THE EFFECTS OF SYSTEMATIC UNLOADING ON MUSCLE ACTIVATION AND FATIGUE DURING RESISTANCE EXERCISE

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This study examined acute, local muscle fatigue and recovery, temporally, during velocity-based resistance exercise. A dynamic single-leg extension resistance exercise model with systematic unloading based on changes in repetition velocity was used to measure changes in quadriceps muscle activation patterns. EMG indices of acute, local muscle fatigue and recovery were closely associated with changes in movement velocity for each unloading condition. Systematic Unloading (SU) is an effective resistance training protocol in order to minimize acute, local muscle fatigue and facilitate muscle fatigue recovery within a set.

KEYWORDS: load reduction, movement velocity, neuromuscular

INTRODUCTION: Past researchers have suggested that in order to maximize muscular strength and mass, training to failure is necessary (Jacobson, 1981). Acute, local muscle (i.e, neuromuscular) fatigue has been defined as a “failure to maintain required or expected force”, or “a temporary lowered capacity to do work at a specified intensity” (Cifrek et al., 2009) and is accompanied by specific and consistent changes in myoelectric activity. Past research has shown that muscle is not entirely fatigued at the point of muscular failure as the muscle is still able to generate force, but less in a longer timeframe (Wan, Qin, Lang & Sun, 2017). As a result, researchers have begun to examine load reduction as an effective strategy to fully fatigue the musculature. Load reduction training has been shown to enable higher amounts of muscular work to be done in one training session by allowing the muscle to complete additional repetitions, with less load, once muscular fatigue is initially reached. A previous study noted that the rating of perceived exertion (RPE) was significantly lower for load reduction groups as compared to a control group who did the more traditional form of training despite a greater workload for the load reduction group (Lima et al., 2018). They concluded that load reduction may be a beneficial strategy to reduce the perception of effort during training while achieving similar or greater improvements in hypertrophy and strength. A second study compared different RT protocols that completed the same workload. One group completed a single drop set and another group performed three sets of traditional RT. They found significant increases in the CSA of the triceps muscle and a significantly lower perceived effort ($P<.01$). They concluded that superior muscle gains may be achieved with the use of drop sets (DS) as compared to traditional RT due to a greater training stimulus placed on the muscle during DS training (Fink, Schoenfeld, Kikuchi & Nakazato, 2018). Researchers have also begun to examine Cluster set (CS) resistance training. The CS RT protocol involves the implementation of intra-set rest periods (15-45 seconds) once a predetermined velocity threshold is reached. A 2019 study found that the use of CS maintained neuromuscular performance while also increasing total workload (Latella, Teo, Drinkwater & Kendall, 2019). By combining load reduction and velocity-based RE training (VBT), termed Systematic Unloading (SU), we can determine on a rep-by-rep basis, a specific, individualized change in movement velocity and then use this as the threshold for decreasing the resistance load as a way to minimize muscular fatigue and increase the volume (i.e., number of repetitions × resistance load) of each set of a resistance exercise. The purpose of this study is to determine if Systematic Unloading is an effective training methodology in order to minimize acute, local muscle fatigue. A secondary purpose of this study was to explore the relationship between movement velocity and measures of EMG as it relates to tracking acute, local muscle fatigue.

METHODS: 8 females and 3 males with moderate resistance training experience volunteered for this study. Initial Anthropometric and Body Composition measurements were recorded prior to participation in the study (See Table 1). All participants completed a single-leg extension One Repetition Maximum (1RM) Test to determine the initial training load; 75% 1RM. 75% of the 1RM was chosen as the initial training load in order to stimulate hypertrophy and to avoid fatiguing participants too quickly. The SU training group completed velocity-based training (VBT). Following a 20-25% decrease in average concentric velocity for 2 consecutive reps, the resistance load was immediately (within 5s) decreased by 20%. SU began with the initial load (IL), unloading of weight occurred twice during each set (UL1 and UL2) and total reps, exercise time and RPE were recorded. Participants completed 3 sets of single-leg extensions using the SU training protocol with 2 minutes of rest between each set. An ultrasound sensor and custom-built software was used to monitor movement velocity of each repetition. Electrodes for EMG analysis were placed on the Vastus Lateralis (VL), Rectus Femoris RF) and Vastus Medialis (VM) muscles on the right leg and VM on the left leg. EMG signals were analyzed for mean and median frequency, total power, average peak amplitude, and mean amplitude during each rep. A 2 (Sets) × 3 (Unloading) × 2 (Reps) Analysis of Variance with Repeated Measures and Within-Subjects Contrasts was used to analyze the data.

Table 1: Descriptive Statistics on Body Composition

Variable	Mean	SD
Ht (m)	1.691	0.0938
Wt (kg)	65.74	13.6678
BMI	22.812	3.0318
%Fat	21.633	9.37
Lean Mass (kg)	29.113	8.7553
Fat Mass (kg)	14	6.6578
Leg Length (cm)	86.4	8
Upper Leg Length (cm)	45.8	5.3
Lower Leg Length (cm)	33.4	3.4

Table 2: Descriptive Statistics on Repetitions

Variable	Mean	SD
Rep Total	39.9	11.7
Set 1 Rep Total	16.3	4.9
Set 2 Rep Total	12.4	3.7
Set 3 Rep Total	11.2	3.3
Set 1 IL Rep Total	7.4	2.7
Set 1 UL 1 Rep Total	5.4	2.7
Set 1 UL 2 Rep Total	5.7	1.7
Set 3 IL Rep Total	5.2	1.5
Set 3 UL 1 Rep Total	3.6	1.3
Set 3 UL 2 Rep Total	3.9	0.1

RESULTS: EMG data shows that the initial repetition (Ri) and final repetition (Rf) differ significantly across the initial Load (IL), the 1st unloading (UL1), and the 2nd Unloading (UL2) conditions for median frequency ($p<0.000$), mean frequency ($p<0.000$), average peak amplitude ($p=0.009$), and mean amplitude ($p<0.000$) for Sets 1 and 3. Additionally, Ri EMG data for IL and UL1 were not significantly different for Sets 1 or 3, but EMG for Ri at UL2 was significantly different. A similar pattern occurred for Rf; EMG data for IL and UL1 were not significantly different for Sets 1 or 3, but Rf at UL2 was significantly different (see Figures 1-4). The patterns in the data are similar across the quadriceps muscles. Also, R1 and Rf Velocity significantly decreased (R1>Rf; $p<0.001$) across each unloading condition. Also, R1 velocities did not differ significantly across load/unloading conditions for set 1 or 3.

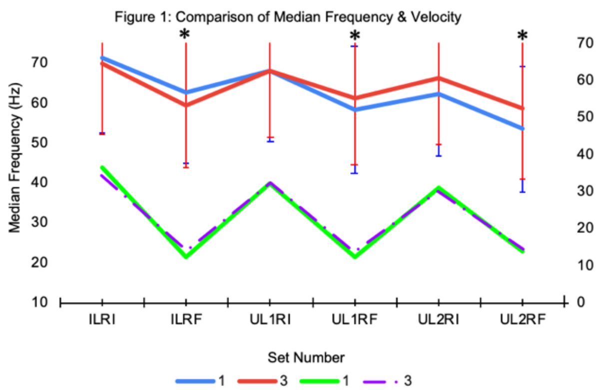

Figure 1. Represents Median Frequency and Velocity values of Set 1 and Set 3 Ri and Rf across the initial load (ILRI, ILRF), unloading one (UL1RI, UL1RF) and unloading two (UL2RI, UL2RF). Each asterisk signifies a significant decrease from Ri-Rf ($p<0.001$).

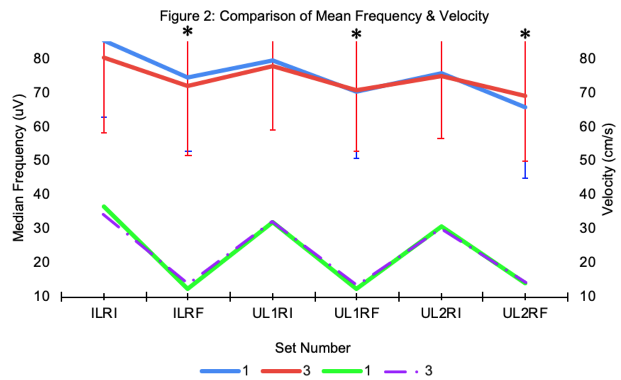

Figure 2. Represents Mean Frequency and Velocity values of Set 1 and Set 3 Ri and Rf across the initial load (ILRI, ILRF), unloading one (UL1RI, UL1RF) and unloading two (UL2RI, UL2RF). Each asterisk signifies a significant decrease from Ri-Rf ($p<0.001$).

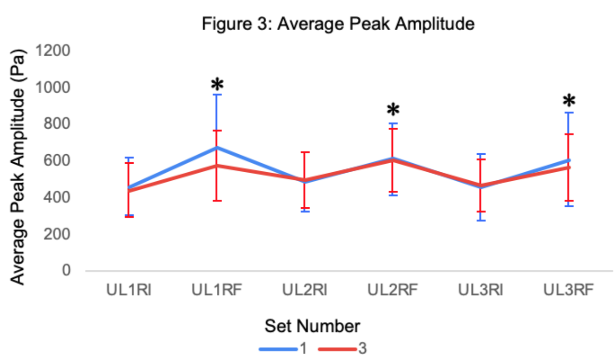

Figure 3. Represents Average Peak Amplitude values of Set 1 and Set 3 Ri and Rf across the initial load (ILRI, ILRF), unloading one (UL1RI, UL1RF) and unloading two (UL2RI, UL2RF). Each asterisk signifies a significant increase from Ri-Rf($p<0.001$).

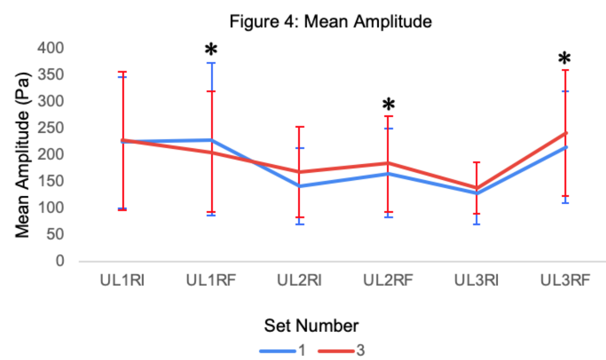

Figure 4. Represents Mean Amplitude values of Set 1 and Set 3 Ri and Rf across the initial load (ILRI, ILRF), unloading one (UL1RI, UL1RF) and unloading two (UL2RI, UL2RF). Each asterisk signifies a significant increase from Ri-Rf ($p<0.001$).

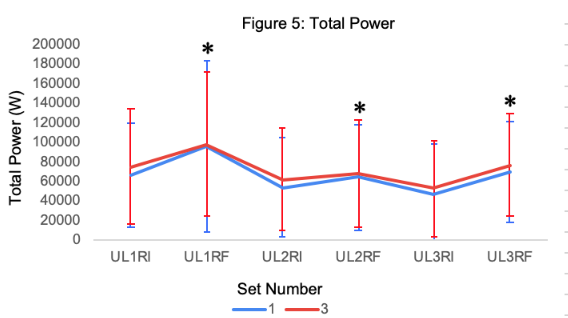

Figure 5. Represents Total Power values of Set 1 and Set 3 Ri and Rf across the initial load, unloading one and unloading two. Each asterisk signifies a significant increase from Ri-Rf($p<0.001$).

DISCUSSION: Systematic Unloading is a novel approach to RT. None of the few studies that measured velocity during a load reduction RT protocol, have used SU. Instead, they have suspended training at a certain velocity threshold or used cluster sets based on velocity changes. The 2019 study implementing cluster sets (CS) RT found CS to be effective in minimizing velocity and power loss during a resistance training session (Latella, Teo, Drinkwater & Kendall, 2019). In our study, the use of SU (minimal to no intra-set rest) showed that when the resistance load was decreased within each unloading condition, measures of EMG and velocity returned to or near to the Ri of the previous loading condition, signifying rapid change in muscle function (See figures 1-4). Furthermore, the velocity of each repetition responded after each repetition in a similar fashion to EMG signals suggesting that EMG and velocity are highly related. Together, these EMG and velocity data suggest that with minimal to no rest between unloading conditions (i.e., intra-set) muscle function recovers and is maintained within and across multiple reps and sets.

CONCLUSION: Our research shows that neuromuscular (i.e., EMG) indices of acute, local muscle fatigue are closely linked with decreases in movement velocity. The data suggests velocity can be used to track acute, local muscle fatigue. Also, these data suggest that when the load is decreased, there is rapid recovery with each of the intra-set unloading conditions. The results of this study indicate that SU is an effective RT methodology in order to minimize acute, local muscle fatigue while increasing RT volume.

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