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AN EXPLORATORY STUDY ON THE USE OF CONCENTRIC VELOCITIES IN THE BACK SQUAT AS A MONITORING TOOL

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INTRODUCTION: The quality of strength and conditioning coaching can be enhanced by the implementation of an athlete monitoring program (Foster, 1998). There is a growing interest in quantitatively monitoring athlete's during resistance training sessions (Hopkins, 1991; McBride et al., 2009). Concentric velocities of the system mass (athlete's mass and bar load) measured longitudinally may provide an indication of an athlete's preparedness, level of fatigue, and other strength characteristics (González-Badillo and Sánchez-Medina, 2010; Jovanović and Flanagan, 2014; Sakamoto and Sinclair, 2006). An important component of common sport skills like running, jumping, and change of direction is the ability to impart high ground reaction forces over brief time periods (i.e., impulse) (Aagaard et al., 2002). According to the impulse-momentum relationship, derived from Newton's second law, an increase in impulse applied to the system leads to a greater change in momentum.

Thus, changes in impulse are related to the resultant change in the system's velocity during lifting movements. Depending on the degree of transfer between the lifting movement and the sport movement, greater concentric velocities in the weight room may improve on-field performance (Mann, 2011).

Decrements in concentric velocity during a training set may be an indicator to the strength and conditioning coach that the prescribed load is too high or fatigue is influencing the quality of training (Jovanović and Flanagan, 2014; Sakamoto and Sinclair, 2006). In such cases, the strength and conditioning coach may choose to adjust an athlete's training program accordingly. Monitoring concentric velocity within a set of a resistance training exercise may be helping in determining whether the prescribed intensity is appropriate (González-Badillo and Sánchez-Medina, 2010; Sakamoto and Sinclair, 2006). Wearable devices, such as PUSH™ (PUSH, Toronto, Canada) provide coaches the ability to quantify concentric velocities wirelessly. The maintenance of concentric velocity can also indicate the athlete's mastery of the exercise being executed. The device is a relatively new concept, but could be able to replace instruments that are typically only accessible in the laboratory setting to measure concentric velocities.

Collecting concentric velocity data during real time training sessions could serve as a daily monitoring tool in addition to laboratory monitoring tests. Monitoring the variability of concentric velocity within a training session and over the duration of a training block can be included along with other monitoring data to provide coaches with information regarding how specific athletes are responding and adapting to the training program. Therefore, the purpose of this study was to explore the use of a wearable inertial measurement device during a back squat exercise as a monitoring tool in NCAA Division I collegiate women's softball players.

METHODS: This exploratory study used the PUSH™ device, a wearable inertial sensor, to monitor and assess two athlete's concentric velocities during a back squat exercise using a variety of loaded conditions. Two NCAA Division I collegiate women's softball players participated in the study(Athlete A 66.7 kg, 171cm, 21.1 years old, Athlete B 70.8 kg, 168 cm, 20.7 years old). This study was approved by the East Tennessee State University Institutional Review Board. The data were collected during 5 training sessions over the course of several weeks during the off-season training, which emphasized hypertrophy and strength development. All resistance training sessions were preceded by a standard dynamic warm-up. Relative intensities were prescribed to each athlete by estimation of a maximum effort for a given set and repetition range. This was based on previous maximum effort lifting totals for a given exercise. The subsequent intensities were percentages based on the estimated maximum effort for that set and repetition combination.

The squat was performed two days per week, where day one had a higher relative intensity (heavier load) than day two to account for accumulated fatigue later in the week. Both subjects performed multiple warm-up sets for the squat exercise, although the absolute load for each set was selected within a five percent range of a prescribed relative intensities. The subjects were given at least twenty-four hours of recovery between each training session involving the back squat exercise.

The PUSH™ device was worn on the athlete's forearm. Average and peak velocity, power, and force as well as total work for each repetition were collected. Although data could be viewed instantly the data were stored for future analysis using Microsoft Excel 2014. For this study average concentric velocities for each back squat repetition were analyzed, and the average concentric velocity per set was reported. Additionally, the percent fall-off based on the highest and lowest average concentric velocity per set was reported. Intra-class correlation coefficients (ICC) and technical error of measurement (TEM) were used to examine reliability between sets for the back squat exercise for all training sessions.

RESULTS: Test-retest reliability of repetition-to-repetition concentric velocities within each session were acceptable range (ICC=0.84) in accordance with previous research regarding intra class correlations (2). The relative TEM for concentric velocity was 4.68%. The average concentric velocity for each training session is listed in Table 1. The average percent fall-off for concentric velocity within each session for the back squat is listed in Table 2. Figure 1 displays the percent fall-off in concentric velocity between highest and lowest repetition from session 1 for both athletes as an example of the analysis.

Table 1. Average concentric velocity (m/s) per back squat session

	Session 1 3x5 @ 75%	Session 2 3x10 @ 70%	Session 3 3x5 @ 60%	Session 4 3x10 @ 85%	Session 5 3x10 @ 75%
Athlete A	0.76±0.07	0.84±0.1	0.9±0.08	0.72±0.11	0.83±0.08
Athlete B	0.69±0.04	0.88±0.04	0.9±0.04	0.75±0.05	0.85±0.05

*Prescribed relative training intensities are shown as percentages based on the given sets and reps

Table 2. Percent fall-off in concentric velocity per back squat session

	Session 1 3x5 @ 75%	Session 2 3x10 @ 70%	Session 3 3x5 @ 60%	Session 4 3x10 @ 85%	Session 5 3x10 @ 75%
Athlete A	22.43±2.79	31.24±2.98	14.95±1.07	41.79±5.49	24.08±8.30
Athlete B	14.28±6.32	12.91±2.34	11.65±5.24	17.83±1.83	17.63±2.91

*Prescribed relative training intensities are shown as percentages based on the given sets and reps

DISCUSSION: The purpose of this study was to explore the use of a wearable inertial measurement device during a back squat exercise as a monitoring tool in NCAA Division I collegiate women's softball players. The primary findings of this study are: 1) that the highest concentric velocities were seen at lower relative intensities, and 2) the greatest fall-off in concentric velocity was experienced with higher relative intensities and repetitions. And 3) idiosyncratic responses were noted between athletes regarding fall-off in concentric velocities when both athletes performed the same number of sets and repetitions at the same relative intensities.

The percent fall-off was greatest for both athletes when the highest relative intensity was prescribed. This is consistent with previous research indicating that declines in concentric velocity are greater at higher exercise intensities (Izguierdo, 2005). It is beyond the scope of this study to determine a causal relationship between the greater percent fall-offs for Athlete A; however future research might expand upon this by monitoring individual training loads, relating tests of maximal strength to percent fall-off at varying relative intensities, or examining specific biomarkers (e.g. creatine kinase, testosterone, cortisol).

Given that Athlete A showed a greater percent fall-off in average concentric velocity intra-session when compared to Athlete B, it may be inferred that there are idiosyncratic responses to the prescribed relative intensities. The athlete's preparedness, level of fatigue, and other strength characteristics may affect the actual intensity performed by the athlete during a training session (González-Badillo and Sánchez-Medina, 2010; Jovanović and Flanagan, 2014; Sakamoto and Sinclair, 2006). Prescribed relative intensities in the presence of outside factors, such as preparedness or fatigue level, may alter the actual relative intensities for an athlete during any given training session. Therefore, it is possible that Athlete A was less accustomed to the back squat, more fatigued, or weaker than Athlete B; although bar velocity or percent fall-off alone is not enough to fully explain the values measured. Although further research would be needed to determine the relationship between relative intensity and concentric velocities, the results here indicate that monitoring concentric velocities might be able to aid strength and conditioning coaches in determining if the actual relative intensity of the back squat exercise is related to the prescribed relative intensity within and across training sessions.

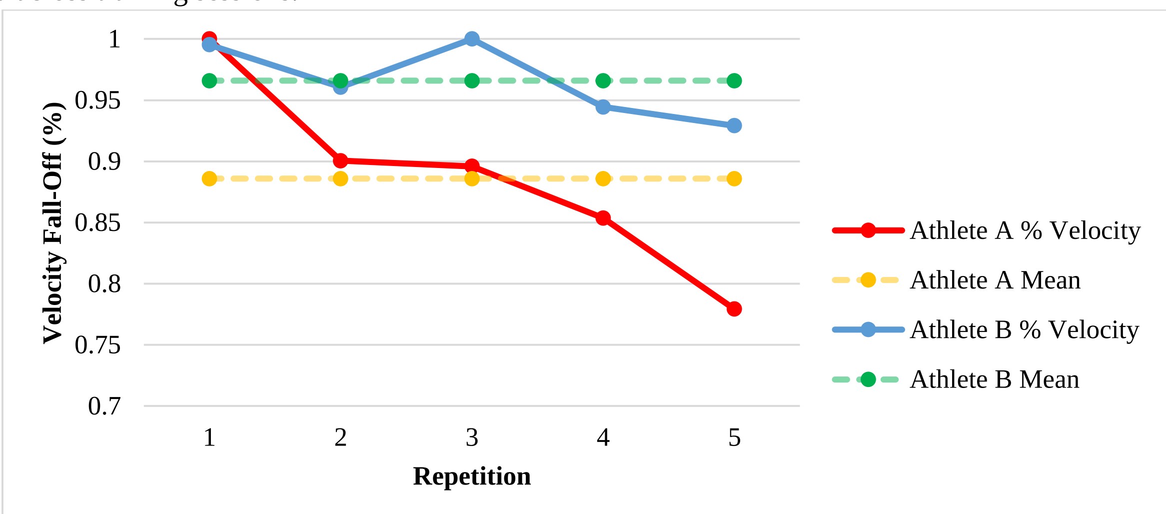

Figure 1: Differences in average concentric velocities (m/s) and percent fall-offs between athletes A and B during the concentric portion of a back squat exercise during 3 sets of 5 repetitions from session 1

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