

RELATIVE CONTRIBUTIONS OF FORCE AND VELOCITY TO PEAK POWER ACROSS A LOAD SPECTRUM

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Abstract

Current resistance training controversies include whether to emphasize maximum force and strength, or to focus on velocity and movement speed. The purpose of this project was to determine the relative contributions of resistance exercise force and velocity to peak power. Weight-trained men ($X \pm SD$; $n=24$, age= 27.8 ± 7.0 yrs) were tested for one repetition maximum (1RM), peak power, force at peak power and velocity at peak power at 40% 1RM, 70% 1RM and 100% 1RM. All lifts were performed on a 45° leg press equipped with a linear position transducer to determine kinetic and kinematic variables. Mean 1RM leg press strength was 197 ± 47 kg. Relative contributions of force and velocity to power at each intensity were determined using multiple linear regressions. The relative contribution of force at 40% 1RM=47.0%, at 70% 1RM=58.2% and at 100% 1RM=45.1%, while relative contribution of velocity at 40% 1RM=53.0%, at 70% 1RM=41.8% and at 100% 1RM=54.9%. These data indicate the relative importance of force and velocity to peak power during the leg press exercise. Although the relative contributions change depending on load, these data suggest that both qualities should be emphasized during training for high power.

Keywords: Kinematics, kinetics, resistance exercise, power

Introduction

Current resistance exercise methods often focus solely on maximizing muscular strength and force production, while other training methods strive to enhance speed and movement velocity. Although often both strength and speed are simultaneously trained, some individuals advocate emphasizing only one or the other (Brzycki, 1995, p. 21-22). The combination of strength and speed is power, and so this paper will briefly examine the contributions of both qualities.

It is well-accepted that high-level sport performance often relies greatly on the development of muscular power. In addition to muscle morphology, muscle power output enhancement lays in the ability to increase firing frequency, recruitment and synchronization of motor units, which has been shown to be improved with weight lifting training (Cormie, McGuigan, & Newton, 2011). In the exercise and sport environment, power can be defined as “the speed at which high levels of force can be generated” (Cormie et al., 2011; Knuttgen & Kraemer, 1987). Specifically, power can be described as follows;

$$P = F \cdot (ds/dt) = F \cdot v$$

(where P=power, F=force, s=displacement, t=time and v=velocity)

The above equation clearly shows that both force and velocity contribute to resulting power. While both factors are vital, it has been shown that development of strength is the most critical factor for increased power production in a young population (Petrella, Kim, Tuggle, & Bamman, 2007). Additionally, when resistance training with pneumatic machines was implemented with an elderly cohort of subjects, the overall peak power output was improved while the velocity measurements were unchanged (de Vos et al., 2008). However, it is critical to note that force influences velocity for isoinertial actions, as illustrated by the impulse-momentum relation;

$$\int F \cdot dt = \int m \cdot dv$$

The role of muscular power production for successful performance has been reported in the sport science literature (Rhea, Kenn, & Dermody, 2009). Despite the inherent contribution of both muscle contraction force and velocity to power production, there is debate as to whether development of muscle force (i.e. strength) or contraction velocity is most beneficial to power production (Meschino, n.d.). Regardless of the training paradigm advocated, it is clear that different types of resistance exercise have differential effects on the power produced (Rhea et al., 2009). Muscle force production, which can be significantly improved with free weight squat exercises, offers a great foundation for improvement of jumping ability, agility, peak power, sprint acceleration and velocity, which are essential factors strongly related to enhanced sport performance (Peterson, Alvar, & Rhea, 2006). While each of the different training methods can contribute to the contractile capabilities of skeletal muscle, it is unclear whether both high force and high velocity training need to be included in training when muscular power is the desired outcome (Meschino, n.d.). In agreement with previous literature, Cronin and colleagues' findings suggest that moderate 50-70% 1RM loads are superior compared to light (30-40% 1RM) and heavy (80% 1RM) loads for increasing peak power output (Cronin, McNair, &

Marshall, 2001). A better understanding of how much force and velocity contribute to power production would provide insight for the optimal combination for training. Therefore, the purpose of the present study was to determine the relative contributions of force and velocity to power across a load spectrum.

Materials and Method

Subjects

Currently weight-trained men (n=24) served as subjects ($X \pm SD$; age=27.8 \pm 7.0yrs, hgt=1.76 \pm 0.07 m, body mass=82.6 \pm 15.6kg, lean body mass=65.3 \pm 8.1kg, % fat=15.5 \pm 4.3 %) for this study. All subjects provided informed consent to participate as approved by the University Institutional Review Board.

Equipment / Experimental set-up

Bilateral lower limb maximal strength testing (1RM) and power testing were performed on a 45° leg press (AMF; Jefferson, IA, USA) using previously described methods (Kraemer & Fry, 1995). For power testing, three maximal effort repetitions were performed at 40%, 70% and 100% 1 RM loads. The leg press was modified to permit maximal acceleration through the entire range of motion. A FiTRO Dyne Premium (FiTRONiC s.r.o.; Bratislava, Slovakia) (100 Hz sampling frequency) interfaced with a computer was mounted on the leg press in line with the axis of the sled's movement which was 45°. Acceleration was derived from velocity-time data and multiplied by the mass of leg press sled, then corrected for the vector of the sled ($\cos 45^\circ$) to calculate the force applied to the sled. Power was calculated as the point-by-point product of force and velocity. Peak power for the repetition with the greatest power was determined, and the force and velocity at the instant of peak power was recorded.

Data analysis

Using peak power as the dependent variable for each load, multiple linear regressions using force and velocity at peak power as predictor variables was used to calculate standardized beta coefficients, and subsequently the percent of explained variance (SPSS 10.0). In this manner, the relative contributions of both force and velocity to the resulting peak power were determined. Significance was determined a priori ($\alpha=.05$).

Results

The mean values for 1RM leg press were 197 \pm 47 kg. The power, force and velocity for each load are reported in Table 1. Multiple regression equations using force and velocity determined explained variances (r^2) for peak power of 93.0% at 40% 1RM, 97.8% at 70% 1RM and 98.2% at 100% 1RM. The resulting β coefficients for force and velocity as well as at each load are represented in the Table 2. The relative contributions of force and velocity to the explained variance for load-specific peak powers are illustrated in Figure 1.

Table 1: Peak power and the force or velocity associated with peak power for each of the relative loads (X±SD).

Load (1RM)	(%)	Peak Power (W)	Force at Peak Power (N)	Velocity at Peak Power (m·s ⁻¹)
100%		847±372	1537±371	0.54±0.17
70%		1151±617	1215±381	0.90±0.26
40%		1137±547	877±365	1.28±0.38

Table 2: Peak power β coefficients and explained variances (r^2)

	40% 1RM	70% 1RM	100% 1RM
β coefficient - Velocity	0.622	0.412	0.571
β coefficient - Force	0.569	0.678	0.647
r^2 (%)	93.0	97.8	98.2

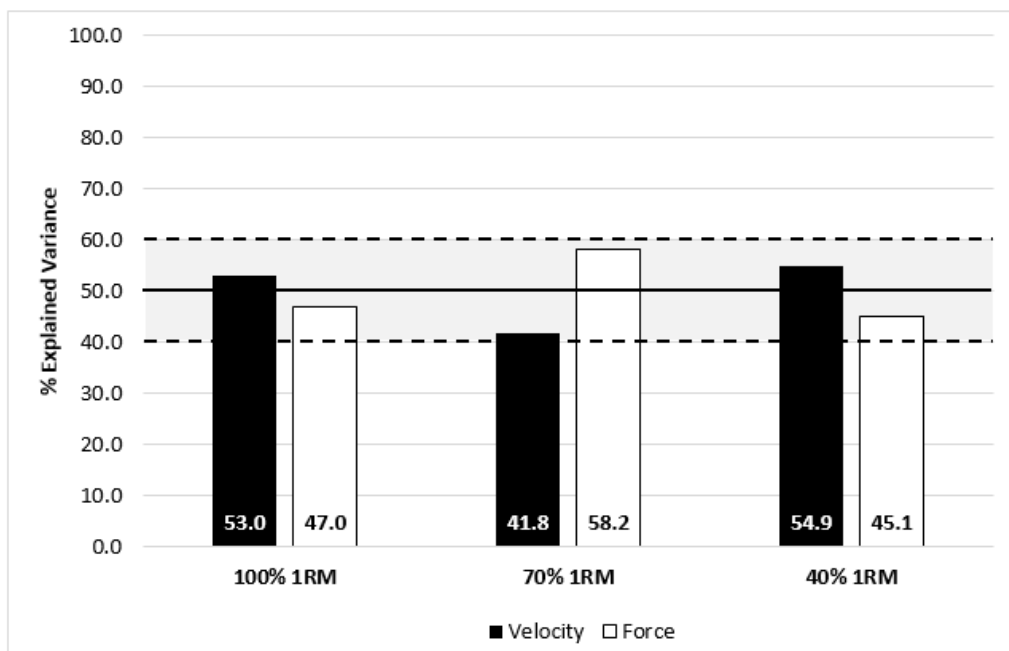


Figure 1: Relative contributions (% explained variance) of force and velocity to peak power at each of three resistance exercise loads.

Discussion

The primary finding of the present study is that force and velocity are relatively equal contributors to peak power for each of the three loads tested (see Figure 1). Even that the contributing values of force and velocity were not identical for all loads, their relative contributions constantly stayed within 40% - 60% range. While it has been suggested that other kinetic variables may be important for maximal sport performance, it is also clear that power is an important variable for many sporting activities (Peterson et al., 2006; Rhea

et al., 2009; Stone, Plisk, & Collins, 2002). As such, practical suggestions for maximizing power capabilities have been proposed. The importance of including training methods for both high force and/or load movements, and high velocity exercises has been suggested as a method to provide the basic physical adaptations to generate high power outputs (Peterson et al., 2006; Petrella et al., 2007; Rhea et al., 2009). Since strength has been defined as “the maximal force a muscle or muscle group can produce at a known or given velocity” (Knuttggen & Kraemer, 1987), the importance of strength capabilities for muscular power is readily apparent. When designing a periodized training program, it would be best practice to prescribe exercises to improve force generation and increase velocity separately and independently, as well as implementing movements that demand both. However, the combination of high velocity actions while generating maximal muscle force appears to result in the greatest power adaptations (Rhea et al., 2009).

Conclusion

In summary, both force and velocity are consistently strong contributors to resistance exercise power across the load spectrum. This suggests that both heavy and light training modalities are critical for increasing muscular force and velocity production, respectively, in addition to more technically advanced movements which require both high force and high velocity generation.

Practical Use

The findings of this research study suggest that when planning and designing resistance exercise training programs for athletes, the need for significant power production in terms of both force and velocity components should be considered and incorporated in order to maximize the benefits of training.

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