**Using velocity loss for monitoring resistance training effort in a real world setting**

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Using velocity loss for monitoring resistance training effort in a real world setting

Running head: Velocity loss and resistance training effort

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Abstract

The purpose of the present study was to evaluate the changes in movement velocity during resistance training with different loads while the trainees are attempting to move the load at a pre-determined repetition duration. Twenty-one resistance-trained men (age: 25.7 ± 5 years; height: 177.0 ± 7.2 cm; mass: 85.4 ± 13.56 kg) volunteered to participate in the study. Participants performed two test sessions. The first to determine 1 repetition maximum (1RM) load, and the second to evaluate velocity loss during a set to failure performed at 75% and 50% of 1RM using a 2 second concentric and 2 second eccentric repetition duration, controlled by a mobile app metronome. When using 75% 1RM there was a significant loss of movement velocity between the antepenultimate and the penultimate repetition (5.33%, p<0.05), as well as during the penultimate and the last (22.11%, p<0.05). At 50% of 1 RM the participants performed the set until momentary failure without significant velocity loss. Monitoring velocity loss during high load resistance training through simple methods can be an important tool for standardize the intensity of effort employed during submaximal training. This can be useful in clinical conditions where maximum exertions are contraindicated or when specific logistics are lacking.

Key Words: Weight training; Strength training; Training to failure; Muscle hypertrophy; Training effort.
Introduction

It remains a contentious issue as to whether training to momentary failure is necessary to promote optimal adaptations in resistance training (Willardson 2007, Davies et al. 2016, Dankel et al. 2017). Some studies suggest that performing repetitions to momentary failure (MF) may be necessary to promote optimal gains in lean mass and muscle strength (Rooney et al. 1994, Drinkwater et al. 2005, Gießing et al. 2016) while others suggest that similar, or even greater, gains in muscle strength, power and athletic performance can be obtained without reaching MF (Folland et al. 2002, Izquierdo 2006, Izquierdo-Gabarren et al. 2010, Martorelli et al. 2017, Pareja-Blanco et al. 2017, Nóbrega et al. 2018). However, it seems that at least employing near maximum efforts is necessary to optimize results from a resistance training intervention (Fisher et al. 2013, 2016, 2017a, Steele et al. 2017c). One practical limitation of training to MF is that, for some exercises (e.g. free-weight barbell bench press) it usually requires specific logistics (safety bars and/or the, presence of a spotter) to maintain a safe exercise environment. Moreover, training to MF might not be feasible in clinical conditions where maximum exertions are contraindicated. On the other hand, when not training to MF it is difficult to standardize the intensity of effort employed (Dankel et al. 2017), which might lead to stimuli below the necessary threshold to promote the pursued adaptations.

Whilst many strategies have been adopted to estimate the effort employed in a training session and thus control the stimuli, many problems emerge when trying to measure a submaximal effort (Steele et al. 2017b, Steele et al. 2017c, Dankel et al. 2017). Using ratings of perceived exertion or volitional fatigue might be particularly misleading, especially because effort might be confounded with discomfort (Steele et al. 2017b, Steele et al. 2017c). Indeed, a higher degree of discomfort, notably associated with reaching MF with lighter load training to failure (Fisher et al. 2017a), might lead to the cessation of training before reaching...
the necessary effort to bring optimal adaptations (Gießing et al. 2016). Another common strategy is to correlate the number of repetitions performed with a given percentage of 1-repetition maximum (1RM). This can also lead to a misrepresentation of effort due to the large variation in the number of repetitions performed at a given relative load among exercises and individuals (Hoeger et al. 1990, Buckner et al. 2017, Gentil et al. 2017).

Before reaching MF, many signs of muscle fatigue are detectable, such as: reduction in muscle force, movement velocity and power output (Allen et al. 1995, Sánchez-Medina and González-Badillo 2011, Mikkola et al. 2012). In this regard, it has recently been shown that monitoring movement velocity might be a reliable strategy to predict effort during resistance training (González-Badillo et al. 2017) and it has been used as an indicator for the interruption of a set of repetitions (Pareja-Blanco et al. 2017). It is important to note, however, that within previous studies protocols involved training with maximum intended velocity and used a special device to measure velocity. Whilst these studies are unquestionably relevant for sports performance, they might have limited application in most strength and conditioning facilities, where devices to constantly measure movement velocity might not be available. Moreover, whilst controlling movement velocity has been a topic of debate (Fisher et al. 2017b, Cadore et al. 2018), those generally performing resistance training with strength or hypertrophy as goals typically perform the exercises with a submaximal, controlled velocity.

Resistance training is usually performed at a predetermined repetition duration (usually 1-3 seconds in each phase of muscle action through a given range of motion) as suggested by popular exercise guidelines (ACSM 2009). However, as exercise approaches MF, it becomes increasingly challenging to maintain a specific, pre-determined velocity. Eventually the set is interrupted because fatigue has resulted in force production loss to the point where attempted dynamic actions turn into an unintended isometric action (Steele et al. 2017b) (Brown and Weir 2001). If one knows how the proximity of MF influences the ability
to adhere to a specific velocity, then it might be possible to objectively predict how far the set is to its endpoint of MF. In this case, the impossibility to comply with the proposed velocity can be used as a practical landmark for exercise interruption before a maximum effort is reached and it can also assure that the set was not interrupted before providing an adequate stimulus. Based on this, the purpose of the present study is to evaluate the changes in movement velocity during resistance exercise performed with different loads while the trainees were attempting to move the load at a pre-determined repetition duration. Our hypothesis is that disregarding the load used, movement velocity will progressively drop, as the exercise gets closer to MF.
Material & methods

Study overview

The participants were tested in two sessions, with 48 to 72 hours between them. The first session involved anthropometric measures and 1RM test in the bench press using a smith machine. For the second session, the participants performed the bench press exercise to MF. Participants were instructed to take 2 seconds for eccentric phase and 2 seconds for the concentric phase until momentary failure. The first test was performed at 75% of 1RM and, ten minutes after its end, the participants performed the same procedure at 50% of 1RM.

Participants

Twenty-one resistance-trained men (age: 25.7 ± 5 years; height: 177.0 ± 7.2 cm; mass: 85.4 ± 13.6 kg) volunteered to participate in the study. To participate, volunteers had to have at least 2 years of resistance training experience, including the performance of bench press at controlled movement velocity. Participant’s mean experience in resistance training was 7.0 ± 4.9 years. No physical limitations, health problems or musculoskeletal injuries that could have affected the test were reported. None of the participants were taking medications or substances expected to affect physical performance. After being informed of the experimental procedures and all possible risks and discomforts related to the study protocol, subjects signed an informed consent form approved by Institutional review board. The present study was performed in accordance with the Declaration of Helsinki.

One repetitions maximum (1RM) test

The 1RM protocol followed previous guidelines concerning muscular strength evaluation (Brown and Weir 2001). Participants performed a warm-up for two sets of 10 reps
at 20-30% of body weight with 3-min intervals between sets. Three minutes after the warm-up, load was increased and the participant was instructed to perform a complete repetition at a self-selected velocity. If the repetition was completed successfully, the load was increased by two to 20 kilograms and, after a 5-min interval, another attempt was performed. The procedure was repeated until achieving the highest load with which the individual could perform a complete repetition. A maximum of five attempts was allowed per session. If the maximum load was not obtained by the fifth attempt, the test was interrupted and retaken on a different day when the participant was rested.

Experimental procedures

Velocity was measured during the bench press exercise using the T-Force Dynamic Measurement System (Ergotech, Murcia, Spain) which was carefully fixed in the bar of a smith machine. During the tests, participants were instructed to move the bar at a constant velocity, taking 2 seconds to complete the eccentric and 2 seconds to complete the concentric phase, with no pause between them. A mobile app metronome programmed in 60 bpm was used to control repetition duration. The participants were instructed to match one beep with the end of concentric/eccentric phase and the other with the middle of the movement. Participants were familiarized with the repetition duration and metronome for two sets without additional load before performing the tests, which also served as a warm up. After familiarization/warm-up, a rest interval of five minutes was given before the beginning the tests. The first test involved performing the exercise at 75% of 1RM until MF. After 10 minutes of rest, the participants performed the same procedure at 50% of 1RM. Evaluators gave verbal instructions to restore the velocity pattern when a participant did not accomplish the established repetition duration and strong verbal encouragement was provided to ensure maximal efforts. A metronome was used in order to help the participants keep a constant
velocity; however, the sets were performed to MF, defined as the inability to complete a full
repetition despite the greatest effort in attempting to do so; (Steele et al. 2017b) therefore the
velocity was not exactly the same during all repetitions. Mean propulsive velocity (MPV)
was recorded for analysis for all completed repetitions, therefore whilst participant’s
exercised to MF, it was only the final repetition; where the participant reached MF which was
not considered.

Statistical analysis

The data are presented as means and standard deviation. MPV of the last 4 complete
repetitions of both tests (75% of 1RM and 50% of 1 RM) was used in the analysis. One way
repeated measures ANOVA were used to compare MPV. Multiple comparison with
confidence interval adjustment by the Bonferroni procedure was used for post hoc
comparisons. Results were considered significant when p < 0.05. Analysis was performed
using the Statistical Package for the Social Sciences 23.0 (SPSS, Chicago, IL).
Results

Mean 1RM load was 98±21.6 Kg, with a relative strength of 1.15±0.2, obtained by ratio of the load of 1RM relative to body mass. The average number of repetitions performed at 75% of 1RM was 7.5±1.7 and 13.7±2,8 for 50% of 1RM.

Figure 1 presents the MPV for both velocities across the final 4 repetitions of each set, while the exercise was performed to MF it only includes the complete repetitions. At 75% of 1RM there was a significant difference among repetitions MPV \( F(1,20) = 30.54; p < 0.001 \). Post hoc analysis revealed that MPV in the last repetition was lower than in the preceding three. Similarly, MPV during the penultimate repetition was lower than during the antepenultimate and the 4th from last. However, there was no difference in MPV between the 4th last and the antepenultimate repetition. Velocity loss from the antepenultimate to the penultimate repetition was 5.33%, from the last to the penultimate was 22.11% and the accumulated loss from the last to the 4th last was 25.4%.

ANOVA for MPV values obtained at 50% 1RM load showed no significant effects \( F(1,20) = 0.81; p = 0.801 \), which suggested the same predetermined velocity pattern was maintained until reaching MF.
Discussion

The aim of the present study was to evaluate if velocity loss could predict the proximity to MF during a set of bench press in an ecologically valid context. The main finding was a significant velocity loss in the last two repetitions before reaching MF when training at 75% but not 50% of 1RM. Although our initial hypothesis was not totally confirmed, this might be of practical interest because it implies that analyzing the movement velocity during high load resistance training might help to define a set endpoint. By controlling repetition duration, it is possible to interrupt the exercise before the impossibility to move the load, but avoid the risk of a suboptimal hypertrophic stimuli. However, no significant velocity loss was observed at 50% 1RM load. Which implies that, when using light loads, velocity loss might not be suitable for determining the interruption of the set. It is important to note, however, that independent of the intended repetition duration being kept constant the participants reported an increased difficulty, and thus applied a greater effort level to complete repetitions as the set progressed towards MF in both cases.

One possible explanation for the different repetition duration responses between training loads might be motor unit recruitment patterns. At lighter loads, a low number of motor units are activated (mostly, low threshold motor units and type I fibers) and, as fatigue ensues, there are a substitution of the fatigued fibers and activation of additional fibers, mainly higher threshold motor units and type II fibers. Therefore, when the movement is approaching MF, as lower threshold motor units fatigue, sequential recruitment of higher threshold motor units may subsequently permit maintenance of constant velocity. However, when using heavier loads a greater number of higher threshold motor units are required, which includes the synchronous recruitment of type II fibers. It seems likely that their subsequent fatigue without replacement by sequential recruitment of other motor units results in a slowing of movement velocity.
Previous studies showed a progressive decline in movement velocity over each repetition until MF. (Izquierdo et al. 2006, Sánchez-Medina and González-Badillo 2011, González-Badillo et al. 2017, Sánchez Moreno et al. 2017, Pareja-Blanco et al. 2017) Based on this it has been suggested that monitoring velocity might be an effective strategy to control for intensity of effort during resistance training. (González-Badillo et al. 2017) The practical application of this strategy was demonstrated by Pareja-Blanco et al., (Pareja-Blanco et al. 2017) who compared the effects of two resistance training programs on muscle structural and functional adaptations in young men. During both protocols the participants performed the same exercise at maximal intended velocity, the programs only differed in the repetition velocity loss allowed in each set (20 vs. 40%). After 8-weeks of training, the group that trained until they lost 40% of initial velocity had greater hypertrophy of vastus lateralis and intermedius, suggesting that progressive accumulation of muscle fatigue, and closer proximity to MF, might be important for muscle hypertrophy. However, the group training to 40% velocity loss also performed a greater volume which may have also contributed to the greater hypertrophy produced. Whilst it is not possible from this study specifically to determine whether the greater fatigue induced or additional volume performed was responsible, this finding suggests that knowing how near a set is to MF could be a valid approach to controlling a training protocol in promoting muscle hypertrophy.

Interestingly, the number of repetitions performed in the present study were notably lower than previously reported by Gonzalez-Badillo et al. (2017). These differences are probably due to the movement velocity adopted, since the present study used a controlled velocity (~2 seconds to each phase), while in the study of Gonzalez-Badillo et al. (2017) the participants performed the exercise as fast as possible. In this regard, previous studies have shown that performing the exercise at higher velocities allow the performance of a higher number of repetitions (LaChance and Hortobagyi 1994).
The present study adds to the current body of literature and provides information that can be easily applicable for most resistance trainers, since the exercise was performed with controlled velocity and used simple methods for controlling repetition duration. Considering that the velocity loss that precedes muscle failure (~20%) is easily perceptible when using high loads, trainees can use a metronome, match the movement of music beats or simply count the seconds taken to perform each repetition, without the need of any special equipment. Moreover, interrupting the set when it is not possible to accomplish a predetermined velocity might lead to near maximum efforts, since our data indicate that after that point the trainee would only be able to perform a maximum of two repetitions. This might be of importance in practice since in some exercises (especially those using free-weight barbells) it is not safe to reach MF without supervision. However, when using low loads, it was not possible to identify such a point, as such the only way to ensure the optimization of results is to continue the set until MF. In this case, it might be interesting to use dumbbells or machines in the absence of a spotter. However, in cases where it is not safe to train to MF, it might be advisable to avoiding training with low loads. This might be particularly interesting since recent studies suggest that it is more difficult to reach MF when using low loads (Steele et al. 2017a), which can be due to the higher discomfort (Fisher et al., 2017).

One important limitation of the study is the performance on a smith machine, a device that limits movement to a vertical movement through a single plane; therefore, it is not known if our results would apply to free weights, where compensatory movements might help in the performance when close to MF. Future studies should test the performance of resistance training using velocity loss to interrupt the sets, as suggested in the present, to verify if this would reflect in better results.
Conflict of interest

The authors have no conflicts of interest to report.
References


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Figure legends

Fig. 1. – Mean propulsive velocity across the final 4 repetitions of each set performed at 50 and 75% of 1RM. * different from the previous repetition (p < 0.05).
Mean propulsive velocity across the final 4 repetitions of each set performed at 50 and 75% of 1RM. * different from the previous repetition (p < 0.05).