lifting at 65%, 80% and 93% of 1 RM prior to drop jumping will have a negative effect on the jump performance, however in contrast to other studies this investigation looked further and examined the effect of back squatting on k_{vert}. A significant improvement was seen in k_{vert} after lifting at 93% of 1 RM and this illustrates the effect that a heavy resistance exercise has on the biomechanical performance of drop jumps. This is an important finding that past complex training research has failed to illustrate due to an over-reliance on performance measures. Research has shown that an increase in k_{vert} will increase the leg cadence of a fast SSC activity, such as hopping or sprinting (Arampatzis et al, 1999; Farley et al. 1991; Farley et al., 1996; McMahon et al., 1987). This will result in the fast SSC performance being quicker, as well as being more dynamic and plyometric in nature. Arampatzis et al. (1999) found that leg stiffness increases with increasing running speed. Farley et al., (1991) found that the stiffness of the leg spring can change as much as twofold to accommodate different hopping frequencies. Similarly, Farley et al. (1996) revealed that the stiffness of the leg spring in running increased by 2.3-fold between the lowest and highest stride frequencies investigated. McMahon et al.

(1987) examined the effects of running with an increased knee flexion ('Groucho running') and found that the stiffness of the leg spring appears to decrease. Essentially an increase in stride length decreases leg stiffness. Research has also shown that sprinters have high leg spring stiffness (Harrison et al., 2004).

CONCLUSION: This study shows that while performing back squats at 93% of 1 RM results in a significant reduction in FT, k_{vert} is significantly improved. This will benefit the performance of a fast SSC activity, such as a DJ, and make it more dynamic and plyometric. From a practical viewpoint the present study provides evidence to support the use of complex training with rugby players, when 93% of 1 RM is the lifting load and when the plyometric exercise is a fast SSC activity.

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