INTRASET VARIABILITY OF CONCENTRIC MEAN VELOCITY IN THE BACK SQUAT

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INTRODUCTION: Periodized strength training programs rely on the manipulation of volume and intensity to achieve specific and sequential physiological adaptations. Training volume is a quantification of work, while intensity represents a power output and can be further defined as either training intensity (work divided by time) or exercise intensity (force times velocity). Traditionally, the method for prescribing exercise intensity has relied on using percentages of the one repetition maximum (1RM) to calculate an absolute percent (percent of 1RM) or a relative percent (percent effort at percent of 1RM) for the athlete to train with. Under this scheme design, training intensity is high when the load is high and velocity is therefore low. Conversely, low load, high velocity movements are considered as low to moderate training intensities. Fixed loading parameters, however, fail to account for several day-to-day readiness factors including normal biological variability, fatigue, and outside stressors (Jovanović & Flanagan, 2014). This can lead to a situation in which an athlete's previous 1RM is as much as 18% above or below their most recent tested 1RM (Jovanović & Flanagan, 2014). Given the aforementioned limitations, 1RM-based training prescriptions may not be optimal.

Velocity based training (VBT) has recently been studied as an alternative to the traditional approach (Jovanović & Flanagan, 2014; J. B. Mann, Ivey, & Sayers, 2015) and attempts to quantify and prescribe exercise intensity using concentric mean velocity. It is evident based on the definition of exercise intensity that the power output at a certain load is dependent upon the velocity of the movement. Furthermore, the principle of specificity mandates that athletes perform each repetition with maximal movement intent, since strength gains are velocity specific (Behm & Sale, 1993b) and may depend on the movement intent rather than the velocity achieved (Behm & Sale, 1993a). In practical terms, athletes who attempt to move loads rapidly and explosively make greater gains in strength and power. Very strong relationships between percentage of 1RM and corresponding concentric mean velocity have been reported in the bench press (González-Badillo & Sánchez-Medina, 2010; Jidovtseff, Harris, Crielaard, & Cronin, 2011) and parallel back squat (Izquierdo et al., 2006). Based on this relationship, daily 1RM estimation is made possible by matching warm-up set velocities to their expected load equivalents. Deviation in either direction is then corrected with on the fly 1RM adjustments, allowing the athlete to train at the desired exercise intensity.

While VBT has recently been recognized as an efficacious method of training and monitoring, little data exist quantifying the intra-set variability and whether load affects this variability. Current research efforts have focused primarily on validity and reliability assessments of VBT technology (Cronin, Hing, & McNair, 2004; Hansen, Cronin, & Newton, 2011) and wearable devices (Sato, K. Beckham, Carroll, Bazyler, & Sha, 2015; Sato, Sands, & Stone, 2012), however only two research efforts have aimed to quantify intra-set variability (Carroll, 2015; Sato, Carroll, & Stone, 2016). Therefore, the purpose of this analysis was to determine the intra-set variability in mean concentric velocity during the high bar back squat (HBS) at 8 different loads.

METHODS: Six weight-trained males (25.0 ± 3.1 y; 177.7 ± 3.8 cm; HBS experience 7.5 ± 4.1 years; 1RM: 157 ± 15.3 kg, 1RM/body mass ratio: 1.8 ± 0.18) from strength and power sport backgrounds familiar with the HBS were recruited for this study. Written informed consent was obtained from the subjects and approval was granted from East Tennessee State University's Institutional Review Board.

Standing height was measured using an electronic stadiometer (Cardinal Scale, Model DHRWM, Webb City, MO) and body mass with a calibrated digital scale (Tanita BF-350, Arlington Heights, IL). Four linear position transducers sampling at 1,000 Hz (Celesco Measurement Specialties, Chatsworth, CA, USA) were used to derive vertical and horizontal bar displacement by mounting one on each top corner of the power rack, with the front units and back units equidistant from the center. Displacement was calculated through trigonometric derivation because the lengths of the front and back linear position transducer cables were equal when the barbell was centered. All data was analyzed using LabVIEW software (ver. 2010, National Instruments, Austin, TX, USA).

High bar squat 1RMs were estimated for each subject based on a recent training repetition maximum using the prediction equation by Brzycki (1993) and validated by LeSuer, McCormick, Mayhew, Wasserstein, and Arnold (1997).

Data collection took place at least 72 hours after a familiarization session. All subjects performed a standardized warm-up prior to both sessions consisting of forward walking lunges, reverse walking lunges, right and left side lunges, walking quad stretch, and walking hamstring stretch followed by five slow bodyweight squats and five fast bodyweight squats. After a three minute rest the subject performed three reps at 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% of 1RM. Between two to three minutes rest was given after each set.

Before each set the subject was reminded to perform the concentric portion of the squat as explosively as possible. They were instructed to un-rack the barbell and step onto the middle of the force plates and stand still. The command "squat!" signaled the start of each repetition, and verbal encouragement was offered for each of the three reps. The subject was made to stand still for two to three seconds between each rep and before racking the barbell to establish baseline displacement and force values for each rep. Full range of motion and a controlled eccentric tempo was verbally instructed and encouraged.

Velocity data was computed using a custom analysis program for LabVIEW software and filtered using a low pass 4^{th} order Butterworth filter sampling at 1,000 hz. Intra-class correlation coefficients (ICC) and the back-transformed mean of the log-transformed coefficient of variation (CV) (Hopkins, Marshall, Batterham, & Hanin, 2009) were calculated to determine intra-set reliability. Type one error rate was set at 0.05 for all statistical analyses. Version 22 of SPSS statistical analysis software (IBM Co., NY, USA) and Microsoft Excel 2013 (Microsoft, Redmond, WA, version 15.0.4711.1000) were used to perform all statistical analyses.

RESULTS: Intra-class correlation coefficients and Hopkins' CV for each load are shown in Table 1. Mean concentric velocity data from all loads are displayed in Figure 1.

DISCUSSION: This pilot study sought to quantify intra-set reliability and variation in mean concentric velocity in the back squat across a range of loads in order to gain further insight into exercise intensity prescriptions for VBT. The CV, ICC, and standard deviation of repetitions at 20% and the standard deviation of repetitions at 90% of 1RM indicate higher intra-set variability at these loads than at 30% to 80% of 1RM (see Table 1). Repetitions at 40%, 60%, and 80% of 1RM displayed the least variability.

This investigation is limited by a small sample size and thus does not have the statistical power to detect small differences between loads. It is likely that the small differences in variability observed in loads 30% through 80% are due entirely to this sampling error, and not differences between velocity output. However, the magnitude of variability difference at 20% and 90% loads is much greater and thus may be closer to a true difference.

There are several factors that may lead to increased variability at 20% of 1RM. In VBT literature, 0-15% of 1RM has been termed the "neurological zone" and is thought to be untrainable (B. Mann, 2015), potentially due to the fact that whole muscle contraction velocity is limited by fiber type distribution, attachment points, and architectural factors that have little adaptability to training. Furthermore, it may be that athletes were not fully warmed up despite completing a standardized warm-up protocol. In this case, each repetition could have served to potentiate the next since it is known that high velocity movements can potentiate subsequent efforts. Figure 1 shows that in the 20% to 50% loads the first one or two repetitions have lower velocities.

The increased variability at 90% of 1RM was likely due to fatigue since this intensity typically corresponds with a 3-4 repetition maximum (Baechle & Earle, 2008; Brzycki, 1993). Figure 1 demonstrates this, as the group mean velocity of the third repetition is the lowest of the set.

The current data illustrates the need to further investigate intra-set variability in concentric mean velocity in the back squat. Research investigating a greater number of continuous repetitions per set, or utilizing single repetitions with submaximal loads may give insight into whether fatigue is a contributor to intra-set variation in velocity output. An athlete must be able to reliably achieve movement velocities that are within their physical capabilities if velocity-based prescriptions and quantitative velocity feedback are to be meaningful.

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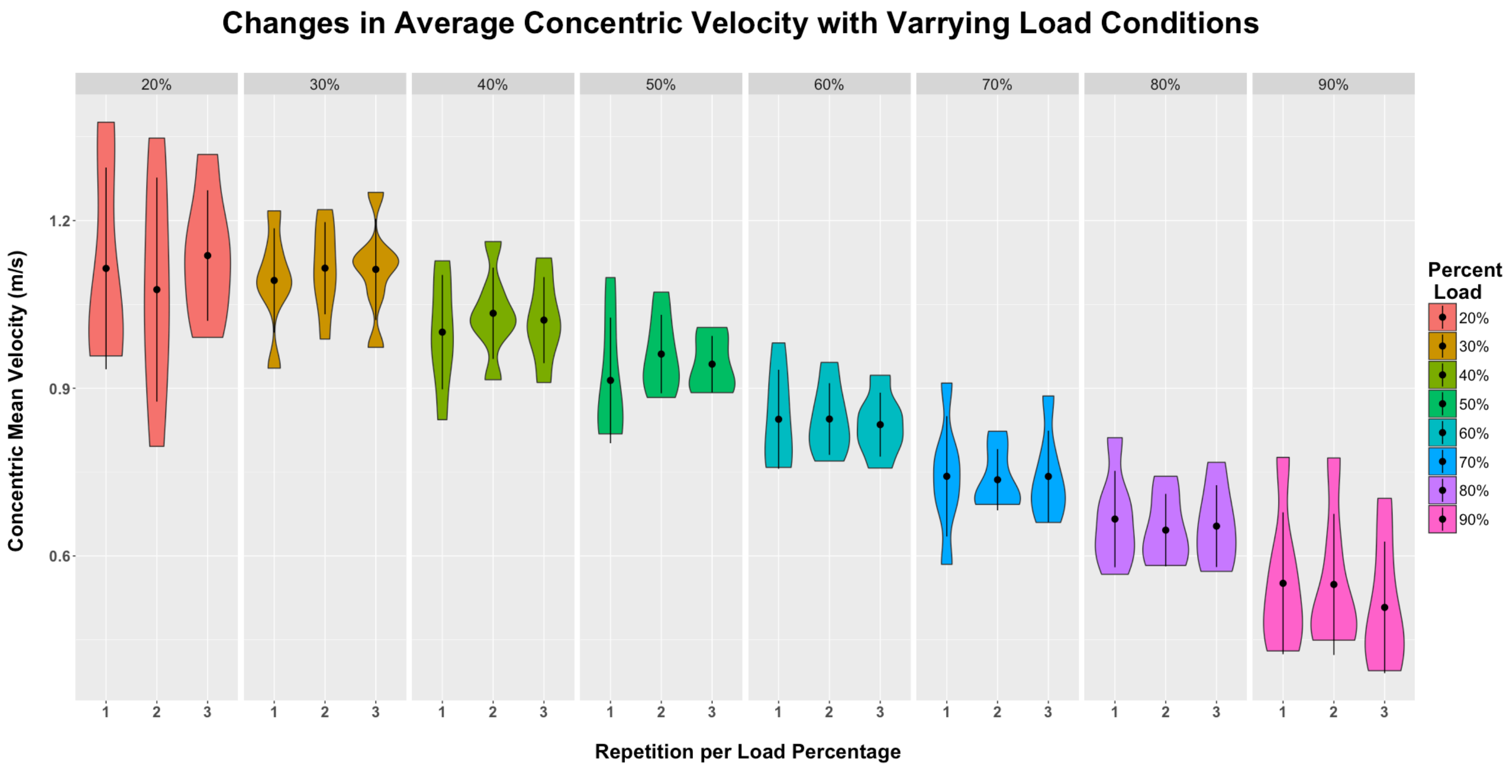
Table 1. Intra-Set Variability of Concentric Mean Velocity

Load	Hopkins CV	ICC
20%	8.6%	80.6%
30%	3.3%	86.5%
40%	1.9%	91.8%
50%	3.0%	76.8%
60%	2.5%	90.8%
70%	3.3%	83.0%
80%	3.3%	90.1%
90%	3.1%	94.6%

Table 2. Average Concentric Mean Velocity at Each Rep.

20% Rep 1	20% Rep 2	20% Rep 3	30% Rep 1	30% Rep 2	30% Rep 3
1.11 ± 0.18	1.08 ± 0.2	1.14 ± 0.12	1.09 ± 0.09	1.11 ± 0.08	1.11 ± 0.09
40% Rep 1	40% Rep 2	40% Rep 3	50% Rep 1	50% Rep 2	50% Rep 3
1 ± 0.1	1.03 ± 0.08	1.02 ± 0.08	0.91 ± 0.11	0.96 ± 0.07	0.94 ± 0.05
60% Rep 1	60% Rep 2	60% Rep 3	70% Rep 1	70% Rep 2	70% Rep 3
0.84 ± 0.09	0.85 ± 0.06	0.83 ± 0.06	0.74 ± 0.11	0.74 ± 0.05	0.74 ± 0.08
80% Rep 1	80% Rep 2	80% Rep 3	90% Rep 1	90% Rep 2	90% Rep 3
0.67 ± 0.09	0.65 ± 0.06	0.65 ± 0.07	0.55 ± 0.13	0.55 ± 0.13	0.51 ± 0.12



Changes in Average Concentric Velocity with Varrying Load Conditions
20%
30%
40%
50%
60%
70%
80%
90%
Concentric Mean Velocity (m/s)
1.2
0.9
0.6
1
2
3
Repetition per Load Percentage
Percent Load
20%
30%
40%
50%
60%
70%
80%
90%