

EXAMINATION OF BAR VELOCITY IN BARBELL BACK SQUAT

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The aim of the study was to examine repetition to repetition changes of bar velocity and its variations from barbell back squat. Participants ($N=19$) performed back squat with a relative intensity of 78-80% of 1RM. Bar velocity was captured using wireless device (PUSH™) placed on their forearm. Data were collected from 3 sets of 10 repetitions. One-way repeated measures ANOVA was used to identify the velocity changes over 10 repetitions. Statistical significance was found ($F(1,17)=45.06$, $p<0.0001$). This indicates that the bar velocity decreased significantly over the 10 repetitions. At the same time, coefficient of variance also increased as the repetitions went higher, indicating that there were differences in individual responses of bar velocity changes. Further examination will be aimed to investigate the bar velocity changes from various strength level of individuals.

KEYWORDS: WIRELESS SENSOR, RESISTANCE TRAINING, MEASUREMENT.

INTRODUCTION: Bar velocity measurement is increasing its popularity in strength and conditioning to measure how fast lifters are moving external loads in training. Instruments such as TENDO-unit™ and gymAware™ have been used to measure bar velocity with a wired connection to the bar (Cronin, Jones, & Hagstrom, 2007; Gonzalez, Hoffman, Rogowski, Burgos, Manalo, Weise, Fragala, & Stout, 2013). This type of measurements have focused on back squat, bench press along with some explosive lifts. In recent years, wireless instruments (via Bluetooth™ connection) such as PUSH™ and BarSensei™ are used for a similar purpose, but provide a user-friendly approach with “no wires” in the testing environment. The PUSH™ unit provides versatility to accommodate non-bar exercises such as dumbbell, kettlebell, and medicine balls. This gives users the ability to test velocity in different types of exercises at chosen intensity.

Based on a force-velocity curve, peak power output is found at different loads depending on the athletic population (Cormie, McBride, & McCaulley, 2007; Kawamori, Crum, Blumert, Kulik, Childers, Wood, Stone, & Haff, 2005; Stone, O'Bryant, McCoy, Cognianese, Lehmkuhl, & Shilling, 2003). The force-velocity curve described in the textbook is somewhat a theory-based shape. When lifters perform an exercise at a given intensity over relatively high repetitions (e.g. 10 repetitions), possible velocity variations at given resistance has not yet been identified or cautiously been checked in a practical setting. While identifying load specific velocity changes seem important and necessary from a safety perspective (Ratamess, Alver, Evetoch, Housh, Kibler, Kraemer, & Triplett, 2009), changes in bar velocity from repetition to repetition (rep-to-rep) could also aid coaches in identifying an athlete's capability to maintain bar velocity throughout a set of lifting, and thus provide feedback. Preliminarily speaking, identifying the rep-to-rep bar velocity on the barbell back squat is a primary concern in the current study. The barbell back squat has been studied for many years from several perspectives such as its influence on athletic performance (Stone, Sands, Pierce, Carlock, Cardinale, & Newton, 2005), and describing injury risk (Flanagan & Salem, 2007). Examining the bar velocity changes over rep-to-rep during the back squat would provide insight for identifying whether one can maintain an appropriate bar velocity or not.

This study specifically focus on changes and variation of bar velocity in relatively high repetitions. From a practical stand point, velocity variations would come from various factors such as acute fatigues, due to intensity (high percentage (%) of repetition maximum (RM)),

technique, and training experience. A comparison of bar velocity changes at different intensities has been investigated before, but the same loads over repetitions also seem relevant and would provide practical knowledge to strength and conditioning coaches. Therefore, the purpose of this study was to examine rep-to-rep bar velocity in the barbell back squat. The study mainly focused on changes in bar velocity over 10 repetitions at a relative intensity of 78-80% of 1RM. This study also examined changes in variations over the 10 repetitions.

METHODS: Nineteen female collegiate-level athletes participated the study (height (cm) = 170.5 ± 5.7 ; mass (kg) = 65.5 ± 7.1 ; body fat (%) = 27.08 ± 5.2). Participants' age ranged from 18 to 21, and in collegiate athletic experience at maximum of 3 years apart. All participants had been instructed by qualified (certified) strength and conditioning coaches to obtain proper technique to perform a barbell back squat. The data collection is a part of on-going athlete monitoring program and was obtained during regular training days. All participants signed informed consent in accordance with the University Institutional Review Board.

It is important to note that data were collected during the team's weight training schedule at identical time. Weekly relative intensity (%1RM) and training volume were already planned prior to the data collection. Data considered for this current study was when athletes performed barbell back squat of 3 sets of 10 repetitions (3x10) at a relative intensity of 78-80% of 1RM. Velocity data were collected with PUSH™ bands, using application of software on a smartphone to select the exercise (in this case, barbell back squat) and the load lifted. The wireless device is relatively new, but showed small error, high reliability, and validated with Vicon™ motion capture and linear transducer in previous studies (Balsalobre-Fernandez, Kuzdub, Poveda-Ortiz, & del Campo-Vecino, 2015; Sato, Beckham, Carroll, Bazylar, Sha, & Haff, 2015).

All participants performed an identical order of dynamic warm-up prior to beginning exercises and also warmed up with lighter weights for the back squat. When they reached the work set, they placed PUSH™ band on their forearm (see Figure 1a). Application software from their smartphone was used to operate the setting. Exercise and loads were chosen from the software (see Figure 1b). Prior to performing the barbell back squat, participants pressed "ready" to start the sensor. They performed the exercise 3x10. When they completed the lift, they pressed "stop". All data were stored data on their application software and exported it out to an excel sheet after the sessions.



Figure 1a. Placement of PUSH™ band on the forearm.

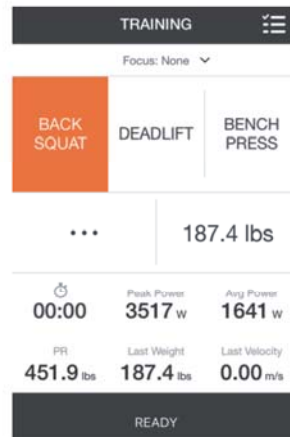


Figure 1b. PUSH™ application software of the smartphone.

Each individual's 3x10 are averaged from 3 data per repetition per participant. Ten repetitions' mean and standard deviation were summarized for data analysis. One-way repeated measure

ANOVA was performed to identify the difference of rep-to-rep average bar velocity as p value was set at 0.05 for significance (IBM SPSS ver. 22, IBM, New York, USA). Coefficient of variation (CV) from each repetition was examined to capture its changes over the 10 repetitions.

RESULTS: The average bar velocity decrease was statistically significant ($F(1,17)=45.06$, $p<0.0001$), indicating that the bar velocity decreased as the repetitions approach the 10th repetition (see Table 1). As a post-hoc test, a pairwise t -test comparison was done to further examine the actual rep-to-rep differences. Although the back to back repetitions such as 1st and 2nd repetitions, or 3rd and 4th repetitions did not show statistical difference, the further the repetitions were away from each other, the greater the p values and t scores. Comparison of average 1st and 10th repetitions differed by 20.42%. Comparison between 2nd, 3rd, 4th, and 5th repetitions with the 10th repetition differed by 14.5%, 13.29%, 11.93%, 10.17%, respectively. The current study also analyzed the CV from each repetition to see changes over the 10 repetitions. The CV was increasing as the repetitions went towards 10 (see Table 1). Further analysis was done to investigate the CV changes over the repetitions from each individual. Interestingly, those participants who produced a faster bar velocity (top 6 out of 19, ranging from 0.75-0.88 m/s) showed relatively small CV (ranging from 1.74-2.96%). Athletes with slower bar velocities (bottom 6 out of 19), bar velocity was 0.59-0.70 m/s with the CV of 9.00-14.43%.

Table 1
Descriptive data on bar velocity (m/s) form repetition to repetition

	1	2	3	4	5	6	7	8	9	10
Mean	0.83	0.78	0.78	0.77	0.76	0.74	0.73	0.73	0.70	0.69
SD	0.07	0.08	0.08	0.08	0.08	0.09	0.10	0.09	0.10	0.10
CV	7.88	9.80	10.52	10.85	10.73	12.77	13.68	12.46	13.58	14.00

DISCUSSION: The primary purpose of this study was to examine the changes in bar velocity over the 10 repetitions at a relative intensity of 78-80% of 1RM. It is obvious that the bar velocity started to decrease as the repetitions increased. There was a gradual decrease of velocity in group average and also from several individuals, confirming that over the 10 repetitions bar velocity changes with a relative intensity of around 80% of 1RM. From a practical stand point, a minimum threshold of back squat bar velocity from previous study was around 0.25-0.30 m/s and down to around 0.18 m/s to be the consideration of maximal strength at 77-84% of 1RM and absolute 1RM test (Carroll, 2015; Jovanovic & Flanagan, 2014). Based on the information, 0.69 m/s at the 10th repetition may be underestimating the 1RM. However, this may need further examination of reps to failure bar velocity.

When considering a gradual decrease in bar velocity over repetitions, on average, it decreased 0.14 m/s between 1st and 10th repetition. In order to maintain or gain the power output, velocity must be consistent or higher at a given load. Force and velocity must be maintained over the repetition to keep a relatively similar power output. Based on the current data, in average, and in some individuals, power output decreased over the 10 repetitions.

This study also examined changes in bar velocity variations over the 10 repetitions. From the 19 participants, CV was relatively low (up to 14%), indicating the homogeneity of the athletes in the current study. But the study also revealed gradual increase in rep-rep CV from 7.88% to 14%, indicating that as the repetitions proceeded, individual responses differed. As mentioned in the results, participants who performed barbell back squat with slower bar velocity had greater variation over 10 repetitions. This may indicate a lack of sufficient strength to perform the back squat over 10 repetitions with consistent bar velocity as compared to those who displayed a relatively higher bar velocity. Further investigation in this measure is necessary. To bridge the gap between science and practice, ways to analyze the raw data seems to be next step. While average data as a trend of tested participants, is indeed important data reporting technique. It is

also important to investigate each individual response to the stimulus. For example, in the current study, an individual who displayed high velocity had very small CV during the 10 repetitions, indicating small to no changes in the bar velocity. In comparison, slow velocity individuals had higher CV, indicating inconsistency in the bar velocity (typically it was due to velocity decrease). Thus, the data must be shared with coaches and strength coaches to focus on technique and physical improvement to reduce the velocity variation during a relatively high repetition sets.

CONCLUSION: Overall, preliminary findings of the velocity changes over the 10 repetitions of back squat found that gradual decrease in bar velocity is apparent. Coefficient of variation also increased over the repetitions. When examined on each participant's data, slower bar velocity athletes displayed greater variations in bar velocity over the 10 repetitions, indicating the individual responses differ. Further investigation is needed to determine how other factors such as various intensity and/or volume affects bar velocity.

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