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Specificity of Velocity in Strength Training

Hiroaki Kanehisa and Mitsumasa Miyashita

Laboratory for Exercise Physiology and Biomechanics, Faculty of Education, University of Tokyo, Hongo 7–3–1, Bunkyoku, Tokyo, Japan

Summary. Twenty-one male volunteers (ages 23–25 years) were tested pre- and post training for maximal knee extension power at five specific speeds (1.05, 2.09, 3.14, 4.19, and 5.24 rad · s^{-1}) with an isokinetic dynamometer. Subjects were assigned randomly to one of three experimental groups; group S, training at 1.05 rad · s^{-1} (n = 8), group I, training at 3.14 rad · s^{-1} (n = 8) or group F, training at 5.24 rad · s^{-1} (n = 5). Subjects trained the knee extensors by performing 10 maximal voluntary efforts in group S, 30 in group I and 50 in group F six times a week for 8 weeks. Though group S showed significant increases in power at all test speeds, the percent increment decreased with test speed from 24.8% at 1.05 rad · s^{-1} to 8.6% at 5.24 rad · s^{-1}. Group I showed almost similar increment in power (18.5–22.4 at all test speeds except at 2.09 rad · s^{-1} (15.4%). On the other hand, group F enhanced power only at faster test speeds (23.9% at 4.19 rad · s^{-1} and 22.8% at 5.24 rad · s^{-1}).

Key words: Isokinetic training – Training velocity – Average power – Specificity

Introduction

There are three major modes of strength training: isometric, isotonic, and isokinetic (Clarke 1973). Isokinetic training is a relatively new method compared to the others, and was first introduced by Thistle et al. in 1967. Isokintic exercise, because of its nature, allows the development of maximal tension throughout the full range of motion (Thistle et al. 1967; Hislop and Perrine 1967). However, it is said that there is specificity of exercise speed in isokinetic training (Sale and MacDougall 1981). For example, high-velocity training provided a significant increase in muscular power output at both slow and fast test speeds, while slow-velocity training brought about a significant increment only at slow test speeds (Moffroid and Whiple 1970; Pipes and Wilmore 1975; Coyle et al. 1981).

If velocity-specific training effects exist, coaches and athletes have to select the training speed appropriate to the atheletic performance speed. However, there are opposing results concerning the effects of much faster speeds, such as 4.19 rad · s^{-1} (Caiozzo et al. 1981) and 5.24 rad · s^{-1} (Coyle et al. 1981). Therefore, the present study was designed to investigate the effect of isokinetic training at high and low velocity on the power output of the knee extensors during maximal isokinetic contractions.

Methods

Subjects. Twenty-one healthy male subjects participated in this experiment. All subjects were fully informed of all risks and stresses associated with the projects, and provided written consents to participate. The subjects were assigned randomly to one of three training groups: Group S, training at 1.05 rad · s^{-1} (n = 8); group I, training at 3.14 rad · s^{-1} (n = 8); or group F, training at 5.24 rad · s^{-1} (n = 5). The means and standard deviations of their ages, body heights and body weights are shown in Table 1.

Testing Procedures. The knee extensors were tested by using a Cybex II isokinetic Dynamometer (Lumex, Inc., New York, USA) before and after training. The subjects were seated on a bench and strapped securely at thigh and hip. The input axis of the

Table 1. Physical characteristics of subjects

	n	Age (yr)	Height (cm)	Weight (kg)
Group S	8	24.1 ± 0.7	170.4 ± 6.4	65.7 ± 10.9
Group I	8	23.6 ± 1.7	178.0 ± 7.2	70.6 ± 7.1
Group F	5	23.0 ± 1.0	174.5 ± 12.0	66.8 ± 12.5

Values are means ± SD

Offprint requests to: M. Miyashita at the above address

Table 2. Average power (watts) at each test speed before and after training

		Test Speed (rad · s^{-1})				
		1.05	2.09	3.14	4.19	5.24
Group S	B	114.22 + 27.84	210.71 + 46.95	276.08 + 52.72	286.13 + 58.96	269.29 + 52.97
	A	139.75 + 25.42	244.03 + 42.31	298.76 + 45.05	307.84 + 51.79	290.26 + 53.36
	G	25.49 + 16.26*	33.31 + 23.60*	19.20 + 35.92*	21.70 + 26.02*	20.97 + 31.81*
Group I	B	125.08 + 25.21	212.93 + 38.84	268.48 + 48.04	284.28 + 47.01	275.33 + 37.53
	A	144.02 + 25.07	243.85 + 39.71	320.47 + 50.29	344.15 + 52.96	334.97 + 45.41
	G	18.94 + 8.55*	30.91 + 17.07*	51.96 + 37.82*	59.86 + 38.01*	59.01 + 27.25*
Group F	B	119.53 + 37.74	214.62 + 74.20	267.34 + 84.90	255.50 + 99.59	251.35 + 73.69
	A	117.61 + 29.67	210.02 + 49.45	285.48 + 69.88	299.42 + 71.39	301.72 + 68.37
	G	− 1.92 + 17.11	− 4.60 + 32.19	18.14 + 32.84	43.92 + 50.48*	50.36 + 22.08*
Group C	B	114.89 + 17.14	206.00 + 35.54	260.53 + 42.75	266.75 + 40.14	258.43 + 28.79
	A	111.73 + 18.44	201.22 + 35.84	259.80 + 36.64	272.00 + 27.47	249.91 + 19.29
	G	− 3.16 + 13.08	0.20 + 22.41	− 0.73 + 23.37	5.25 + 26.44	− 8.52 + 24.81

Values are means + SD
B: Before training A: After training G: Gain in average power after training
* Statistically significant by *t*-test for paired observations

dynamometer was visually aligned with the axis of the knee. The dynamometer lever was attached to the tibia at the ankle, and maximal knee extension was performed from 90° to 0° (0° = full extension). The subjects were encouraged verbally by the investigator to exert maximal effort throughout.

The torque was measured at five different test speeds (1.05, 2.09, 3.14, 4.19, and 5.24 rad · s^{-1}). The force curve in each contraction was recorded on a magnetic data-recorder (Sony Co., Tokyo, Japan) for subsequent analysis. The work done by each contraction was determined by integrating the area under the force curve, and an average power was calculated by dividing it by the time for the knee extensors to develop the force. Calibration of the dynamometer were accomplished periodically in the way described by Caiozzo et al. (1981).

Training Procedures. All training groups trained the knee extensors in the same manner as in the testing procedure by using the isokinetic dynamometer. They completed three work bouts per day with 2 min of relief between each work bout. The subjects repeated 10 maximal knee extensions in each bout for group S, 30 extensions for group I and 50 extensions for group F, respectively. Therefore, it took approximately 40 s to perform each work bout regardless of the group. The subjects exercised 6 days per week for 8 weeks.

Statistics. Conventional statistical methods were used for calculating the means and standard deviations (SD). Changes within a group from pre-training were analysed by using Student's *t*-ratios. For studying the learning effect on isokinetic power output, eight male subjects (age: 22.6 ± 1.0 years, height: 173.5 ± 5.2 cm, weight: 66.8 ± 8.7 kg) were tested before and after 2 months in the other experiments. The results (Table 2: group C) showed no improvement in power output at five different test speeds. Therefore, a one-way analysis of variance was used to determine whether a significance between group means existed. All comparisons were considered to be statistically significant when $P < 0.05$.

Results and Discussion

In most athletic events, power (work done per unit time) is more important or decisive in physical performance than static strength (e.g., isometric contraction) or instantaneous force (e.g., peak torque during isokinetic contraction). In other words, the problem is how much power an athlete can exert, rather than how much muscular strength. Therefore, in the present study, the average power exerted by a single maximal isokinetic contraction was studied.

The means of average power measured before and after training are presented in Table 2. It is observed in all groups that the average power increases with increasing contraction velocity up to 4.19 rad · s^{-1} and slightly decreases to 5.24 rad · s^{-1}. These results agree with previous reports that maximal power output occurred at approximately 4.19 rad · s^{-1} for untrained individuals (Perrine and Edgerton 1978), and at velocities greater than 5.03 rad · s^{-1} for highly trained athletes (Greger et al. 1979).

Groups S and I showed statistically significant increases in average power at all test speeds, while group F showed statistically significant increases only at faster test speeds of 4.19 and 5.24 rad · s^{-1}. The relationship between post-training increases and test speeds for each group is presented in Fig. 1. The percent increment in power obtained by group S decreases with increasing test speed from 24.8% to 8.6% at 5.24 rad · s^{-1}. On the other hand, group I showed almost similar percent increments (18.5–22.4%) at all test speeds except at 2.09 rad · s^{-1} (15.4%). In addition, groups I and F demonstrated statistically greater increases in power than group S at the faster test speeds of 4.19 and 5.24 rad · s^{-1}.

The effects of isokinetic training at relatively low velocities (0.42–1.68 rad · s^{-1}) are consistent among the previous studies (Pipes and Wilmore 1975; Coyle

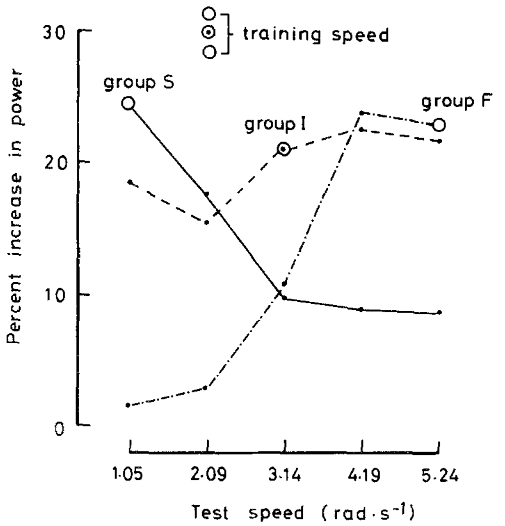

Fig. 1. Relationship between relative post-training increases and test speeds for each group. Symbols indicate training speed: group S (–○–), group I (- -⊙- -), group F (···○···)

et al. 1981; Caiozzo et al. 1981). Namely, the gains in muscular strength at slow test speeds are greater than gains at fast test speeds. In the present study, although there are significant power improvements in group S at all test speeds, the gain decreases with increasing test speed.

On the other hand, the effects of training at high velocity (more than 3.49 rad · s^{-1}) on muscular output vary in previous reports. For example, Caiozzo et al. (1981) reported that the significant gain after training at 4.19 rad · s^{-1} were brought about only with test speeds similar to the training speed. Also Smith and Melton (1981) reported that isokinetic exercise at high speeds produced much better results when the results tested are in high-speed contraction velocity performances (e.g., 40 yard dash, standing broad jump). However, Coyle et al. (1981) showed that training at 5.24 rad · s^{-1} provided significant increases in peak torque at both slow and fast test speeds.

In the present study, group F showed the great gains only at the faster test speeds of 4.19 and 5.24 rad · s^{-1}. Thus the present results contradict those of Coyle et al. (1981), but coincide well with those of Caiozzo et al. (1981). Since most previous investigations have examined the effects of training at relatively slower velocities, and consequently little is known about training at higher velocities, it is difficult to propose a definitive conclusion concerning the effects of higher-velocity training at present.

However, the authors hardly confirm the description by Sale and MacDougall (1981) that fast training produced almost the same results at both high and low velocities, while slow training produced markedly better results at low velocity. The present results indicate that there is a specificity of velocity effect; slow-velocity training brings about power improvement mainly at slow muscular contraction, while high-velocity training develops the power only with fast muscular contraction. But, the fact that group I training at 3.14 rad · s^{-1} showed significant gains in power at all test speeds might indicate a possible existence of a non-specific velocity of training effect. That is, intermediate-velocity training can improve muscular output over a wide range of contraction speeds.

Considering the fact that most athletic performances occur at limb speeds greater than 3.14 rad · s^{-1}, the most interesting finding in the present study was that group I training at 3.14 rad · s^{-1} provided relatively great and almost constant gains in power at all test speeds. Therefore, it might be expected that the velocity-specific adaptations within both the muscles and the nervous system occured during training at 3.14 rad · s^{-1}.

In conclusion, the present results suggest that there are velocity-specific training effects derived from slow or fast contraction, and that an intermediate training velocity may exist which can enhance muscular power output over a wide range of contraction velocities.

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