TRENDS IN MOVEMENT VELOCITY DURING A GRADED PERFORMANCE TEST IN THE BACK SQUAT: IMPLICATIONS FOR RESISTANCE TRAINING PROGRAMS

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INTRODUCTION: In sport, kinetic and kinematic variables such as force and power are vital components which all athletes should strive to maximize (G. R. Harris, Stone, O'Bryant, Proulx, & Johnson, 2000; M. H. Stone et al., 2003). Muscular power is the product of the force and velocity of muscle contraction. For strength and power related sports, inclusion of resistance training practices with an emphasis on both high-force and high-velocity production are of utmost importance (G. R. Harris et al., 2000; Michael H Stone, Stone, & Sands, 2007). In practical terms, high-force and high-velocity training are not performed simultaneously (Cronin, McNair, & Marshall, 2002). High-force resistance training usually includes heavier loads than high-velocity training, which typically consists of lower absolute loads. The nature of competition is such that athletes often incur situations which require high-force or high-velocity productions, thus creating a need to train along the whole power-load continuum (McBride, Triplett-McBride, Davie, & Newton, 1999).

Muscular power and force have been extensively examined in the research (Haff et al., 1997; G. R. Harris et al., 2000; Kraska et al., 2009; M. H. Stone et al., 2003). Velocity is a necessary underpinning of kinetics and kinematics, yet has received very little attention in the research to date with concern to resistance training. However, current trends in research have begun using movement velocity as an evaluation tool in resistance training (Gonzalez-Badillo & Sanchez-Medina, 2010; Judovtseff, Harris, Crielaard, & Cronin, 2011). Concentric movement velocity has shown to be proportional (r= -0.98) to exercise intensity (% one repetition maximum) in resistance training (Judovtseff et al., 2011). It has also been shown that training at specific velocities elicit specific adaptations (Jones, Bishop, Hunter, & Fleisig, 2001). It may be difficult to relate specific exercise intensities, usually expressed in percentages, to work rates encountered in sport competition. Therefore, it may be more practical for coaches to use concentric velocity as an indicator of exercise specificity. This concept of using concentric velocity in the periodization of resistance training has been termed “velocity-based training” (Jovanovic & Flanagan, 2014).

Velocity-based training attempts to emphasize certain performance characteristics by monitoring velocity of specific exercises during a training phase. For example, faster concentric velocities would be expected during a speed-strength phase when compared to a strength-speed phase. Thus, it is necessary to explore the interrelatedness of velocity and known resistance training variables such as exercise intensity or training emphases. Given the strong relationship of velocity to exercise intensity and its importance in power production, it is worthwhile to monitor during resistance training. Application of a velocity-based approach has the potential to provide coaches with valuable insight into athlete monitoring, exercise intensity, and transferability to sport-specific skills. Therefore, the purpose of the current study was to examine the relationship between concentric movement velocity and exercise intensity in the back squat exercise. An additional purpose was to determine the between subject variance associated with increasing intensity in the back squat.

METHODS: Fourteen male subjects volunteered to participate in the study (age= 25.0 years ± 2.6, height= 178.9 cm ± 8.1, body mass= 88.2 kg ± 15.8). Prior to beginning testing procedures, all subjects were required to have: no current or past injuries that affected their ability to back squat, at least one year of experience with the back squat, the ability to perform a back squat to at least parallel (Drinkwater, Moore, & Bird, 2012), and at least 18 years of age. Subjects were also instructed not to perform any fatiguing activity for 48 hours prior to testing. All subjects read and signed written informed consent documents as approved by the University's Institutional Review Board.

The study design examined kinematic variables during a one repetition maximum (1-RM) back squat test. All subjects provided an estimated back squat 1-RM to the investigators. A standardized warm-up procedure (Beckham et al., 2013) was performed prior to performance testing. Each subject's movement velocity was collected during the back squat with increasing intensity until a 1-RM was achieved. To approximate movement velocity, four custom linear position transducers (Celecso Measurement Specialists, Chatsworth, CA, USA) was attached to the barbell during testing (N. K. Harris, Cronin, Taylor, Boris, & Sheppard, 2010).

A modified 1-RM protocol (M.H. Stone & O'Bryant, 1986) was used where subjects performed 65%, 75%, 85%, and 95% of their estimated 1-RM for 5, 3, 2, and 1 repetitions, respectively, before attempting their 1-RM. Subjects were instructed to move every repetition with maximal lifting effort throughout each load condition. The eccentric portion of the squat was performed until the subject was verbally instructed to begin the concentric portion of the lift, upon reaching a parallel squat(Drinkwater et al., 2012). A resistance band was placed at the required depth for each subject as a visual aid to the tester. Three minutes of rest were given between each warm-up set and between each 1-RM attempt (Matuszak, Fry, Weiss, Ireland, & McKnight, 2003). After the initial 1-RM attempt, subjects continued to increase the load on the barbell by a minimum of 2.0 kg and performed additional 1-RM attempts until they failed to complete an attempt. Each subject achieved their 1-RM within 4 attempts.

Kinematic variables were processed using a custom LabView analysis program (LabVIEW, National Instruments, Austin, TX, USA). Inter-subject mean concentric velocity (MCV) of each load condition, standard deviations (SD), coefficient of variation (CV), standard error of the estimate (SEE), and 95% confidence intervals (CI) were calculated for each testing condition. To assess the trend of movement velocity on increasing intensity in the back squat, a Spearman's rho (r_s) was performed between the mean concentric velocity and the tested intensities. These data were analyzed using Microsoft Excel^{TM} 2010, (Version 2010, Redmond, WA, USA).

RESULTS: The mean concentric velocity showed a decreasing trend with increasing load while the variation showed an increasing trend (Table 1). There was a statistically significant negative relationship (r_s= -0.943, p≤0.001) between exercise intensity and mean concentric velocity (R^2=0.797) (Figure 1).

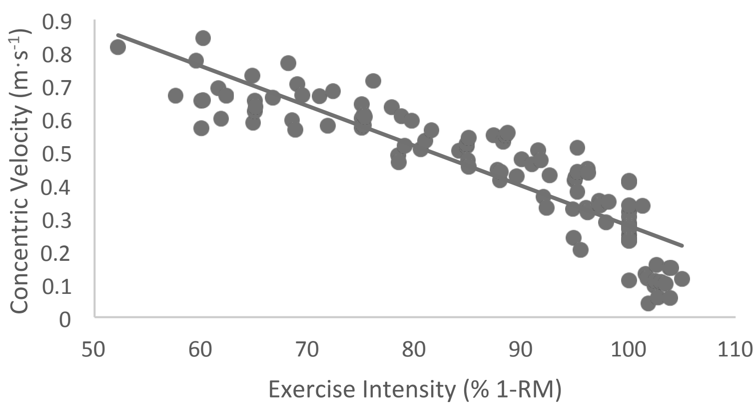
Table 1: MCV, SD, CV, SEE, & 95% CI associated with increasing load conditions in the back squat

Condition (mean % 1-RM ± SD)*	CV	MCV ($m \cdot s^{-1}$) ± SD	CV	SEE	95% CI
Load 1 (61.89% ± 3.95)	6.39	0.662 ± 0.067	10.116	0.058	0.034

Load 2 (72.81% ± 6.25)	8.59	0.627 + 0.080	12.690	0.051	0.040
Load 3 (80.91% + 5.20)	6.43	0.544 + 0.086	15.827	0.052	0.044
Load 4 (90.61% + 5.83)	6.44	0.478 + 0.079	16.594	0.062	0.040
1RM Load (100.00% + 0.00)	0.00	0.278 + 0.072	25.773	N/A	0.036
Failed 1RM Load (102.84% + 1.06)	1.03	0.123 + 0.068	55.119	0.070	0.034

**% 1-RM during each load condition was calculated after 1-RM testing to determine the mean exercise intensity*

Figure 1: Trend of concentric velocity during increasing exercise intensity



DISCUSSION: The results of this study support other research (Judovtseff et al., 2011) indicating a strong relationship between exercise intensity and concentric velocity. However, as intensity increased, the within group variation amongst participants also increased. Practically, this might suggest that as exercise intensity increases, the degree of predictability of velocity is diminished. Previous research has suggested velocity at maximal intensity is a known and predictable value (Izquierdo et al., 2006), yet our results indicate at higher intensities (i.e. near, at, or above 1-RM loads) variation in velocity is larger. Further research should consider establishing normative data for velocity "ranges" coinciding with various volumes, intensities, training emphases, and individual characteristics. In conclusion, concentric velocity at lower intensities may be more predictable than velocities at higher intensities. While intensity and velocity are closely related, coaches should understand that there is no exact velocity that corresponds with a particular intensity; rather there are velocity ranges at a given intensity. The magnitude of these ranges are potentially intensity-dependent. This has important implications when considering a velocity-based approach for training emphases which are focused on either high-force or high-velocity production.

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