Relationships between concentric and eccentric strength, jumping performance, speed and change of direction in academy rugby union players

Lee A. Bridgeman [1 2], **Michael R. McGuigan** [1 3], **Nicholas D. Gill** [4 5], **Deborah K. Dulson** [6]

[1]Sports Performance Research Institute New Zealand, Auckland University of Technology, Auckland, New Zealand,[2]Department of Sport and Exercise Science, Solent University, Southampton, England,[3]School of Medical and Health Sciences, Edith Cowan University, Perth, Australia,[4]New Zealand Rugby Union, Wellington, New Zealand,[5]University of Waikato, Tauranga, New Zealand, and [6]Newcastle University, Newcastle, England

Eccentric | Peak Force | Performance

Headline

Previously it has been reported that eccentric muscle actions result in higher force production (20 – 60%) compared to concentric muscle actions (1, 2). This may be the result of both mechanical (2, 3) and neural differences (4-6) between the two actions. As a consequence of athletes being stronger eccentrically, traditional strength testing may not adequately assess eccentric strength (7). Therefore, it may be necessary to assess eccentric muscle actions independently.

Aim

This study aimed to investigate if differences exist between lower body eccentric and concentric strength and secondly to explore the relationships between lower body eccentric strength and athletic performance.

Methods

Athletes

Fifteen male rugby union academy players (9 forwards and 6 backs) agreed to participate in this study. All of the subjects were over 18 years of age (mean ± SD; age: 19.7 ± 1.0 years; height: 182.3 ± 9.8 cm; mass: 92.1 ± 5.9 kg; 1RM squat relative to BW = 1.69 ± 0.17). All subjects had at least one year of strength training experience and were engaged in regular strength training (at least three times per week), which included the squat exercise. Before participating all subjects provided written informed consent. The Auckland University of Technology Ethics Committee approved this study.

Design

Subjects attended the laboratory on three separate occasions over a two-week period. During the initial session, the subjects were familiarised with the protocols. The following week each subject completed the jump and strength testing and then 48 hours later, the sprint and change of direction (COD) testing.

Speed and Change of Direction Testing

Each subject completed three maximal 40m sprints. SWIFT dual beam Speedlight gates (Speed Light V2 gate, Swift, Wacoi, QLD, Australia) were set up at the start line and at 10 (CV = 5.6%), 30 (CV = 0.7%) and 40m (CV = 0.7%) to capture timing splits. Upon completion of the sprint testing the subjects completed four 5-0-5 runs in a randomised order; two changing directions with a left foot plant and two with a right foot plant. The average times for each leg were calculated, and the dominant leg was used during further analysis (8).

Jump and Strength Assessment

Subjects completed three maximal countermovement jumps (CMJ) followed by three squat jumps (SJ). The variable of interest during these jumps was jump height (cm) (CMJ CV = 2.6% and SJ CV = 2.2%). All jumps were completed utilising the SwiftSpeedMat (Swift, Wacoi, QLD, Australia) with the mean of the three trials for each jump used in further analysis. The subjects then completed three drop jumps (DJ) from a height of 52cm onto the SwiftSpeedMat. The variables of interest during these DJs were jump height (JH) (CV = 6.2%), contact time (CT) (CV = 16.8%), flight time (FT) (CV = 3%) and the reactive strength index (RSI = JH ÷ CT(9)) (CV = 15.1%). The means of the three jumps were used in further analysis. After a rest period subjects peak eccentric and concentric squat force (N) was assessed utilising the Exerbotics squat device (eSQ, Exerbotics, LLC, Tulsa, OK). This testing was conducted, as described previously (10). The reliability of this method of testing in our laboratory is high (concentric peak force CV = 10% and eccentric peak force CV = 7.2%) (11).

Statistical Analysis

During this study, the statistical analysis was completed using the SPSS software. A Spearman's correlation coefficient (rs) was utilised to investigate the relationships between the variables of interest due to the non-parametric nature of the data. The strength of the relationship was considered small (0.1 to 0.3), moderate (0.3 to 0.5), large (0.5 to 0.7), very large (0.7 to 0.9) and nearly perfect (0.9 to 1.0) (12). A Wilcoxon matched pairs signed rank test was used to establish any differences between concentric and eccentric PF.

Results

The means and SDs for the Exerbotics squat, jump, speed and COD assessments are displayed in table 1. Eccentric PF was found to be significantly greater than concentric PF ($p < 0.05$, ES = 0.67). The correlation coefficient results are displayed in table 2. The strength of the relationships between concentric PF, CMJ and SJ height was small (rs = -0.07 and -0.20 respectively). The strength of the relationship between eccentric PF and CMJ and SJ height was small (rs = -0.27) and moderate (rs = -0.34) respectively. The relationships between both concentric and eccentric PF and the DJ variables (jump height, CT, FT and RSI) were small in magnitude (rs = -0.01 – 0.14). Concentric PF had a large positive relationship with 10, 30 and 40m sprint performance (rs = 0.53 – 0.57), whilst eccentric PF had a moderate positive relationship with the same variables (rs = 0.36 – 0.47). Small relationships were found between all concentric and eccentric PF measures and COD performance (rs = -0.01 – 0.20).

Table 1. Mean ± SD strength, jumping, speed and change of direction (COD) variables (n = 15).

Variable	Mean ± SD
Concentric Peak Force (N)	2738.00 ± 639.65
Eccentric Peak Force (N)	3194.79 ± 536.85
CMJ height (cm)	43.64 ± 6.65
SJ height (cm)	40.43 ± 5.74
Drop Jump height (cm)	39.82 ± 5.01
Contact Time (s)	0.39 ± 0.06
Flight Time (s)	0.57 ± 0.04
Reactive Strength Index (RSI)	105.47 ± 19.58
10 m sprint (s)	1.76 ± 0.11
30 m sprint (s)	4.25 ± 0.25
40 m sprint (s)	5.42 ± 0.25
Best COD (s)	2.41 ± 0.10

Table 2. Spearman's correlation coefficients (rs) matrix of strength, CMJ, SJ, DJ (height, CT, FT, RSI), Speed and Change of Direction (COD) performance.

Variable	Con PF	Ecc PF	CMJ height	SJ height	DJ height	DJ CT	DJ FT	RSI	10-m time	30-m time	40-m time	COD
Con PF	1.00											
Ecc PF	0.73**	1.00										
CMJ height	-0.07	-0.27	1.00									
SJ height	-0.20	-0.34	0.96**	1.00								
DJ height	-0.19	-0.19	0.76**	0.72**	1.00							
DJ CT (s)	0.14	-0.01	-0.08	0.01	0.02	1.00						
DJ FT (s)	-0.14	-0.18	0.78**	0.75**	0.98**	0.02	1.00					
RSI	-0.11	-0.08	0.49	0.44	0.68**	-0.28	0.66**	1.00				
10-m time (s)	0.55*	0.47	-0.49	-0.53*	-0.58*	-0.02	-0.60*	-0.40	1.00			
30-m time (s)	0.53*	0.36	-0.64*	-0.72**	-0.64**	0.08	-0.65**	-0.41	0.90**	1.00		
40-m time (s)	0.57*	0.39	-0.66**	-0.75**	-0.69**	0.10	-0.70**	-0.43	0.87**	0.98**	1.00	
COD (s)	0.20	0.01	-0.69**	-0.66**	-0.70**	0.27	-0.67**	-0.65**	0.35	0.59*	0.61*	1.00

Con = Concentric; Ecc = Eccentric; N = Newtons; PF = Peak Force; DJH = Drop jump height; CMJ = Countermovement jump; SJ = Squat jump; DJ = Drop jump; FT = Flight time; CT = Contact time; RSI = Reactive strength index; COD = Change of direction.
** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Discussion

This study aimed to explore the relationships between eccentric strength and athletic performance. The results of this study support the findings of previous research that eccentric strength is significantly higher than concentric strength (13, 14). Therefore, it is proposed that eccentric strength should be assessed if the aim of the testing is to prescribe eccentric training that enhances eccentric PF. For a summary on eccentric training methods and how to implement them, the readers are directed to the excellent reviews by Suchomel et al. (15, 16).

In the current study, there was a negative relationship found between eccentric PF and CMJ and SJ height (Table 2). This is in contrast with previous research utilising the same methods where Bridgeman et al. (10) reported a large positive, relationship between eccentric PF and CMJ height. In this previous study, the subjects were not team sport athletes and also achieved greater mean CMJ heights than observed in this current study (47.21 ± 4.68cm vs 43.64 ± 6.65cm). Therefore, it is proposed that further research with a broader range of athletes is required to investigate the relationship between eccentric strength and jump performance.

Previously Spiteri et al. (8) reported strong relationships between relative eccentric strength and COD performance (505 test r = -0.89 and t-test r = -0.87) in elite female basketball players which led the authors to speculate that the ability to tolerate a greater eccentric load may be crucial for a successful COD (8). The results of a study by Jones et al. (17) reported that eccentric knee extensor strength had large correlations with COD performance in female soccer players (eccentric knee extensor r = -0.67 and eccentric knee flexor r = -0.60). In contrast, the current results showed a small positive relationship between COD performance and eccentric PF. In the Spiteri et al. (8) study, the subjects performed a dynamic eccentric squat test and had a faster eccentric movement velocity than utilised in the current study. Therefore, we propose that the strength and direction of the reported relationships may depend on both the mode (isokinetic, isotonic or isometric) and the speed of movement used during testing.

When examining the relationship between PF and sprint performance, concentric PF was found to have a large positive relationship and eccentric PF, a moderate positive relationship at 10, 30 and 40m (Table 2). This is in contrast with earlier research which has reported large negative relationships between total strength and sprint performance (18, 19). In rugby union, the stronger players are typically forwards who are generally slower than, the faster but weaker backs (20). This may have influenced our results as the majority of the subjects were forwards who despite producing greater PF had slower sprint times. In studies which have investigated the effects of eccentric training on sprint performance, Cook et al. (21) reported that eccentric training alone did not result in improved sprint performance over 40m despite an increase in overall strength. In contrast, Douglas et al. (22) found that the use of accentuated eccentric load (AEL) training with a slow tempo resulted in improved 40m times (-0.07 seconds; effect size = 0.28). The results of these previous studies are mixed, and therefore, further research is required to establish if enhancements in eccentric strength can lead to improvements in sprint performance.

Practical Applications

- To get a true measure of eccentric strength, this should be assessed independently from concentric strength.
- The results of this testing will allow training that overloads the eccentric muscle action to be prescribed.
- As an isokinetic squat did not have strong relationships with athletic performance a more dynamic lower body test to assess eccentric strength may be preferable (see Spiteri et al. (8) for an example of how to achieve this).

Limitations

- This study only had a small sample size from one sport as a result the relationships reported in this current study cannot be generalised to other sports. Thus, further research across a range of sports and athletes is recommended.

References

1. Hollander DB, Kraemer RR, Kilpatrick MW, Ramadan ZG, Reeves GV, Francois M, et al. Maximal eccentric and concentric strength discrepancies between young men and women for dynamic resistance exercise. J Strength Cond Res. 2007;21(1):34-40.
2. Douglas J, Pearson S, Ross A, McGuigan M. Eccentric Exercise: Physiological Characteristics and Acute Responses. Sports Med. 2016:1-13.
3. Bridgeman L, A., McGuigan M, R., Gill N, D. Eccentric exercise as a training modality. JASC. 2015;23(5):52-66.
4. Enoka RM. Eccentric contractions require unique activation strategies by the nervous system. J Appl Physiol (1985). 1996;81(6):2339-46.
5. Nardone A, Romano C, Schieppati M. Selective recruitment of high-threshold human motor units during voluntary isotonic lengthening of active muscles. J Physiol. 1989;409(1):451-71.
6. Pensini M, Martin A, Maffiuletti NA. Central versus peripheral adaptations following eccentric resistance training. Int J Sports Med. 2002;23(8):567-74.
7. Moore CA, Weiss LW, Schilling BK, Fry AC, Li Y. Acute effects of augmented eccentric loading on jump squat performance. J Strength Cond Res. 2007;21(2):372-7.
8. Spiteri T, Nimphius S, Hart NH, Specos C, Sheppard JM, Newton RU. Contribution of strength characteristics to change of direction and agility performance in female basketball athletes. J Strength Cond Res. 2014;28(9):2415-23.
9. Flanagan EP, Comyns TM. The use of contact time and the reactive strength index to optimize fast stretch-shortening cycle training. Strength Cond J. 2008;30(5):32-8.
10. Bridgeman LA, McGuigan MR, Gill ND, Dulson DK. Relationships Between Concentric and Eccentric Strength and Countermovement Jump Performance in Resistance Trained Men. J Strength Cond Res. 2018;32(1):255-60.
11. Bridgeman LA, McGuigan MR, Gill ND, Dulson D. Test-retest reliability of a novel isokinetic squat device. J Strength Cond Res. 2016.
12. Hopkins WG. A scale of magnitudes for effect statistics. A New View of Statistics [Internet]. 2009.
13. Isner-Horobeti ME, Dufour SP, Vautravers P, Geny B, Coudeyre E, Richard R. Eccentric exercise training: modalities, applications and perspectives. Sports Med. 2013;43(6):483-512.
14. Roig M, O'Brien K, Kirk G, Murray R, McKinnon P, Shadgan B, et al. The effects of eccentric versus concentric resistance training on muscle strength and mass in healthy adults: a systematic review with meta-analysis. Br J Sports Med. 2009;43(8):556-68.
15. Suchomel TJ, Wagle JP, Douglas J, Taber CB, Harden M, Haff GG, et al. Implementing Eccentric Resistance Training—Part 1: A Brief Review of Existing Methods. J Funct Morphol Kinesiol. 2019;4(2):38.
16. Suchomel TJ, Wagle JP, Douglas J, Taber CB, Harden M, Haff GG, et al. Implementing eccentric resistance training—part 2: Practical recommendations. J Funct Morphol Kinesiol. 2019;4(3):55.
17. Jones PA, Thomas C, Dos'Santos T, McMahon JJ, Graham-Smith P. The Role of Eccentric Strength in 180 degrees Turns in Female Soccer Players. Sports (Basel). 2017;5(2):42.
18. Baker D, Nance S. The Relation Between Running Speed and Measures of Strength and Power in Professional Rugby League Players. J Strength Cond Res. 1999;13(3):230-5.
19. McBride JM, Blow D, Kirby TJ, Haines TL, Dayne AM, Triplett NT. Relationship between maximal squat strength and five, ten, and forty yard sprint times. J Strength Cond Res. 2009;23(6):1633-6.
20. Brown S, Brughelli M, Bridgeman L. Profiling isokinetic strength by leg preference and position in rugby union athletes. Int J Sports Physiol Perform. 2015.
21. Cook CJ, Beaven CM, Kilduff LP. Three weeks of eccentric training combined with overspeed exercises enhances power and running speed performance gains in trained athletes. J Strength Cond Res. 2013;27(5):1280-6.
22. Douglas J, Pearson S, Ross A, McGuigan M. Effects of Accentuated Eccentric Loading on Muscle Properties, Strength, Power, and Speed in Resistance-Trained Rugby Players. J Strength Cond Res. 2018;32(10):2750-61.