Difference in Kinematics and Kinetics Between High- and Low-Velocity Resistance Loading Equated by Volume: Implications for Hypertrophy Training

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Abstract

Mohamad, NI, Cronin, JB, and Nosaka, KK. Difference in kinematics and kinetics between high- and low-velocity resistance loading equated by volume: implications for hypertrophy training. *J Strength Cond Res* 26(1): 269–275, 2012—Although it is generally accepted that a high load is necessary for muscle hypertrophy, it is possible that a low load with a high velocity results in greater kinematics and kinetics than does a high load with a slow velocity. The purpose of this study was to determine if 2 training loads (35 and 70% 1 repetition maximum [1RM]) equated by volume, differed in terms of their session kinematic and kinetic characteristics. Twelve subjects were recruited in this acute randomized within-subject crossover design study. Two bouts of a half-squat exercise were performed 1 week apart, one with high load-low velocity (HLLV = 3 sets of 12 reps at 70% 1RM) and the other with low-load high-velocity (LLHV = 6 sets of 12 reps at 35% 1RM). Time under tension (TUT), average force, peak force (PF), average power (AP), peak power (PP), work (TW), and total impulse (TI) were calculated and compared between loads for the eccentric and concentric phases. For average eccentric and concentric single repetition values, significantly ($p < 0.05$) greater (~15–22%) PP outputs were associated with the LLHV loading, whereas significantly greater (~7–61%) values were associated with the HLLV condition for most other variables of interest. However, in terms of total session kinematics and kinetics, the LLHV protocol resulted in significantly greater (~16–61%) eccentric and concentric TUT, PF, AP, PP, and TW. The only variable that was significantly greater for the HLLV protocol than for the LLHV protocol was TI (~20–24%). From these results, it seems that the LLHV protocol may offer an equal if not better training stimulus for muscular adaptation than the HLLV protocol, because of the greater time under tension, power, force, and work output when the total volume of the exercise is equated.

Key Words squat, time under tension, force, loading parameters

Introduction

Loading the muscle with loads >60–70% 1 repetition maximum (1RM) is thought to be fundamental to the development of maximal strength and an important stimulus for muscle hypertrophy (1,17,18,24). In strength trained athletes, even greater loading intensities (70–100% 1RM) are thought to be critical for the development of maximal strength (16,17,24). The importance of these higher loading intensities (>70% 1RM) in inducing maximal strength and hypertrophic changes, however, may be questioned in relation to some research in this area. For example, explosive strength training at 10% of 1RM was able to stimulate muscle hypertrophy, and the hypertrophy was of the same magnitude as that of training at 90% 1RM (11). Schmidtbleicher and Buehrle (25) compared the changes in force-time curves and cross-sectional area (CSA) of subjects who were allocated to a high load group (>90% maximum voluntary contraction [MVC]), a power group (45% MVC), a high repetition group (70% MVC), and a control group. After 12 weeks of resistance training, similar changes in maximum force occurred in all the training groups (18–21%). Changes in CSA were similar in the power and high load groups and superior in the high repetition group (25). Given that force or tension within the muscle is thought to be important as a hypertrophic stimulus, these findings may be explained by the fact that force can be defined mechanically by the equation; force equals mass times acceleration ($F = m \times a$). Typically, resistance strength training programs focus on the mass component for improving the force capability of

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TABLE 1. Average single repetition eccentric values (mean ± *SD*) for the 35 and 70% 1RM schemes equated by volume.*

Variable	35% 1RM	70% 1RM	% Difference	Significance†
Time under tension (s)	0.61 ± 0.09	0.99 ± 0.14	38.4	0.000
Average velocity ($m \cdot s^{-1}$)	0.70 ± 0.09	0.39 ± 0.05	44.3	0.000
Peak velocity ($m \cdot s^{-1}$)	1.17 ± 0.14	0.69 ± 0.08	40.0	0.000
Peak force (N)	727 ± 17.5	1,091 ± 82.5	33.7	0.000
Average power (W)	525 ± 69.7	438 ± 76.9	16.6	0.020
Peak power (W)	1,100 ± 74.6	853 ± 141	22.5	0.002
Total work (J)	295 ± 21.9	428 ± 46.2	31.1	0.000
Total impulse (ms)	421 ± 58.4	1,080 ± 199	61.0	0.000

*1RM = 1 repetition maximum.
†*p* Value is based on a paired *t*-test.

muscle with little attention given to modifying the acceleration component. It may be that the higher velocities and accelerations associated with lighter load training may compensate for the lighter mass; the subsequent force thereafter is not substantially different to a more typical higher load hypertrophic program.

Another possible reason that may explain the conjecture in the literature regarding the efficacy of high-load low-velocity (HLLV ≥ 70% 1RM) as opposed to low-load high-velocity (LLHV ~35% 1RM) loading schemes in increasing strength and hypertrophy is that much of the research in this area has failed to equate training volume (load × repetitions × sets) between interventions. If training volume is not equated, then the effect of load is practically impossible to disentangle. If volume is equated, then the magnitude (acute studies) and effect (training studies) of various mechanical variables can be quantified. Although there is a great deal of literature that has investigated the kinematics and kinetics of a single repetition (9,20–22), the findings do not, however, reflect the true nature of resistance strength training as undoubtedly kinematics and kinetics differ between repetitions in a set, between sets in a workout and between workouts.

In terms of the lower body, some research has investigated the kinematics and kinetics of a single set across loads (30, 60, and 90% 1RM) on a supine squat machine (10) and multiple sets across loads (45, 75, and 88% 1RM) on a modified Smith machine and supine squat machine (8). Both these research studies found superior kinematics and kinetics for the lighter loading schemes in most of the variables of interest when equated by volume. Research of this nature gives a better insight into the mechanical stimuli associated with various loading schemes and may provide a better framework for understanding some of the inconsistencies in the literature, which is why certain lighter loading schemes are equally successful in increasing strength and hypertrophy. Certainly, such research can provide better insight into the adaptational

TABLE 2. Average single repetition concentric values (mean ± *SD*) for the 35 and 70% 1RM schemes equated by volume.*

Variable	35% 1RM	70% 1RM	% Difference	Significance†
Time under tension (s)	0.56 ± 0.06	0.82 ± 0.07	31.7	0.000
Average velocity ($m \cdot s^{-1}$)	0.75 ± 0.06	0.46 ± 0.04	38.7	0.000
Peak velocity ($m \cdot s^{-1}$)	1.25 ± 0.10	0.80 ± 0.07	36.0	0.000
Peak force (N)	1,318 ± 105	1,430 ± 92.6	7.83	0.002
Average power (W)	515 ± 39.6	508 ± 61.5	1.4	0.843
Peak power (W)	1,169 ± 137	989 ± 136	15.4	0.017
Total work (J)	531 ± 79.4	546 ± 63.0	2.8	0.648
Total impulse (ms)	362 ± 37.7	887 ± 121	59.2	0.000

*1RM = 1 repetition maximum.
†*p* Value is based on a paired *t*-test.

Table 3. Total eccentric values (mean ± *SD*) for the 35 and 70% 1RM schemes equated by volume.*

Variable	35% 1RM	70% 1RM	% Difference	Significance†
Time under tension (s)	35.3 ± 5.93	29.4 ± 4.52	16.7	0.016
Average velocity ($m \cdot s^{-1}$)	41.2 ± 9.82	11.5 ± 2.10	72.1	0.000
Peak velocity ($m \cdot s^{-1}$)	68.4 ± 14.3	20.5 ± 3.74	70.0	0.000
Peak force (N)	42,504 ± 22,906	32,447 ± 11,182	23.7	0.013
Average power (W)	30,823 ± 18,170	13,044 ± 6,115	57.7	0.000
Peak power (W)	64,680 ± 31,484	25,396 ± 10,519	60.7	0.000
Total work (J)	17,102 ± 8,029	12,736 ± 4,674	25.6	0.003
Total impulse (ms)	24,385 ± 10,566	32,106 ± 10,761	24.0	0.003

*1RM = 1 repetition maximum.
†*p* Value is based on a paired *t*-test.

effects of various loading schemes, and such analyses should underpin longitudinal research.

Of particular interest in this research is quantifying the set and session kinematics associated with HLLV loading as opposed to LLHV loading as potential mechanical stimuli to increase strength and hypertrophy. In terms of hypertrophy for sporting performance, it would appear advantageous for hypertrophic adaptation to occur side by side with high-velocity adaptation because adaptation of muscle contractile properties via training are dependent on the type of exercise and protocol performed (12,14), because muscle fiber type shift occurs according to the stimulus applied, which is normally from faster to slower myosin isoforms (7). The use of lighter loads therefore is intuitively appealing in this regards, because there is evidence that training at higher velocities particularly during lengthening contractions increases protein remodeling and preferential hypertrophy of fast fibers (13,27).

As intimated previously, an understanding of the mechanical stimuli presented by various loading parameters is thought to be important and needs to underpin the rationale for longitudinal studies such as investigating high-velocity hypertrophic adaptation. To the knowledge of these authors, no research has quantified the set and session mechanical stimuli associated with 2 traditional free weight squat loading schemes that take 2 divergent approaches to hypertrophic adaptation. Consequently, the purpose of this study was to determine if 2 training loads (35 and 70% 1RM) equated by volume differed in terms of their session kinematic and kinetic characteristics. The findings will clarify the magnitude of the mechanical stimuli associated with HLLV as opposed to LLHV loading schemes and may provide an insight into the adaptational effects with repeated application of these schemes.

Methods

Experimental Approach to the Problem

In this acute randomized within-subject crossover design, we recruited 12 recreationally trained male student athletes to investigate the effects of load on set and session free-weight squat kinematics and kinetics. Two loading schemes were

Table 4. Total concentric values (mean ± *SD*) for the 35 and 70% 1RM schemes equated by volume.*

Variable	35% 1RM	70% 1RM	% Difference	Significance†
Time under tension (s)	32.5 ± 4.78	24.6 ± 4.31	24.3	0.000
Average velocity ($m \cdot s^{-1}$)	44.0 ± 7.95	13.9 ± 1.75	68.4	0.000
Peak velocity ($m \cdot s^{-1}$)	72.8 ± 11.5	23.9 ± 3.39	67.2	0.000
Peak force (N)	77,023 ± 30,156	42,725 ± 12,032	44.5	0.000
Average power (W)	30,129 ± 18,255	15,189 ± 6,326	49.6	0.001
Peak power (W)	68,250 ± 32,222	29,562 ± 11,569	56.7	0.000
Total work (J)	31,840 ± 11,159	16,151 ± 5,005	49.3	0.000
Total impulse (ms)	21,031 ± 9,531	26,506 ± 8,989	20.7	0.011

*1RM = 1 repetition maximum.
†*p* Value is based on a paired *t*-test.

equated by volume (3 sets of 12 reps at 70% 1RM vs. 6 sets of 12 reps at 35% 1RM) and the dependent variables of interest that were quantified during the eccentric and concentric phases were time under tension (TUT), average force (AF), peak force (PF), average power (AP), peak power (PP), work (TW), and total impulse (TI). The average repetition value for each set and the total set and session values of each of the variables for both the eccentric and concentric phases were then used for statistical analysis.

Subjects

Twelve recreationally trained male athletes with at least 6 months of resistance strength training experience volunteered to participate in this research. Subject mean (±*SD*) age, height, mass, and 1RM squat strength were 26.3 (3.0) years, 175.3 (4.0) cm, 80.3 (11.2) kg, and 125 (35.2) kg, respectively. All the subjects recruited were considered injury-free as indicated by no lower limb and spine injury record for the past 2 years. The subjects completed an informed consent form before the experiment. Ethics approval from the Human Research Committee of Edith Cowan University was also obtained before commencing the study.

Equipment

The subjects performed the squat on a force plate (400 Series, Fitness Technology, Adelaide, Australia) supported by a Power Cage (FT 700, Fitness Technology). The Olympic bar was interfaced with the Ballistic Measurement System (BMS, Fitness Technology), which consisted of a position transducer (Celesco, PT5A-0150-V62-UP-1K-M6, Chatsworth, CA, USA), computer interface (XPV Interface, Fitness Technology), and the BMS software (BMS, Version 2007.2.3, Innervations, Adelaide, Australia). Sampling frequency of the BMS system was set at 200 Hz.

Procedures

The procedures involved 1 familiarization and 2 testing sessions. The testing sessions were randomized to eliminate any learning, order or fatigue effects that could confound the statistical analysis. A minimum of 72 hours of rest was given between all sessions to ensure full recovery. The participants were asked to replicate exercise and dietary intake 24 hours before each testing occasion.

Preliminary Assessments and Familiarization. During the first session, technique and maximum squat strength (1RM) were assessed and anthropometric measurements taken. The anthropometric variables of interest included standing height (centimeters) and body mass (kilograms). Movement for the half-squat was analyzed, and corrections to technique were made as necessary. Half-squat 1RM was determined according to standardized procedures outlined by Brown and Weir (3). The participants were asked to provide their estimated half-squat 1RM based on their past performance. A 5-minute general warm-up was undertaken. Each participant was then required to perform 2 warm-up sets of 8 reps at 50% of estimated 1RM and 3 reps at 70% of estimated 1RM, respectively. After a 5-minute rest, each subject's 1RM was determined (4- to 5-minute rest in between 1RM lifts).

Half-Squat Technique. The squat movement began from a standing position with the feet approximately shoulder width apart. The squat was initiated by a controlled downward eccentric knee bend until the tops of the thighs became parallel to the floor, which was followed by a concentric phase.

Testing Procedures. The subjects were randomly allocated to 1 of the 2 testing sessions (35% of 1RM and 70% of 1RM). The participants performed a general warm-up before each testing session, for example, jogging and 2 warm-up sets of 8 reps at about 50% of the session load and 3 reps at about 70% of the session load, respectively. The subjects then performed either 6 sets of 12 reps at 35% of 1RM (2,520 kg) or 3 sets of 12 reps at 70% of 1RM (2,520 kg) loading (5). A 90-second interset rest period was used for both conditions.

Statistical Analyses

The force plate was synchronized with a linear position transducer attached to the bar to measure the various dependent variables of interest at a sampling frequency of 200 Hz. The eccentric (maximum to minimum vertical displacement) and concentric (minimum to maximum vertical displacement) phases were determined from the linear position transducer. All variables of interest (TUT, AF, PF, AP, PP, TW, and TI) were calculated for each eccentric and concentric contraction for each repetition, and for each set and session involved, via the BMS software data analysis program. The variables of interest in this study have been proven to be stable within and between sessions (i.e., typical coefficient of variation $<5\%$ and intraclass correlation coefficient ~ 0.95).

The average repetition value for each set was calculated and used for the repetition analysis (Tables 1 and 2). The summed repetition and set values for each session were used as the total session kinematics and kinetics and compared between loading schemes (Tables 3 and 4).

Means and *SD*s were used to represent the centrality and the spread of data. Paired sample *t*-test comparisons were used to determine if significant differences existed between the dependent variables (eccentric and concentric TUT, AF, PF, AP, PP, TW, and TI) across the 2 loading schemes. The percent difference between loading schemes was calculated (% Difference = [1 − Lowest Variable/Highest Variable] × 100). An alpha level of 0.05 was set to assess the statistical significance for all tests.

Results

The average eccentric single repetition values for the 35 and 70% 1RM protocols can be observed in Table 1. Significantly ($p < 0.05$) greater average and peak eccentric power output (16.6 and 22.5%) were associated with the 35% protocol, whereas significantly greater values (31.1–61.1%) were associated with the 75% protocol for all the other variables of interest.

The average concentric single repetition values for the 35 and 70% 1RM protocols are detailed in Table 2. Interload nonsignificant differences (1.36–2.75%, $p > 0.05$) were found for AP and total work. Significantly greater concentric PP output (15.4%) was associated with the 35% 1RM loading scheme, whereas significantly greater values (7.83–59.2%) were associated with the 70% 1RM loading scheme for all the other variables of interest.

Tables 3 and 4 compare the total eccentric and concentric outputs from both schemes when equated by volume, that is, 35% 1RM = 6 sets of 10 reps at 35% 1RM vs. 70% 1RM = 3 sets of 10 reps at 70% 1RM. With regards to the 35% 1RM eccentric values, significantly greater (16.7–60.7%) outputs were associated with TUT, PF, AP, PP, and TW. The only variable that was found to be significantly greater for the 70% 1RM loading scheme was TI (24.0%). In terms of the 35% 1RM concentric values (Table 4), significantly greater (24.3–56.7%) values were associated with all the variables apart from TI, which once more was greater (20.7%, $p = 0.01$) in the heavier loading scheme.

Discussion

The aim of this study was to quantify whether 2 different loading schemes that were termed high-load low-velocity (HLLV ≥ 70% 1RM) as opposed to low-load high-velocity (LLHV ~35% 1RM) loading schemes differ in terms of their kinematics and kinetics when equated by volume. The interest in this analysis was prompted by research that has found significant hypertrophy with lighter loads, without identifying the kinematics and kinetics associated with these loading schemes (4,27). Understanding the mechanical stimuli associated with various repetitions, set and session loading schemes is of paramount importance, if strength and conditioning practitioners are to prescribe and understand the adaptational effects of resistance exercise to better effect.

The first level of mechanical analysis involved comparing the average repetition outputs for the eccentric and concentric phases of both loading schemes (Tables 1 and 2). This analysis enables a loose comparison to those studies that have quantified the repetition kinematics and kinetics of the squat and its derivatives (6,10,26). To the knowledge of these authors, no other study has quantified the single repetition kinematics and kinetics of both the eccentric and concentric phases of the free weight squat. Furthermore, a direct comparison between the kinematics and kinetics of this and other studies is problematic given the differences in design. For example, (a) training status: Crewther et al. (8) used well-trained athletes who were lifting twice a week as compared with the recreational athletes used in this study; (b) Different level of maximal strength (1RM), therefore each samples will be lifting different relative masses, which will equate to different forces, impulses, etc.; (c) some research used only position transducer data (8,10)–the dual use of force plate and position transducer more accurate than that used in this study; (d) different methodological approaches, for example, the use of mass vs. system mass in the calculations and whether using a ballistic or nonballistic technique (6,8,10,26); (e) different machinery as in the use of a Smith machine, supine squat machine, and a free weight squat, which will undoubtedly affect kinematics and kinetics (8,10); and, (f) different comparative loads, for example, Crewther et al. (8) used power and hypertrophy loads of 45 and 75% 1RM, respectively.

Nonetheless, the research design closest to this study's was that of Crewther et al. (8) who described the eccentric and concentric kinematics and kinetics of the squat using 3 loading schemes on 2 pieces of equipment, that is, Smith machine and supine squat. The most relevant comparisons to our study are between their power (45% 1RM) and hypertrophy loading schemes (75% 1RM) performed on the Smith machine. Similar to the findings of this study, greater eccentric and concentric time under tension (~30–42%), force (~38–46%), impulse (~62–64%), and work (22–33%) were associated with the HLLV loading scheme. However, the eccentric power between loading schemes was not significantly different (0.5%), whereas the concentric power output (25.5%) was significantly greater for the LLHV scheme, which is somewhat different to our results depending on whether AP or PP are used for the analysis.

In terms of power production, peak eccentric and concentric power and concentric AP were significantly higher in the 35% 1RM loading scheme in this study. This finding is not unusual because a great deal of literature has found greater mechanical power outputs associated with lighter loads (2,6,15,28,29). It would seem that for power to be optimized, the use of lighter loads that enable a higher velocity component is the loading scheme of choice. Furthermore, research (19,30) modeling the interplay between muscle strength, CSA and explosive power found that the optimization of power was based upon (a) increasing muscle CSA; (b) increasing maximal strength; and (c) translating that strength to power. A contention of this article is that LLHV loading may offer a better means of increasing muscle CSA if maximizing explosive power output is a desired outcome, that is, LLHV superior in terms of total session kinematics and kinetics–significantly greater (~16–61%) eccentric and concentric TUT, PF, AP, PP, and TW. Certainly, the low-load high-velocity approach would seem the method of choice to translate strength adaptations to power.

With regards to hypertrophy, if a single repetition was to be used as the basis of loading musculature, then the HLLV loading scheme would seem the loading scheme of choice, given its significantly greater time under tension, force output, and TI for both the eccentric and concentric phases. Furthermore, significantly greater total eccentric work was associated with the heavier loading scheme. However, as intimated previously, workouts are more than a single repetition, and to disentangle the effect of load on strength and power adaptation, an equivolume design is required for the analysis of total session kinematics and kinetics.

The second level of analysis involved comparing the total session outputs for the eccentric and concentric phases of both loading schemes (Tables 3 and 4). This analysis enables a comparison to those studies that have quantified the set and session kinematics and kinetics of the squat and its derivatives (8). However, to our knowledge, no study has performed such an analysis using the free weight squat. Furthermore, the Crewther et al. (8) study only equated their power and maximal strength loading schemes and not the hypertrophy scheme; therefore, comparison between session kinematics and kinetics to this study is of limited value. Cronin and Crewther (10) quantified the kinematics and kinetics of 30, 60, and 90% 1RM loads equated by volume on a supine squat machine. Furthermore, the instructions were to move all loads "explosively" as possible, which is dissimilar to instructions given to traditional hypertrophy training and the instructions of this study. The reader needs to be cognizant of these differences when between-studies comparisons are made in the following paragraphs.

This study found that in terms of total repetition/session kinematics and kinetics, both eccentric and concentric TUT (~16–24%), force (~23–44%), power (~50–60%), and TW (~25–50%) outputs were significantly greater for the LLHV loading scheme. The only variable that was significantly greater for the HLLV scheme for both the eccentric and concentric phases was the TI (~20–24%). These are similar to the findings of Cronin and Crewther (10) who found significantly greater total concentric TUT (31%), eccentric and concentric AFs (~9–14%), eccentric and concentric APs (~25–40%), and eccentric and concentric TWs (~9–14%) with the 30% 1RM condition as compared with those with the 60% 1RM variable.

The only variables that were found to be significantly greater (~20–24%) for the HLLV condition were eccentric and concentric TIs. Once again, this is similar to the findings of Cronin and Crewther (10) who reported significantly greater concentric TI (19%) for the 60% 1RM condition. They concluded that if session total forces and time under tension were thought to be important for increasing strength via hypertrophic adaptation, then the lighter load would seem the load of choice. However, it may be that the product of force and time (impulse) may be the more important stimulus for strength and hypertrophic adaptation, and therefore, heavier loads would appear a superior training stimulus. As these researchers point out, the relationship between hypertrophy and impulse is not well documented, and there seems a need to disentangle this relationship via longitudinal research.

Of interest to these researchers was the concept of high-velocity hypertrophic adaptation. As evidenced in Tables 1 and 2, significantly greater eccentric and concentric mean and peak velocities were associated with the LLHV loading scheme. Given that the superior kinematics and kinetics were also associated with this loading scheme when equated by volume, there seems a case to explore the contention of sport-specific LLHV hypertrophic adaptation further via a longitudinal design that maps changes in CSA with performance changes. Such a contention is reinforced by research studies that have found greater strength (13,23) and hypertrophy (13,27) with faster vs. slower lengthening contractions, which has been attributed to greater protein remodeling. Furthermore, it was hypothesized that because of the nature of muscle mechanics and the force-velocity relationship of muscle, high-velocity eccentric contractions generate greater forces, which may also stimulate greater protein synthesis (27). It may be that the real benefit of LLHV loading in terms of hypertrophic adaptation is the accentuated eccentric training stimulus.

Finally, no doubt there is some critical threshold that is a prerequisite for hypertrophy to occur, but this is hard to disentangle given the findings in the literature. In the past, a certain threshold of % 1RM (e.g., 60–70% 1RM) has been cited as critical to hypertrophic adaptation, but it may be more appropriate to cite this threshold as a force given the formula mass × acceleration. That is, load is not the critical determinant, but the forces associated with that load, and how we move the load is. However, to identify that, threshold force will no doubt require a great deal of research and likely be very individual.

Practical Applications

The free weight squat is one of the most prescribed movement patterns for the lower body; therefore, understanding the kinematics and kinetics associated with loading schemes that use this exercise would seem fundamental to understanding the adaptational effects of exercise prescription using this movement. As intimated previously, an understanding of the mechanical stimuli presented by various loading parameters is thought to be important and needs to underpin the rationale for longitudinal studies such as investigating high-velocity hypertrophic adaptation. We found that when LLHV and HLLV schemes were equated by volume, the lighter load for the most part resulted in greater eccentric and concentric time under tension, forces, power, and work. Given this, time under tension, force, and work are thought to be critical determinants of hypertrophic adaptation, coupled with the fact that higher velocities associated with the 35% 1RM loading scheme seem to support the contention that training with such loading parameters may offer a better alternative for sport-specific hypertrophic adaptation compared with the heavier-slower hypertrophy loading parameters that are traditionally prescribed. Such a contention, however, warrants investigation via a longitudinal design that maps changes in CSA with performance changes. Furthermore, there may be differential effects depending on the training status of the subjects that need investigation. It should be noted that the benefits of the LLHV scheme would no doubt be magnified if ballistic free-weight squats were used. That is, movement that allows unloading or projection of oneself results in greater velocities and accelerations and as a consequence force and power outputs. Furthermore, because this ballistic movement better simulates athletic and sporting movement patterns, this type of movement may offer superior sport-specific hypertrophic adaptation. Once more, such a contention needs validation via a longitudinal research approach. Finally, it has been suggested that the real benefit of LLHV loading for hypertrophic adaptation may be because of the greater eccentric velocities (accentuated eccentric training stimulus) and subsequent protein synthetic response. This needs further examination, but there is no doubt that the higher eccentric velocities associated with LLHV loading better simulate the velocities associated with athletic movement and therefore may more likely optimize transference from the gymnasium-based gains to on field performance.

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