Specificity of Training on Computer Obtained Isokinetic Measures

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Abstract:
The purpose of this study was to examine the effects of 7 weeks of isokinetic training on knee extension and flexion peak torque, torque acceleration energy, average power, and total work, and to observe the relationship between the increases in each of the isokinetic measures. Seventeen intercollegiate lacrosse players served as subjects and were assigned to an exercise or control group. Isokinetic training consisted of 3 sets of 25 repetitions at 270° /sec, 3 days per week for 7 weeks on an orthotron isokinetic dynamometer. All subjects were tested on a Cybex® isokinetic dynamometer at speeds of 60, 180, and 270° /sec pre- and post-exercise or control condition. Results showed a significant training effect at 270° /sec for knee extension peak torque, torque acceleration energy, and average power, and knee flexion torque acceleration energy. High correlations were observed between the increases in peak torque, average power, and torque acceleration energy. These findings suggest that increases in average power, peak torque and instantaneous power may be expected as a result of isokinetic exercise training in healthy athletes.

Article:
The relationship between adequate levels of peak torque and power to successful athletic performance has been well documented (5, 6, 12). Isokinetic dynamometry enables the evaluation of single muscle group peak torque, power, and work (7). Peak torque is the highest level of torque produced during a given isokinetic contraction, work is force times distance, and power is the rate of doing work (7). The interfacing of microprocessors with isokinetic dynamometers has enabled the rapid and reliable quantification of these muscular forces including peak torque, torque acceleration energy, average power, and total work. Peak torque is the highest torque produced during a given contraction, while torque acceleration energy is defined and measured as the amount of work performed in the first one-eighth second of torque production. Average power is the sum of total work accumulated during the test repetition divided by the total contraction time. Total work is the sum total of area under all the torque curves in the test repetitions. The reliability of these measures obtained by a Cybex Data Reduction Computer® (Lumex, Ronkonkoma, NY) has previously been reported (9).

Increases in peak torque and power resulting from isokinetic training have been documented (1, 2, 4, 14). However, the effect of training on these isokinetic measures relative to each other is unclear. Certain levels of single muscle group peak torque are not necessarily associated with relatively similar levels of power and work (10). Furthermore, the relationship between increases in computer obtained measures of peak torque, work, and power subsequent to isokinetic training has not been established. The documentation of these relationships in healthy subjects would assist clinicians in establishing realistic therapeutic exercise guidelines for the rehabilitating patient.

The purpose of this investigation was to examine the effects of 7 weeks of high speed isokinetic training on peak torque, torque acceleration energy, average power, and total work. The study measured the increases in each of these isokinetic measures and determined the correlation between the observed increases. Finally, the overflow in peak torque from higher to slower isokinetic speeds was determined. It was hypothesized that a training effect would be observed for each isokinetic measure and that the highest correlations would be between the values related to the development of power.

METHODS

Subjects

Seventeen intercollegiate lacrosse players participated in the study. Mean age was 19.1 years, mean height was 182.2 cm, and mean weight was 84.4 kg. Subjects were randomly assigned to either a training (experimental) group (n = 8) or a control group (n 9). Subjects were screened for prior musculoskeletal injury to the thigh or knee, and all individuals gave written consent to participate in the experiment in accordance with established human subject protocols.

Strength Measurements

Pre-training strength parameters were assessed with a Cybex (Lumex, Ronkonkoma, NY) isokinetic dynamometer. The Cybex dual channel recorder and dynamometer were interfaced with a Cybex Data Reduction Computer (CDRC) for analysis of test results. The Cybex and CDRC were calibrated prior to each data collection session. Each subject underwent isokinetic testing for the right and left knee extensor and flexor muscle groups. Subjects were stabilized with straps during testing, and the knee joint's axis of rotation was aligned with the input shaft of the dynamometer. To provide gravity correction during knee testing, the gravitational moment of the Cybex arm, shank, and the leg were determined by the CDRC.

Isokinetic exercise was explained to the subjects prior to testing. The test protocol for assessing knee extension and flexion strength included 4 repetitions at both 60 and 180°/sec, and a 25-repetition work test at 270°/sec. Warm-up at each test speed included 3 submaximal repetitions immediately followed by 3 maximal repetitions. Peak torque measures were obtained at all 3 test speeds, and torque acceleration energy, average power, and total work were obtained during the 270°/sec work test. Post-training strength parameters were measured using an identical test protocol.

Training Protocol

An orthotron isokinetic dynamometer (Lumex, Ronkonkoma, NY) was used to train the right and left quadricep and hamstring muscle groups. Subjects in the training group performed 3 sets of 25 repetitions with each leg at a training velocity of 270°/sec (No. 10 orthotron setting). Subjects trained in pairs so as to provide verbal encouragement to each other during exercise sessions. Training occured 3 days per week for a period of 7 weeks.

Data Analysis

Student t-tests were computed to determine if any differences existed between the right and left side muscle groups for each isokinetic measure. Because no differences were observed, the right and left side scores were averaged and used for analysis of test results. A two-way analysis of variance model was used pre- versus post-training, training versus control group) to determine if a training effect had occurred for any of the isokinetic measures. Since the present study was interested in differences between change scores, the two way interaction was the statistic of greatest relevance. Correlation coefficients were computed to determine the relationship between the increases in each of the isokinetic measures. The percentage change in pre to post test scores for the experimental group were used to compute the correlations between each isokinetic measure.

RESULTS

Table 1 presents changes in peak torque, during knee extension at velocities of 60, 180, and 270°/ sec, as a result of training. For the training group, a significant increase in peak torque (+21.5 Nm, $p < 0.05$) was observed post training at 270°/ sec. Statistically significant increases for peak torque post training at velocities of 60 and 180°/ sec were not observed. The control group's peak torque during knee extension did not change pre- to post-training. Results observed for peak torque generated during knee flexion (Table 1) indicated no significant training effect at velocities of 60, 180 or 270°/sec.

Changes in torque acceleration energy observed at 270°/sec (25 repetition work test) are presented in Table 1. For both knee extension and flexion the training group showed a significant improvement in TAE as a result of training (+9.7 Nm for extension, $p < 0.05$; +11.5 Nm for flexion, $p < 0.05$). Torque acceleration energy in the control group did not change significantly.

Average power at 270°/sec (Table 1) increased during knee extension by 119.7 watts ($p < 0.01$). The control group did not change. No significant change was observed for either group for total work during knee extension or flexion (Table 1).

Tables 2 and 3 present the correlation matrices for knee extension and flexion peak torque, torque acceleration energy, average power, and total work. For knee extension, the highest correlation was observed between average power and peak torque at 270°/sec ($r = 0.89$), and the lowest was between total work and peak torque at 60°/sec ($r = 0.58$) (Table 2). Similar correlations for knee flexion were observed with the highest between torque acceleration energy and peak torque at 270°/sec and between average power and peak torque ($r = 0.81$). The lowest correlation for knee flexion was between total work and peak torque at 60°/sec ($r = 0.28$) (Table 3).

DISCUSSION

The increases in peak torque and power in this investigation were consistent with those found by other authors (4, 14). Knee extension peak torque at 270°/sec increased 21.5 Nm while average power increased 119.7 watts. Although statistically significant increases were not found for peak torque and average power relative to controls during knee flexion, increases of 15.5 Nm and 51.1 watts respectively were observed.

TABLE 1 IS MISSING FROM THIS DOCUMENT FORMAT

TABLE 2

*Correlations between increases in isokinetic measures during knee extension**

	PT 180°/sec	PT 270°/sec	TAE	AP	TW
PT 60°/sec	0.76	0.82	0.66	0.76	0.58
PT 180°/sec		0.69	0.64	0.64	0.69
PT 270°/sec			0.77	0.89	0.65
TAE				0.72	0.62
AP					0.76
TW					

* See Table 1 for key.

TABLE 3

*Correlations between increases in isokinetic measures during knee flexion**

	PT 180°/sec	PT 270°/sec	TAE	AP	TW
PT 60°/sec	0.52	0.60	0.44	0.51	0.28
PT 180°/sec		0.78	0.74	0.81	0.74
PT 270°/sec			0.81	0.79	0.59
TAE				0.77	0.59
AP					0.73
TW					

* See Table 1 for key.

The failure to see a statistically significant response in hamstring muscle group peak torque and average power may be related to the greater external resistance encountered by the quadricep muscle group. Training of both muscle groups occuRred at a controlled velocity of 270°/sec. However, knee extension was performed against the effect of gravity while knee flexion did not encounter the added resistance of gravity. Thus, the added resistance encountered by the quadricep muscle group over a period of seven weeks may have been sufficient to produce a greater response to training.

Torque acceleration energy (TAE) increased significantly for both the knee extensor and flexor muscle groups. Previous observations of "instantaneous" or "contractile" power have included measurement of the power exerted between the initiation of muscular force and the attainment of peak torque (7). Some have criticized the concept of torque acceleration energy as lacking a basis from Newtonian physics (11). While the authors recognize this fact, several points may establish TAE as a useful measure. First, the reliability of this measure has previously been demonstrated (9). Second, TAE has been shown to correlate with traditional measures of anaerobic power (3). Finally, this investigation found increases in TAE of 9.7 and 11.5 Nm for quadricep and hamstring muscle groups respectively, indicating torque acceleration energy can be enhanced by high speed isokinetic training. Thus, while "instantaneous power" is better terminology, torque acceleration energy or "instantaneous power" as a concept is a useful parameter in clinical practice.

The greatest training effect was observed for average power for the knee extensor (119.7 watts) muscle group. This finding was not surprising due to the specificity of the average power test with the 25 repetition training program. The correlation coefficients indicated a close relationship between "instantaneous power," i.e., torque acceleration energy, peak torque at 270°/sec, and average power. These findings suggest that a training protocol such as employed in this study is useful for the development of velocity specific peak torque, instantaneous power, and average power.

The lowest correlation coefficients were found between total work and peak torque for both muscle groups. Since total work is more representative of the endurance capability of a muscle group, this finding was not unexpected. In contrast, peak torque, torque acceleration energy, and average power are not related to the endurance of a muscle group, and as expected, the highest correlation coefficients were observed among these measures.

Several authors have reported isokinetic training overflow effects from fast to slower speeds (2, 4, 7, 8, 13). Statistically significant increases were not observed for knee extension and flexion peak torque at 180 or 60°/sec in this investigation. However, a trend in training overflow to slower speeds seemed apparent for peak torque at 180 and 60°/sec for both muscle groups. For example, knee extension peak torque increased 15, 12, and 8% at 270, 180, and 60°/ sec, respectively. This observation may suggest that had the training protocol extended for longer than 7 weeks or if a greater number of subjects had participated, statistically significant increases may have been found.

CONCLUSION

This study demonstrated that a 7 week program of high speed isokinetic training is adequate for the development of velocity specific peak torque and of instantaneous and average power. Longer periods of training may be necessary for the development of total work and for an overflow increase in peak torque to slower speeds. The study also demonstrated that isokinetic power training is effective for the development of not only average power but of peak torque and instantaneous power as well.

The subjects used for this study were healthy university athletes. The use of a high speed isokinetic training protocol appears useful for enhancement of torque and power in healthy athletes. It is hoped that these data will provide useful information for establishing goals for computer obtained isokinetic measures in a rehabilitating athlete. Additional research should be undertaken which examines the effects of isokinetic training on torque, power and work in a rehabilitating population.

REFERENCES

1. Adeyanju K, Crews TR, Meadors WJ: Effects of two speeds of isokinetic training on muscular strength, power and endurance. J Sports Med 23:352-356, 1983

2. Coyle EF, Feiring DC, Rotkis TC, Cote RW, Roby FB, Lee W, Wilmore JH: Specificity of power improvements through slow and fast isokinetic training. J Appl Physiol 51:1437-1442, 1981

3. Lephart SM, Perrin DH, Manning JM, Gieck JH, McCue FC, Saliba EN: Torque acceleration energy as an alternative predictor of anaerobic power. (Abstract) Med Sci Sports Exerc 19:59, 1987

4. Lesmes GR, Costili DL, Coyle EF, Fink WJ: Muscle strength and power changes during maximal isokinetic training. Med Sci Sports Exerc 10:266-269, 1978

5. Manning JM, Dooly-Manning CR, Terrell DT, Sales E: Effects of a power circuit weight training program on power production and performance. J Swim Res 2:24-29, 1986

6. Miyashita M, Kanehisa H: Dynamic peak torque related to age, sex, and performance. Res Quart 50:249-255, 1979

7. Moffroid MT, Kusiak ET: The power struggle—definition and evaluation of power of muscular performance. Phys Ther 55:1098- 1104,1979

8. Moffroid M, Whipple RK: Specificity of speed of exercise. Phys Ther 50:1699-1700,1970
9. Perrin DH: Reliability of isokinetic measures. Athl Train 21:319-321, 1986

10. Perrin DH, Robertson RJ, Ray RL: Bilateral isokinetic peak torque, torque acceleration energy, power, and work relationships in athletes and non-athletes. J Orthop Sports Phys Ther 9:184-189, 1987

11. Rothstein JM, Lamb RL, Mayhew RP: Clinical uses of isokinetic measurements. Phys Ther 67:1840-1844, 1987

12. Sharp RL: Muscle strength and power as related to competitive swimming. J Swim Res 2:5-10, 1986

13. Timm KE: Investigation of the physiological overflow effect from speed-specific isokinetic activity. J Orthop Sports Phys Ther 9:106-110,1987

14. Vitti GJ: The effects of variable training speeds on leg strength and power. Athl Train 19:26-29,1984