The Effect of Isokinetic Training on Maximum Torque Output of Swimmers, Using the Akron Isokinetic Dynamometer

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INTRODUCTION

The important aspect of isokinetic exercise is that it allows the muscles to move at a constant predetermined angular velocity. This mode of exercise is based upon electromechanical devices with feedback systems which maintain the preset angular velocity of the limbs around the joint to be tested.

The importance of isokinetic strength training for swimming performance is well supported by a number of studies (3, 7, 13).

The purpose of this study was to determine if isokinetic training using a new isokinetic dynamometer, (AKRON, Ipswich, England), would increase the isokinetic strength of swimmers.

METHOD

One group of swimmers trained the shoulder and knee flexor and extensor muscle groups using the AKRON isokinetic dynamometer. Pre- and post- training tests assessed the effect of this training. A control group was not included in this study because of limited subject availability.

Subjects

Six males, members of the Liverpool University Swimming and Water-Polo Club, volunteered as subjects in this study. Their age, weight and height values are shown in Table 1. No injury in the knee or shoulder joints was reported during this study. The subjects did not participate in another strength training programme during the period of this study, except their normal swimming training.

SUBJECT	AGE (YS)	WEIGHT (KG)	HEIGHT (M)
1. P.S.	19	64.8	1.78
2. C.F.	22	70.2	1.76
3. N.W.	19	74.2	1.77
4. B.O.	22	70.3	1.84
5. C.D.	22	80.5	1.92
6. M.G.	22	83.3	1.86
$\bar{X} \pm SD$	21 ± 1.4	73.8 ± 6.3	1.82 ± 0.05

Instrumentation

An AKRON isokinetic dynamometer was used for training and testing. The dynamometer consists of the following components:

1) A fully adjustable table:

The design of this table and the supporting devices enables the correct positioning and stabilization for testing all the major muscle groups of the body.

2) Dynamometer main unit:

This component includes an electromechanical control system. The muscular force applied to the input shaft is registered by two pressure transducers. The resistive force produced by the dynamometer is equal to the input force provided the movement angular velocity exceeds the preset operation speed. This can be varied from 30 deg/sec to 240 deg/sec. Therefore there is no net accelerating force and a constant speed of movement is maintained. A goniometer controls the range of movement and can be adjusted to prevent any further movement outside the preset limits. The position of the lever arm in the preset ROM is monitored in a bar graph display. The display board consists of two bar graph torque displays, one for each direction of movement. On each display, either a target level or a minimum indicator can be set. A repetition counter and speed indicators are also provided. The control features three torque range scales (0-100, 0-300, 0-600 NM). There is also an analog output for the chart recorder. The main unit is mounted onto a rail on either side of the table so that it can be easily moved to accomodate all measurment positions.

3) Pen chart recorder:

This component has two operational modes and plots on graph paper either torque versus angular displacement or torque versus time. The pen speed when in the time mode varies from 0.2 to 100 m/sec. A signal conditioner is also provided.

The system was calibrated prior to the pre- and post- training tests using the following method: Weights of 20 and 40 kg were placed at the last input position of the lever arm and the centre of gravity of this system was determined using standard weighing techniques. The system was allowed to move from the vertical position through a 180 deg. arc at a preset angular velocity of 60 deg/sec. The level of accuracy obtained was +2 NM for the 0-300 NM scale.

Testing procedures

Maximum torque of the knee and shoulder flexor and extensor muscle groups, before and after a six week isokinetic training programme was measured.

Knee extension-flexion

Each of the six repetitions consisted of a knee extension followed by flexion. The ROM was set from 0 deg (absolute knee angle 90 deg) to 60 deg (absolute knee angle 150 deg). During the tests the subjects were seated in the adjustable chair and the lever arm axis of rotation was aligned with the anatomical axis of rotation through the knee joint. Although Patteson et al (12), suggest that the peak torque generated by the quadriceps and hamstings at 60 and 80 deg/sec are not signifficantly influenced by stabilization of the opposite leg, in this study the opposite lower leg, the thigh and the hips were stabilized with belts. The «Stop mode» at the limits of the ROM was disconnected, so that the subjects were able to overcome the above limits. All subjects were motivated verbally to encourage maximum effort in both flexion and extension throughout the entire range of movement and to change direction after the signal from the goniometer at the limits of the preset ROM.

Shoulder extension-flexion

Subjects were placed in the supine position in the adjustable table and the hips stabilized with belts. Since the anatomical axis of rotation of the shoulder joint changes during extension and flexion, the shoulder was aligned with the dynamometer axis of rotation when the limb was in a horizontal position at 0 deg. From this position each subject performed six reciprocal extension - flexion movements around the shoulder joint. The ROM was from 0 deg (horizontal) to 120 deg, with an angular velocity of 240 deg/sec. The sequence of testing procedures was the following:

1) Left Knee
2) Right Shoulder
3) Left Shoulder
4) Right Knee

Resting periods of two minutes were given between the tests. A familiarisation session was given to every subject, in which basic instructions for the use of the dynamometer were given and each subject performed one testing and one training protocol. The pre-training test was completed within the week prior to the first week of training. The post-training test was conducted in the second training session of the last week of training. Pre- and post- training tests and training sessions were conducted between 10 am and 2 pm for all subjects. Informed consent was provided prior to the first test.

Training procedures

The training period was six weeks, with two training sessions each week. Each training session consisted of three sets of 25 repetitions for each movement tested, performed in the same sequence. The ROM was the same throughout the training period. During the first two weeks the angular velocity was the same as in the pre-training test. In the following weeks the angular velocity was decreased 30 deg/sec every two weeks for each movement. With this method the subjects were allowed to exert a greater amount of force, since the force generated at lower angular velocities is greater because more muscle fibers within the muscle have the contractile velocity capability to contribute to the total muscle tension (1,2,4,8,9). Two minutes warm-up was given before the exercise in each movement and each training session lasted about 45 minutes. Positioning and stabilization of the subjects was the same as in the pre- and post-training tests.

Data Reduction

Maximum torque and angular displacement data were extracted from the chart recorder graph output. Maximum torque data were corrected for the effect of gravity torque (11,16). The positions of thw C. of G. of the two lever arms used, was determined using standard weighing techniques, for the different positions of the lever arm attachments. The position of thw C. of G. of the system limb-lever arm was determined relative to knee-ankle and shoulder wrist axes for the two different settings. A computer program performed the gravity correction using as input the leg and arm length and the weight of thw subject. The leg and arm lengths were measured using tape measurement techniques, as this method was reported to be valid and reliable when compared with X-ray measurements (6). The signal conditioner was set to zero because it was reported earlier that damping shifts the torque curve in the time axis (15), and maximum torque values were measured after the initial «overshoot» were observed. T-test was used to analyse the results statistically, using the 0.05 level of significance.

RESULTS

There was a significant increase in the maximum torque produced pre- to post-training by right and left shoulder muscle groups ($p < 0.05$), ranging from an average increase of 22.6% to 31.0% as shown in table 2 and figures 1,2. The difference in the angular position where the maximum torques were produced pre- and post-training was non significant (table 3). There was also a significant increase in the maximum torque produced pre- to post-training by right and left knee in extension

T-TEST SUMMARY TABLE

	Maximum Torque	Ang. Displacement
R. Shoulder Extension	2.692 ***	−0.801 n.s.
R. Shoulder Flexion	3.296 ***	−0.193 n.s.
L. Shoulder Extension	2.112 n.s.	0.862 n.s.
L. Shoulder Flexion	3.121 ***	0.579 n.s.
R. Knee Extension	3.544 ***	1.351 n.s.
R. Knee Flexion	2.088 n.s.	4.081 ***
L. Knee Extension	2.962 ***	2.299 n.s.
L. Knee Flexion	0.737 n.s.	3.695 ***

5 d.f. $p=0.05$ $t=2.571$ (*** $p<0.05$)

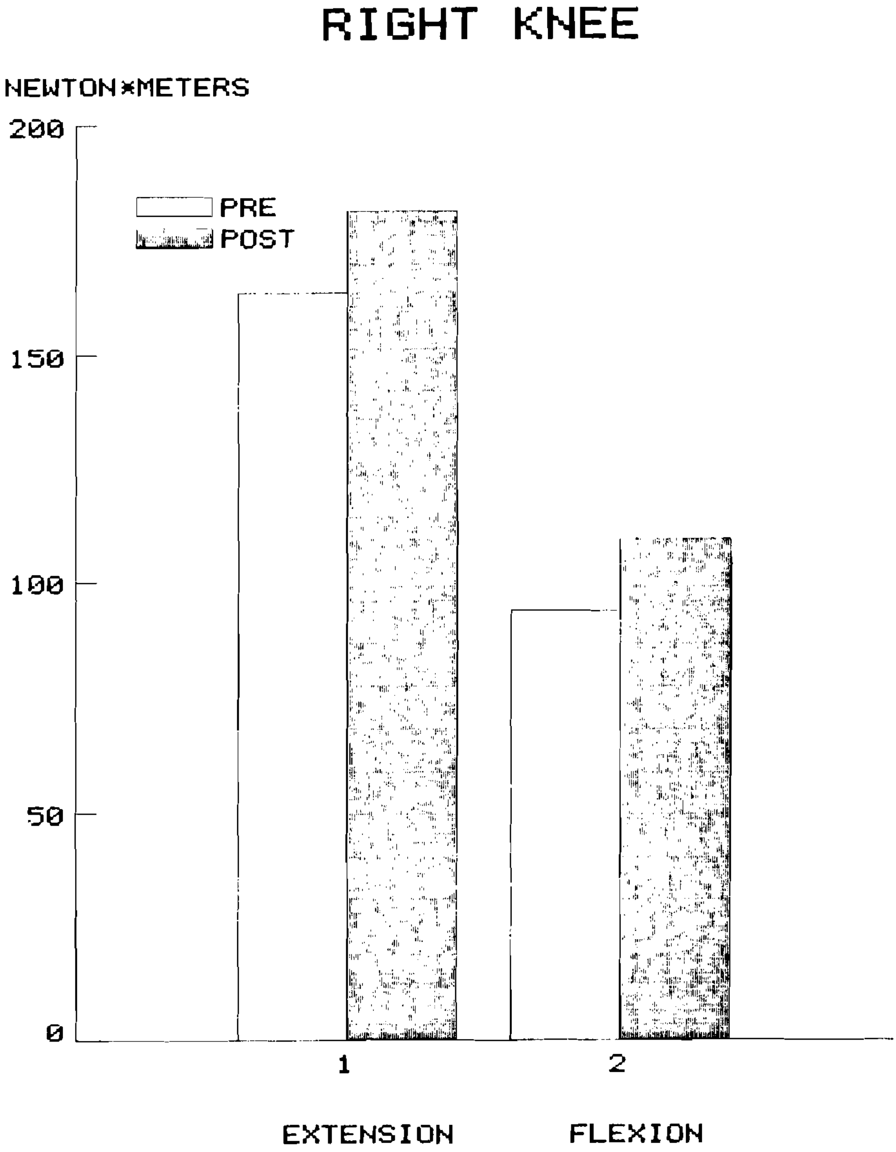

RIGHT KNEE
NEWTON*METERS
200
150
100
50
0
PRE
POST
1
2
EXTENSION
FLEXION

Fig. 1

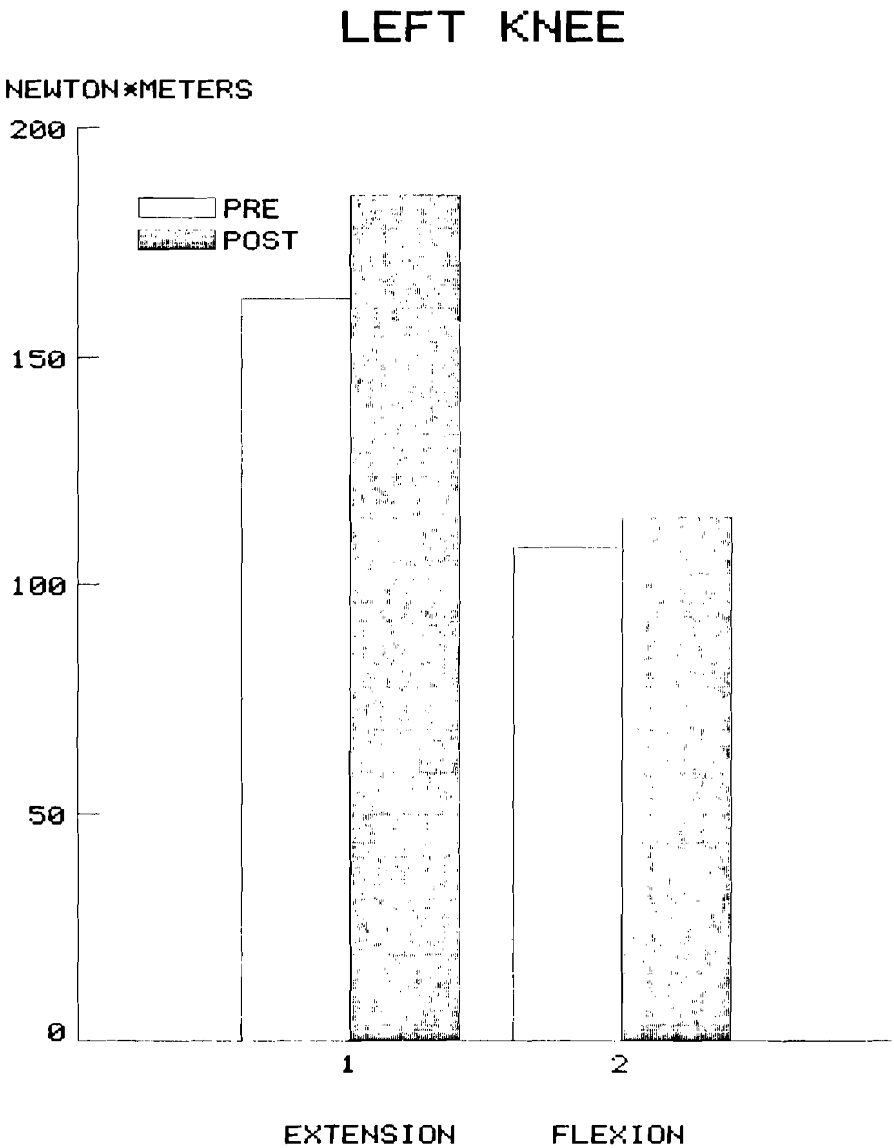

LEFT KNEE
NEWTON*METERS
200
150
100
50
0
PRE
POST
1
2
EXTENSION
FLEXION

Fig. 2

TABLE 3
MEAN ±SD VALUES OF MAXIMUM TORQUE AND ANG. DISPLACEMENT

	Maximum Torque (N*M)		Ang. Displacement (DEG)	
	Pre	Post	Pre	Post
R. Shoulder:				
Extension	53.3± 8.2	65.7±13.1	113.6± 6.9	101.6±35.3
Flexion	64.6±15.6	79.2±21.6	92.6±27.8	88.6±31.6
L. Shoulder:				
Extension	53.1±10.4	69.7±13.8	67.5±50.7	90.8±43.4
Flexion	59.6±17.8	75.0±24.5	75.8±27.4	82.1±35.2
R. Knee:				
Extension	163.6±28.6	181.3±26.1	26.8± 3.6	32.0± 6.2
Flexion	93.7±26.5	109.5±17.0	21.1± 3.1	32.5± 6.1
L. Knee:				
Extension	162.7±43.1	185.2±27.5	28.0± 4.4	35.3± 5.1
Flexion	107.9±23.3	114.5±10.6	25.5± 3.9	35.1± 5.3

($p < 0.05$), while the increase in flexion was non significant (fig. 3,4). The difference in angular position where the maximum torques were produced pre- to post- training was non significant in extension but there was a significant difference in flexion, with the angular position of maximum torque occuring earlier in the post-training test. There was a non significant difference in the hamstrings to quadriceps ratio ($p > 0.05$) pre- to post-training for right and left knee (fig. 5).

DISCUSSION

Power is a more accurate measurement than maximum torque output when assessing muscular performance because it measures the force output throughout the range of movement (10). Because a computer interface program for the dynamometer was not available at the time of this study, maximum torque, as obtained from the chart recorder output was used as a measurement of muscular performance.

A signifficant increase in the maximum torque produced by shoulder muscle groups was also reported by Garnica (5). However Garnica also reported that the point in ROM where peak torque was generated occured earlier in the test following the training. In this study there was no significant changes in the joint position where the maximum torque was generated pre- and post-training. These results are very important for muscular force development in swimmers, since the propulsive movements in swimming involve isokinetic contractions of the muscles.

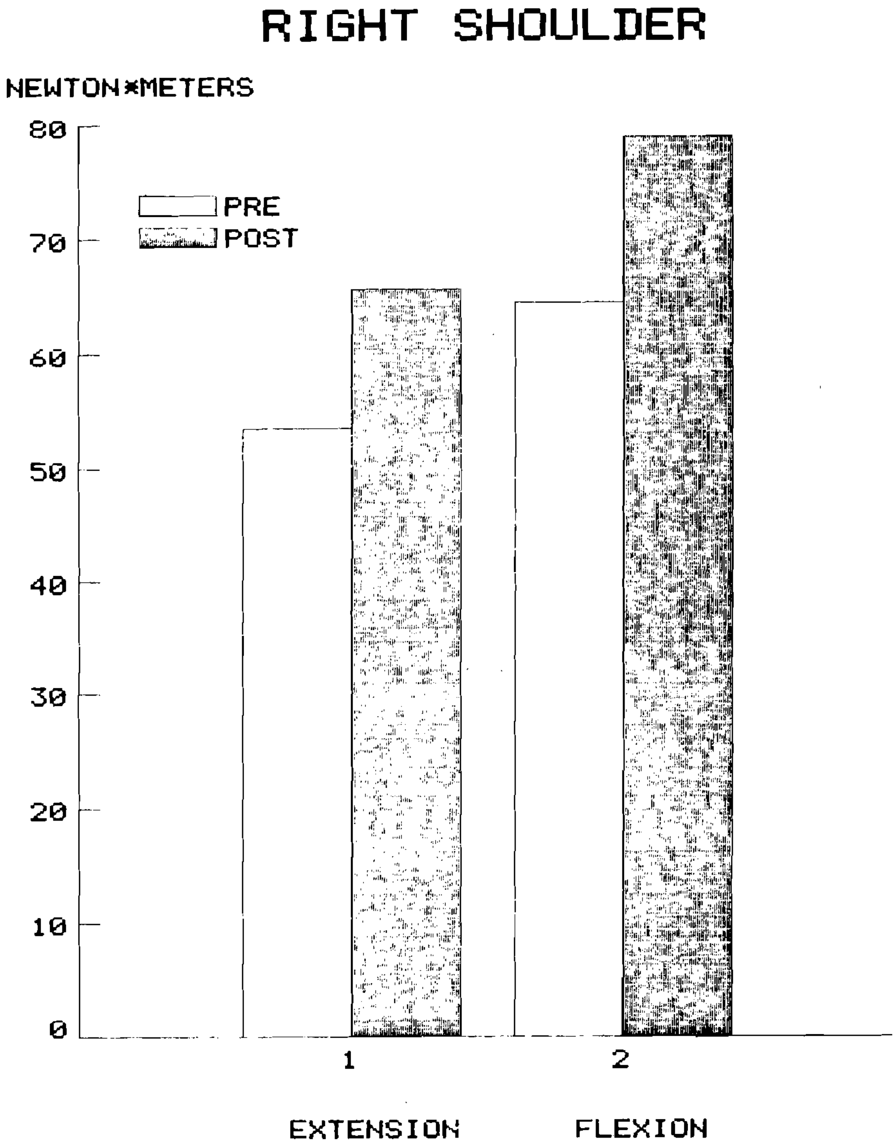

RIGHT SHOULDER
NEWTON*METERS
80
70
60
50
40
30
20
10
0
PRE
POST
1
2
EXTENSION
FLEXION

Fig. 3

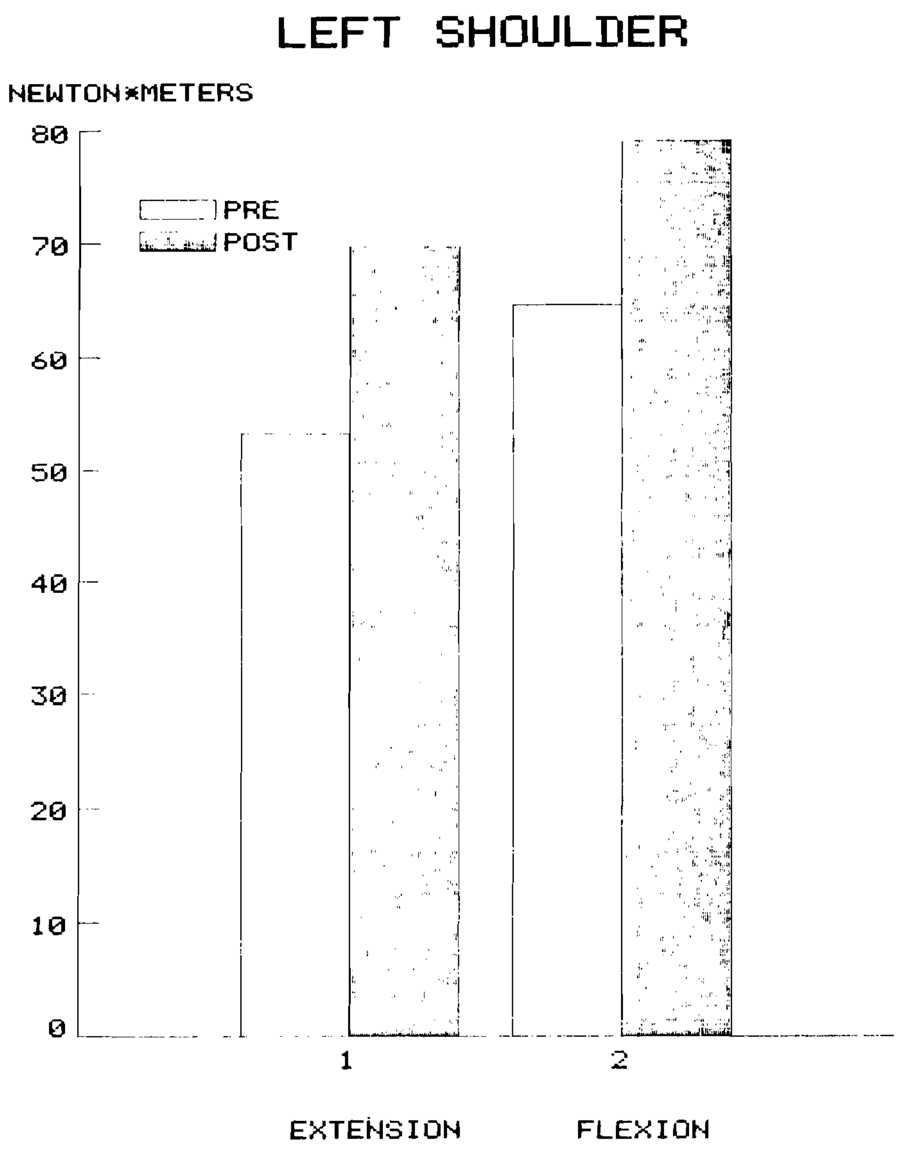
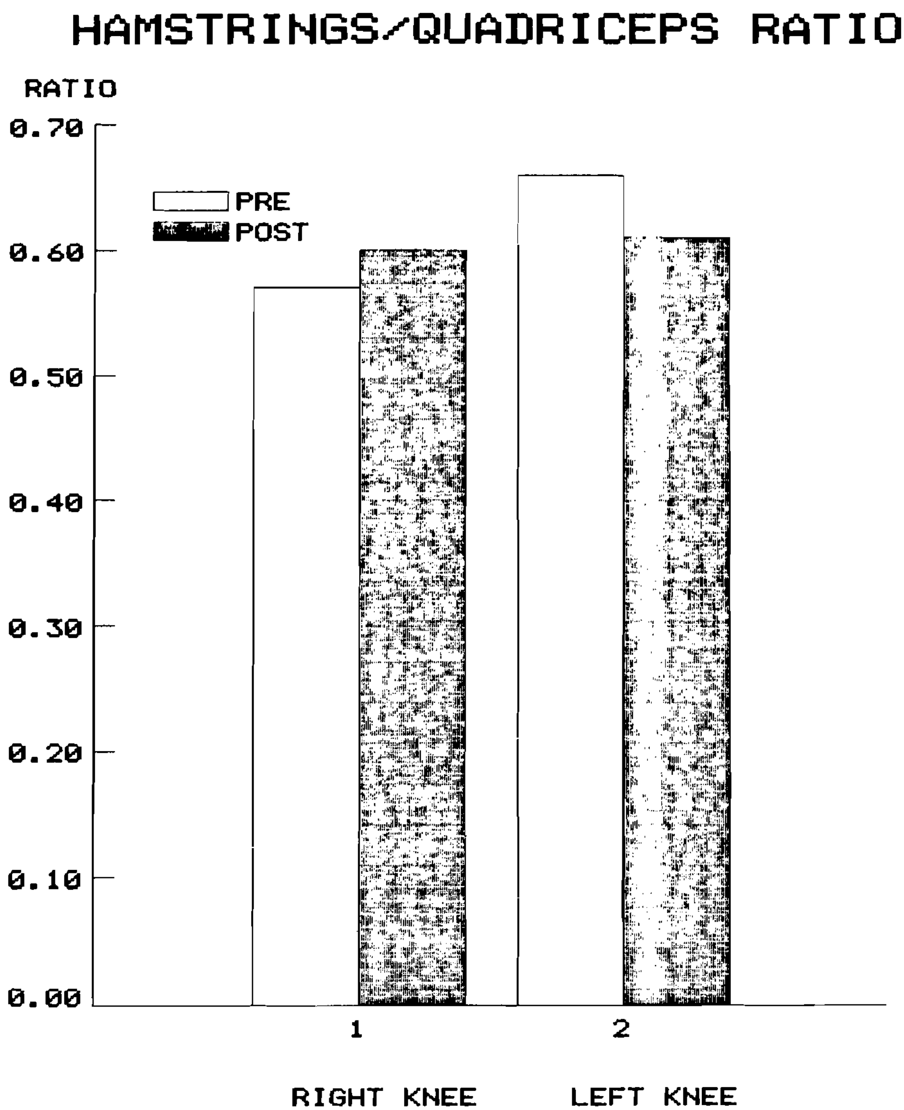

LEFT SHOULDER
NEWTON*METERS
80
70
60
50
40
30
20
10
0
PRE
POST
1
2
EXTENSION
FLEXION

Fig. 4



HAMSTRINGS/QUADRICEPS RATIO
RATIO
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
PRE
POST
1
2
RIGHT KNEE
LEFT KNEE

Fig. 5

Moreover the shoulder flexors contribute more than any other muscle group in swimming propulsion. The superiority of isokinetic training for swimming performance upon other modes of training has been investigated earlier (7). Therefore a training programme involving isokinetic exercise of 60 minutes per week, according to the concept of specificity, may have beneficial results in performance in short distance racing in swimming, where muscular power is the most contributory factor.

A significant increase in the maximum torque of the knee extensors muscles was observed in this study. Similar results were reported by Caiozzo et al (2) and Jenkins et al (8). There was a non significant difference in the point where the maximum torque was generated pre- to post-training.

The increase in maximum torque of the knee flexors was non significant and the point of the maximum torque post-training occured earlier, at a greater absolute angle in the knee joint. A similar trend was observed by Garnica (5), although the testing movement involved shoulder muscle groups and it was related to some form of «neural» adaptation. According to Sale et al (14), isotonic training increased the ability to raise motoneuron excitability during voluntary effort and therefore allowing the muscles to generate a force more efficiently or in less time. The proposed mechanism required the assumption that the subjects were unable to activate their muscles fully prior to training. This suggests that although the subjects in this study were instructed to encounter maximum effort throughout the range of movement in both flexion and extension, the hamstrings activation in the pre-training test was not maximum.

The implication for swimming is that even with well trained swimmers an overload land training programme, closely realated to their sport, can be of benefit for increasing relevant muscular force. This was particularly relevant as the frequency of land training was only twice weekly, thus contributing relatively little in total training time.

SUMMARY AND CONLUSIONS

Six male swimmers participated in a six week training programme using the Akron isokinetic dynamometer. The results demonstrated that significant improvements can be achieved in the maximum torque produced by shoulder flexors and knee extensors. This suggests that isokinetic training resembling the functional action of the sport can have beneficial effects on muscular force development.

REFERENCES

1. Barnes, W., The relationship of motor unit activation to isokinetic muscular contraction at different contractile velocities, Physical Therapy, (60), 9:1152-1158, 1980.
2. Caiozzo V. and Perrine, J., Training induced alterations of the in vivo force-velocity relationship of human muscle, Journal of Applied Physiology, (51):750-754, 1981.
3. Counsilman, J., Isokinetic exercise, Athletic Journal, (52):6, 1972.
4. Coyle, E., Feiring, D., Rotkis, T., Cote, R., Roby, F., Lee, W. and Wilmore, J., Specificity of power impovements through slow and fast isokinetic training, Journal of Applied Physiology, (51): 1437-1422, 1981.
5. Garnica, R., Muscular power in young women after slow and fast isokinetic training, The Journal of Orthopedic and Sports Physical Therapy, (8), 1:1-9, 1986.
6. Gogia, P. and Braatz, J., Validity and reliability of leg length measurements, The Journal of Orthopedic and Sports Physical Therapy, (8), 4: 185-188, 1986.
7. Hutinger, P., Comparisons of isokinetic, isotonic and isometric developed strength to speed in swimming the crawl stroke, Doctoral dissertation, Indiana University, 1970.
8. Jenkins, W., Thackaberry, M. and Killian, C., Speed specific isokinetic training, The journal of Orthopedic and Sports Physical Therapy, (6), 3:181-183, 1984.
9. Lesmes, R., Costill, D., Coyle, F. and Fink, J., Mucle strength and power changes during maximal isokinetic training, Medicine and Science in Sports and Exercise, (10):266-269.
10. Moffroid, M. and Kusial, E., The power struggle-definition and evaluation of power of muscular performance, Physical Therapy, (55): 1098-1104, 1975.
11. Nelson, S. and Duncan, P., Correction of isokinetic and isometric torque recordings for the effect of gravity, Physical Therapy, (63), 5:674-677, 1983.
12. Patteson, M., Nelson, S. and Duncan, P., Effects of stabilizing the nontested lower extremity during isokinetic evaluation of the quadriceps and hamstrings, The Journal of Orthopedic and Sports Physical Therapy, (6), 1:18-20, 1984.
13. Pipes, T., Isokinetic strength training and its effectiveness for the competitive swimmer, Swimming Technique, (3):10, 1978.
14. Sale, D., McDougall, G., Upton, A. and McComas, A., Effect of strength training upon motoneuron excitability in man, Medicine and Science in Sports and Exercise, (15): 57-62, 1983.
15. Sinacore, D. and Rothstein, J., Effect of damp on isokinetic measurements, Physical Therapy, (63), 8: 1248-1250, 1983.
16. Winter, W., Wells, R. and Orr, G., Errors in the use of isokinetic dynamometers, European Journal of Aplied Physiology, (46): 397-408, 1981.