Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

THE RELATIONSHIP BETWEEN MAXIMAL STRENGTH AND PLYOMETRIC ABILITY IN RUGBY PLAYERS

Charlotte Dymond[1], Eamonn P. Flanagan[2] and Anthony P. Turner[3]

Sharjah Womens College, Higher Colleges of Technology, U.A.E.[1]
Edinburgh Rugby, Scottish Rugby Union, Edinburgh, U.K.[2]
Institute of Sport, P.E. & Health Sciences, University of Edinburgh, Edinburgh, U.K.[3]

This study examined the role of maximal strength in plyometric exercise performance in twenty strength-trained rugby players. Players' maximal leg strength was assessed using a 3 or 5RM barbell back squat strength testing procedure. Plyometric ability was assessed using ground contact times and the reactive strength index variable during depth jumps from a variety of box heights (12, 36 and 51cm) performed on a force plate. The data indicated a strong positive relationship between strength levels and plyometric ability. Stronger subjects achieved better reactive strength indices than weaker counterparts and are more capable of performing depth jumps at higher intensities. Stronger athletes may benefit more from fast SSC plyometric training than their weaker counterparts.

KEY WORDS: Reactive strength index, strength training, plyometrics, rugby.

INTRODUCTION: Plyometric exercises use rapid, powerful movements that are preceded by a preloading countermovement that activates the stretch-shortening cycle (SSC). Schmidtbleicher (1992) has suggested that the SSC can be classified as either slow or fast. These SSCs are underpinned by different biomechanical mechanisms. The fast SSC is characterized by short contraction or ground contact times (CT) or 0.25 seconds or less and small angular displacements of the hips, knees, and ankles. Depth jumps are one of the most commonly used fast SSC plyometric exercises. A depth jump requires the athlete to step from a specific box height and, on landing on the ground, perform a maximal effort vertical jump with a short ground-contact period. The intensity of plyometric depth jumps is determined by the height of box used: the greater the box height, the greater the eccentric loading the player must overcome to successfully complete the jump. Fast SSC plyometrics are commonly used in training for strength and power sports such as rugby. Plyometric exercises have been demonstrated to improve power output (Luebbers et al. 2003), agility (Miller et al. 2006) and running economy (Saunders et al. 2006).
The reactive strength index (RSI) describes an individual's ability to explosively transition from an eccentric to concentric muscular contraction (Young, 1995). The RSI can be used to optimise box height during depth jump training or to assess improvements in reactive strength following a plyometric training intervention (Flanagan & Comyns, 2008). Strength is the ability to generate maximal external force. Traditionally, lower body maximal strength is trained and/or assessed through resistance training exercises such as the barbell bar squat. Anecdotally it has been suggested that athletes should reach a specific level of lower body strength before undertaking specific plyometric exercises such as depth jumps. While studies have examined the relationship between maximal strength and jumping ability, research has not been undertaken which investigates the relationship between maximal strength and fast SSC plyometric ability using the RSI. The goal of this study was to examine the role of maximal strength in plyometric exercise performance and to establish optimal box heights for use in plyometric depth jumping for rugby players of specific strength levels.

METHOD: Data Collection: Twenty rugby players (mean ± SD: age 19 ± 2 years; height 183 ± 8 cm; and weight 95 ± 12 kg) were recruited for participation in the study. The players were members of a national rugby academy (n=12 talent identified, full-time athletes) or a sub-academy rugby program (n=8 talent identified, amateur players). Ethical approval was obtained from the University's ethics committee and the national governing rugby union. For players under the age of 18 years written parental consent was obtained. All players were

involved in regular strength training under the supervision of strength and conditioning professionals. Players' lower body strength levels were assessed in the barbell back squat exercise. A 3 or 5 repetition maximum (RM) test was used for each player depending on their individual training status. Players' reactive strength abilities were assessed using a B1400 series force platform (Ballistic Measurement FT 700 Power System, Fit-Tech, Australia) which sampled at 200Hz. Players performed depth jumps with hands on hips from 12, 36, and 51-cm high boxes onto the platform. Players were given a verbal instruction of the jumping action to be used. Staying on the balls of the feet and getting off the ground quickly on each jump was strongly emphasised. The players were given a visual demonstration of the jumping action to be used. Players performed two practice jumps at each height. Data was recorded during two depth jumps performed at each box height in a randomised order. A 1-minute rest interval was used between each jump. Testing for maximal strength and reactive strength took place in a randomised order within a 4-week testing window.
Data Analysis: All strength testing scores were converted to 1RM equivalents based on an established percentage 1RM-relationship (Baechle and Earle, 2008). These 1RM scores were divided by the player's body weight to give a relative strength score. In the reactive strength testing protocol the instants of initial foot contact, take-off and landing were identified using the force traces collected for every jump performed. Contact time (CT) was defined as the time between initial foot contact and take-off. Flight time (FT) was calculated as the time between take-off and landing. RSI was calculated as the height jumped divided by CT, with jump height approximated as $(9.81 * FT^2)/8$. The trial to trial reliability of calculating RSI in this manner has been established (Flanagan et al., 2008).The calculated CT and RSI for both jumps at each box height were averaged for each player. From these averages each player's peak RSI (pRSI) and minimum CT (mCT) were also identified across all box heights. The overall group (n=20) was divided into two groups consisting of the top 8 and bottom 8 players based on relative strength. The top 8 group (INT) were of intermediate strength levels (1.9 1RM/BW) while the bottom 8 group (NOV) were of novice strength levels (1.5 1RM/BW). The middle 4 players were excluded from group analyses. Differences between these groups were investigated to elucidate the role of maximal strength in plyometric ability.
Statistical Analyses: The relationship between maximal strength and reactive strength and the relationship between pRSI and the box height at which it was performed was investigated across all players (n=20) using correlation analysis. The strength of these relationships were expressed using the correlation coefficient (r) and the variance explained statistic (r^2). The calculated correlation coefficient was interpreted using Cohen's scale for correlation classification reported by Hopkins (2004). The dependent variables of CT and RSI were compared between the INT and NOV groups across all box heights. The pRSI and mCT were also compared between groups. These comparisons were conducted by using independent sample t-tests with 95% confidence intervals. Effect sizes were used to determine the magnitude of difference between groups. These were calculated using Cohen's *d* and interpreted using the scale for effect size classification by Hopkins (2004).

RESULTS: A strong positive correlation was observed between relative strength and RSI. The correlation coefficient (r) was 0.632 with a variance explained statistic (r^2) of 0.399. This suggests that changes in maximal strength can account for approximately 40% of changes in reactive strength. Of the 20 players tested, 7 produced their pRSI at the lowest box height (35%), 5 at the medium box height (25%) and 8 at the highest box height (40%). Across all 20 players no relationship between pRSI and the box height at which it was performed was observed (r = 0.01). In the INT group, 4 players produced their pRSI at the low box height, 1 at the medium box height and 3 at the high box height. In the NOV group, 2 players produced their pRSI at the low box height, 3 at the medium box height and 3 at the high box height.
Average RSI for the INT group was 1.47 (±0.4), 1.45 (±0.36), 1.57 (±0.33) for the low, medium and high boxes respectively. The average pRSI value was 1.62 (±0.33). For the NOV group average RSI was 1.13 (±0.43), 1.12 (±0.38), 1.17 (±0.37) for the low, medium and high boxes respectively. The average pRSI value was 1.25s (±0.38). The INT group had a significantly greater relative strength (1.9 1RM/BW) compared with the NOV group (1.5

1RM/BW) ($p=0.001$). The stronger INT group produced higher RSI across all box heights and produced greater pRSI as evidenced by moderate effect sizes (*d* = 0.78 to 0.99). The difference in RSI between groups was statistically significant at the high box height ($p=0.04$). The difference between groups in pRSI showed trend level significance ($p=0.06$).

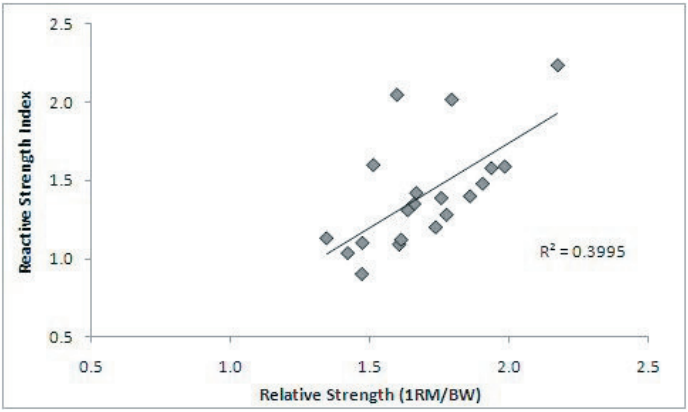

Figure 1: The relationship between maximal relative strength and reactive strength (n=20)

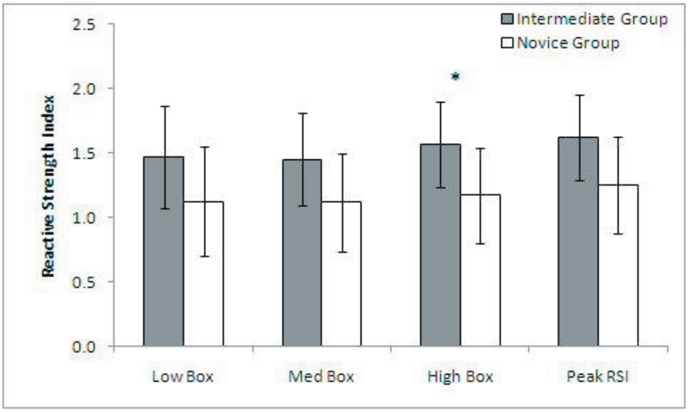

Figure 2: RSI and pRSI across box heights for the INT and NOV groups. * denotes significant difference between groups ($p<0.05$)

Average CT for the INT group was 0.21s (±0.05), 0.22 (±0.03), 0.23s (±0.04) for the low, medium and high boxes respectively. The average mCT value was 0.21s (±0.04). For the NOV group average CT was 0.21s (±0.05), 0.25 (±0.05), 0.24s (±0.04) for the low, medium and high boxes respectively. The average mCT value for the INT group was 0.21s (±0.04). There were no statistically significant differences in CT or mCT observed between the groups. Small effect sizes were in evidence at the low and high box heights (*d* = 0.01 and 0.43 respectively) and a moderate effect size was seen at the medium box height (0.68). A small effect size was present between groups in the mCT variable (*d* = 0.43).

DISCUSSION: To our knowledge this was the first study to examine the relationship between maximal strength and the plyometric monitoring variable of RSI in high level rugby players. The goal of this study was to elucidate the role of maximal strength in plyometric exercise performance and to attempt to establish optimal box heights for use in plyometric depth jumping for rugby players of specific strength levels. The primary finding of this study was the existence of a strong positive relationship between lower body strength levels and plyometric ability. This is in agreement with previous research by Wisloff et al. (2004) using slow SSC vertical jumps. In the present study, players with higher levels of maximal relative strength demonstrated moderately higher levels of RSI in depth jumps across a variety of box heights and produced statistically significant greater RSI at the highest box height (51cm).

No differences were found between the INT and NOV groups in CT at any of the box heights. Strength levels did not appear to affect players' ability to react off the ground quickly and execute the fast SSC during depth jumping. Both groups successfully completed the jumps with an average CT of less than the fast SSC classification of Schmidtbleicher of 0.25s. This suggests that players with relative strength levels of between 1.5 to 1.9 1RM/BW can effectively perform the fast SSC in depth jumps from box heights of 51cm and below. The CT data also suggests that although the INT and NOV players spent the same time periods in contact with the ground during each jump, the stronger, INT players used this time more effectively and were able to produce greater RSI scores in the same amount of time. This finding indicates that stronger athletes may benefit more from fast SSC plyometric training than their weaker counterparts and that maximal strength should be trained in conjunction with fast SSC plyometrics. This finding is in keeping with anecdotal opinion that a reasonable level of maximal strength must be in place before athletes incorporate fast SSC plyometrics in their training regimens.

No strong rationale for box height selection based on strength levels can be made from this study. Players demonstrated highly individualised performances from the varying box heights. While stronger players did produce higher RSIs at all box heights, they did not demonstrate a trend for more successful performance at any given box height. Different players performed better at different heights regardless of strength levels.

CONCLUSION: Stronger rugby players tended to perform plyometric depth jumps more effectively than their weaker counterparts and were more capable in performing higher intensity depth jumps from higher box heights. To optimise the outcome from fast SSC plyometric training a good level of maximal strength should be acheived before undertaking high intensity exercises (>1.5 1RM/BW). During depth jumps different players performed better at different box heights regardless of strength levels. Strength and conditioning coaches should use an individualised testing procedure, as outlined in this study, to identify individual player's optimal box height for use in depth jump training.

REFERENCES:

Baechle, T., Earle, R. (2008). Essentials of Strength Training and Conditioning. Champaign, IL: Human Kinetics.

Flanagan, E.P., Ebben W.P., Jensen, R.A. (2008). The reliability of the reactive strength index and time to stabilization during depth jumps. *Journal of Strength and Conditioning Research.* 22: 1677.

Hopkins, W.G. (2004). A new view of statistics. Online article: http://sportsci.org/resource/stats
Date accessed: 14th January 2011.

Luebbers P.E., Potteiger J.A., Hulver M.W., Thyfault J.P., Carper M.J., Lockwood R.H. (2003). Effects of plyometric training and recovery on vertical jump performance and anaerobic power. *Journal of Strength and Conditioning Research.* 17: 704–709.

Miller M.G., Herniman J.J., Ricard M.D., Cheatham C.C., Michael T.J. (2006) The effects of a 6-week plyometric training program on agility. *Journal of Sports Science and Medicine*. 5: 459–465.

Saunders P.U., Telford R.D., Pyne D.B., Peltola E.M., Cunningham R.B., Gore C.J., Hawley J.A. (2006). Short-term plyometric training improved running economy in highly trained middle and long distance runners. *Journal of Strength and Conditioning Research*. 20: 947–954.

Wisloff, U., Castagna, C., Helgerus, J., Jones, R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, *38,* 285-288.

Young, W. (1995). Laboratory strength assessment of athletes. *New Studies in Athletics*. 10: 88–96.

Acknowledgement
The authors wish to thank Mark Drury and Josh Clarke for their assistance with subject recruitment and collection of strength testing data.