1-1-2017

Relationship Between Concentric Velocities at Varying Intensity in the Back Squat Using a Wireless Inertial Sensor

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Citation Information

Carroll, Kevin M.; Sato, Kimitake; Beckham, George K.; Triplett, N. Travis; Griggs, Cameron V.; and Stone, Michael H.. 2017. Relationship Between Concentric Velocities at Varying Intensity in the Back Squat Using a Wireless Inertial Sensor. *Journal of Trainology*. Vol.6(1). 9-12. https://doi.org/10.17338/trainology.6.1_9 ISSN: 2186-5264

Short Communication

Relationship between concentric velocities at varying intensity in the back squat using a wireless inertial sensor

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Objectives: The purpose of this study was to examine the relationship of velocities in the back squat between one repetition maximum (1RM) and submaximally loaded repetition maximum (RM) conditions, specifically in regard to what has been described as the minimal velocity threshold (MVT). The MVT describes a minimum concentric velocity that an individual must reach or surpass in order to successfully complete a repetition.

Design: To test the presence of a MVT, participants were tested for 1RM and RM back squat ability. The mean concentric velocities (MCV) of the last successful repetition of each condition were then compared.

Methods: Fourteen male participants familiar with the back squat volunteered to participate in the current study (age = 25.0 y ± 2.6, height = 178.9 cm ± 8.1, body mass = 88.2 kg ± 15.8). The mean concentric velocity (MCV) during the last successful repetition from each testing condition was considered for the comparison.

Results: Results indicated a non-significant negative relationship of MCV between the 1RM and RM conditions (r = -0.135), no statistical difference between testing conditions (p = 0.266), with a small-to-moderate effect size (d = 0.468).

Conclusions: The results of this study suggest that MVT should be further investigated to enhance its use in the practical setting. Additionally, coaches considering using a velocity-based approach for testing athletes should use data from either 1RM or RM conditions, but not both interchangeably. Coaches should be cautious when considering group averages or comparing velocity data between athletes, which may not be appropriate based on our results.

(*Journal of Trainology* 2017;6:9-12)

Key words: Velocity-based training ■ Minimal velocity threshold ■ Strength and conditioning ■ Resistance training

INTRODUCTION

In resistance training (RT) theory and practice, training is progressed and variation is provided by manipulating one or more training variables (e.g. volume, intensity) in order to elicit a desired training effect.[1] Variables such as volume and intensity have been researched extensively[1-3] and have fairly specific roles in periodization and programming.[1] Recently, movement velocity has been the subject of research examining its use as a RT variable for monitoring.[4-6] There is evidence that velocity is related to absolute load ($R^2 = 0.98$)[7] and may provide coaches with quantitative values to enhance autoregulatory methods of training and load adjustment,[4] although not all research agrees.[8] Velocity measurement may be an attractive option for coaches due to its proposed ability to quantify loading intensity. Coaches potentially could use velocity as a method to ensure that prescribed intensities and training emphases are actually being implemented. For example, if a coach prescribed maximal strength using heavy loading, velocity decline throughout a set could indicate fatigue and thus a heavy load for that athlete. However, the factors influencing the velocity of resistance training exercises are not well understood; different testing protocols, set and repetition schemes, levels of fatigue from previous training sessions or exercises, and other factors may affect the velocity of exercise execution in addition to load.[9,10]

A velocity-based approach in prescribing resistance training has evidence supporting its use.[4,5,11] Specifically, velocity ranges have been suggested to correspond with a particular training emphasis (i.e. high velocities indicate training for explosiveness while lower velocities indicate training for maximal strength). Previous research has utilized bar velocity in determining what has been called a minimal velocity threshold (MVT) for specific exercises.[12] The MVT concept suggests there is a minimum velocity for a specific exercise (e.g. back squat or bench press), which a lifter must surpass in order to successfully complete a repetition regardless of the load or level of fatigue.[5] This concept has practical significance because different training emphases would likely necessitate that velocities either be closer or further away from the MVT. For example, training for maximum strength might include loading patterns that are close to the MVT while training for power or explosiveness might include loading patterns that are further from the MVT. Thus, a greater understanding of MVT may provide insight into structuring resistance training programs using a velocity-based training approach.

Received September 30, 2016; accepted January 26, 2017

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Research conducted in a controlled environment (Smith machine) has indicated an exercise-specific MVT.[12] Participants in this research have completed both one repetition maximum (1RM) and submaximally loaded repetition maximum (RM) tests and have achieved similar mean concentric velocity (MCV) measures during the critical repetition (last successful) in each condition.[12] Current there is a paucity of research examining the MVT concept in a typical resistance training environment (i.e. free weights). Thus, the purpose of the study was to examine the relationship of velocities in the free weight back squat between 1RM and submaximally loaded RM conditions.

METHODS

Participants

Fourteen males participated in the current study (age = 25.0 y ± 2.6, height = 178.9 cm ± 8.1, body mass = 88.2 kg ± 15.8). Participants were recreationally trained (> 1 year of self-guided resistance training experience) and had experience with the back squat. Participants were instructed to avoid any fatiguing activity for 48 hours prior to testing and during the testing protocol. All participants read and signed written informed consent documents as approved by the University's Institutional Review Board.

Design

To investigate the relationship between MCV at various intensities, a repeated measures design was used. MCV has been shown to be the most representative measure of the concentric portion of an exercise when compared to peak concentric velocity in resistance training exercises,[5] thus MCV was used for analysis of lifting performance. Each participant's kinematic data for the back squat were collected during a 1RM and during each repetition of a RM test. To evaluate the MVT, MCV data from the last successful repetition of the 1RM and RM conditions were compared.

Procedures

During testing, a wireless inertia-measuring device (PUSH, Inc., Toronto, Canada) with a sampling frequency of 200 Hz was used to collect kinematic data. The device has shown to be a valid tool for the measurement of concentric barbell velocity.[13] The device was attached to each participant's forearm. Prior to the initial testing, subject anthropometric measurements were collected. All participants performed 2 testing procedures with each testing session separated by 7 days. In the first testing session, each participant's 1RM for the back squat was tested using a free weight standard 20kg barbell. In the second session, participants performed repetitions until voluntary failure using 70% of 1RM.

During the first testing session (1RM back squat), participants were instructed to perform the concentric portion of each lift with maximal movement velocity, including the warm-up attempts and all 1RM attempts. The participants performed the eccentric portion of the squat at a self-selected pace to establish greater ecological validity. A resistance band was placed at the parallel depth for each subject as a visual aid for the tester to indicate when the required depth had been reached. Participants were given verbal encouragement for the concentric portion of each repetition. Participants were instructed to pause for 1-2 seconds at the top between repetitions but were permitted to begin each repetition voluntarily. A modified 1RM protocol was used where participants performed 65%, 75%, 85%, and 95% of their estimated 1RM for 5, 3, 2, and 1 repetitions, respectively, before attempting their 1RM.[14] Three minutes of rest were given between each warm-up condition and between each 1RM attempt.[15] After the initial 1RM attempt, participants continued to increase the load on the barbell by a minimum of 2.0 kg and performed additional 1RM attempts until they failed to complete an attempt. Each subject achieved their 1RM within 4 attempts. The last successful repetition was considered the participant's 1RM and the MCV of that repetition was recorded as the MVT.

Participants returned in 7 days for the second testing session during which they lifted 70% of their 1RM until they failed to complete an additional repetition. Participants had the same depth requirements as in the first testing session. Participants were reminded to use maximal lifting effort during the concentric phase of each repetition in the warm-up and RM testing conditions, and to pause 1-2 seconds between repetitions. Two warm-up sets were performed prior to the submaximally loaded RM condition. The warm-up sets included 55% and 65% of 1RM for 5 repetitions each. Three minutes of rest were given between each warm-up condition and before the submaximally loaded RM condition. Participants then performed repetitions until failure with 70% of 1RM. The MCV of the last successful repetition was used for analysis of the MVT.

Statistical Analysis

The MCV derived from the PUSH™ device's kinematic data during the last successful repetition during both the 1RM and the repetitions until failure conditions was used to examine the MVT. Descriptive statistics (mean, standard deviation, and between-subject coefficient of variation) were calculated for group data for all loading conditions. A Pearson product-moment zero-order correlation was used to identify the relationship between the two MCVs. A paired t-test, typical error, and effect size using Cohen's *d* were used to determine differences between each testing condition. The criteria for statistical significance was set at $p \leqq 0.05$. Correlations and effect size using Cohen's *d* were interpreted according to the scale developed by Hopkins.[16]

RESULTS

The MVT in the 1RM (0.32 ± 0.06 m·s^{-1}) and the submaximally loaded RM (0.35 ± 0.05 m·s^{-1}) conditions were not statistically different from one another ($p = 0.266$), but had only a weak relationship ($r = -0.135$). A small effect size was also observed ($d = 0.468$) between conditions. The mean subject MCV decreased as the intensity (load) increased during the 1RM testing condition and with progressing task duration during the submaximal RM condition. Additionally, the coefficient of variation generally increased with greater intensity (Tables 1 and 2).

Table 1 1RM session MCV: mean, SD, CV over several conditions

	Mean MCV ($m \cdot s^{-1}$)	SD	CV
First Warm-Up Set (65% 1RM 5 repetitions)	0.65	0.08	12.84
Second Warm-Up Set (75% 1RM 3 repetitions)	0.62	0.07	11.96
Third Warm-Up Set (85% 1RM 2 repetitions)	0.54	0.07	13.67
Fourth Warm-Up Set (95% 1RM 1 repetition)	0.47	0.08	17.57
First Successful 1RM Attempt	0.39	0.09	22.35
Last Successful 1RM Attempt	0.32	0.06	17.35

Table 2 Submaximally Loaded (70% 1RM) RM MCV: mean, SD, CV over several conditions

	Mean MCV ($m \cdot s^{-1}$)	SD	CV
First Warm-Up Set (55% 1RM 5 repetitions)	0.73	0.11	14.77
Second Warm-Up Set (65% 1RM 5 repetitions)	0.66	0.10	14.62
All Successful Reps Until Failure	0.53	0.11	20.58
Last Successful Rep Until Failure	0.35	0.05	15.59

Each participant's 1RM was found within 4 attempts. There was an average increase of 2.7 ± 1.0% in load from the last successful attempt to the failed attempt. Average tested 1RM was 141.5 ± 32.4 kg. In the RM condition, 22 ± 7 repetitions were completed amongst the participants with 70% 1RM.

DISCUSSION

The purpose of this study was to examine the relationship of velocities in the free weight back squat between 1RM and submaximally loaded RM conditions. The main finding of the study shows a non-significant relationship between the MVT in the 1RM and the submaximally loaded RM conditions along with a small-moderate effect size. The lack of significant relationship suggests that velocity responses may differ depending on the type of test (e.g. single effort or fatiguing multiple effort), which may aid coaches to interpret their velocity data collection more effectively. No statistical difference was found between 1RM and RM conditions, however it is interesting that the relationship between 1RM and RM MVT was so low. Perhaps this is due to idiosyncrasies in technique or strength between participants; on average the MVT may be similar for the group, but there may be individual differences in the relationship between each subject. Recently, it has been observed that more experienced lifters have decreased within-set variation in bar velocity compared with less experienced lifters,[6] possibly explaining some of the heterogeneous findings of the current study. The between-subject variation of MVT may be indicative of this variability.

It has been shown that MVT in the parallel back squat exercise (Smith machine) was similar between participants' performance of maximal tests of 1RM and RM in previous research.[12] Past research has also indicated MVT can be considered "exercise-specific" meaning that a particular exercise (e.g. back squat) has a similar MVT across participants and conditions.[5,12] If MVT is variable or individual specific, using regression equations to predict 1RM may not provide appropriate or consistent feedback.[8]

Although the findings of this study counter-indicate the presence of a MVT in the back squat exercise using free weights, there are several limitations that should be addressed in future literature. The lack of speed control during the eccentric portion of the squat, while necessary to establish ecological validity, may have impacted the results of the study. Muscle morphological aspects and other anthropometric factors should also be considered when examining velocities in resistance training. The training age of the participants may have impacted technical homogeneity. More trained participants may have more stable squat technique, limiting technique as a confounding factor.

Our results indicate a non-significant relationship between the two testing conditions in terms of MVT. Furthermore, coaches should consider these results when interpreting MVT data of their athletes. If MVT is indeed specific to individual athletes, then perhaps the use of MVT needs to be used on an individual athlete basis, rather than using group data. Future research should further examine if the MVT is test (e.g. 1RM vs. RM), exercise (e.g. back squat vs. bench press), or athlete specific and reliable across testing sessions (e.g. multiple 1RM testing sessions for each subject). An attempt to control for individual differences, such as differing strength levels, training age, or physiological differences may help to tease out the individual variability in MVT seen in this and other studies.[6]

CONCLUSIONS

In conclusion, our results show that MVT is not stable between 1RM and submaximal repetitions until failure conditions. This is the first study to the authors' knowledge concerning the MVT concept in the free weight back squat. Our results provide important insight for coaches and sport scientists considering using a velocity-based training approach. The results of the current study do not support the comparison of velocities between athletes at maximal intensities. Thus, velocity data at these maximal intensities should not currently be examined to monitor a group of athletes, but rather to monitor individual athletes.

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