Effects of Isokinetic Exercise on Adolescents With Cerebral Palsy

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The purpose of this study was to examine the effects of isokinetic resistance exercise on torque development and movement time of individuals with cerebral palsy. Subjects (N = 30) 10 to 20 years of age were matched and assigned to one of three treatment groups: IR, isokinetic resistance; NR, repetitive practice with no resistance; and C, control. The treatment protocol consisted of exercising the triceps extensor group with 3 sets of 10 maximal speed repetitions, 3 times per week for 6 weeks. Data were collected for movement time on the Dekan Performance Analyzer with adapted photoelectric switches. Torque data were collected on the Cybex II with dual channel recorder. Significant differences (p < .05) occurred on both movement time and torque development for the isokinetically trained group. It was concluded that isokinetic resistance exercise affected neuromuscular performance in these youths with cerebral palsy similar to the nonhandicapped population.

Sports opportunities for individuals with various handicapping conditions have grown tremendously over the last 10 years. As is true of sports for the nonhandicapped, performances improve each year, records are broken, and it is again realized that there are no limits in sight. Despite the handicap, individuals are performing with greater speed, power, endurance, and coordination. Obviously, one of the important variables accounting for the improved performances is the amount and type of training the athletes engage in prior to competition. Although the same principles used in training able-bodied athletes would logically apply to handicapped individuals, there are some conditions under which a traditional training practice may be either inadvisable or controversial with respect to contemporary treatment practices.

The opportunity for individuals with cerebral palsy to participate in organized sport is relatively new; the National Association of Sport for Cerebral Palsy was founded in 1976 to promote competitive sport for those with cerebral palsy. The primary dysfunction for individuals with cerebral palsy is the abnormal development of motor skills, which results from damage to a developing or immature brain. The severity of the dysfunction depends on the size and location of neurological lesion (Milner-Brown & Penn, 1979). The most frequently encountered impediment to volitional movement in cerebral palsy is spasticity, which is directly related to a hyperactive stretch reflex. The hyperactive reflex mechanism causes the antagonist muscle to contract, limiting the functional movement
of the agonist. This interferes with the ability to maintain normal muscle tone and control of the reciprocal contracton and relaxation of opposing muscle groups (Holt, 1966). The movement is also impaired by a limited and prolonged recruitment of the agonist muscle (Sahrmann & Norton, 1977). Of particular interest, therefore, is the amount of coordination and control that can be developed in individuals with varying degrees of cerebral palsy.

Improved motor performance in individuals with cerebral palsy, as in able-bodied athletes, involves changes in many physical and motor fitness variables. Particularly important is strength and speed of movement. Since cerebral palsy results in inefficient muscular contractions, which in turn result in ineffective applications of strength and speed of movement, techniques to enhance their development need to be studied.

An effective way to increase strength and speed of movement with nonhandicapped subjects is through resistance exercise. Research has demonstrated that resistance exercise training improves neuromuscular function (Brouha, 1974; DeVries, 1968; Komi, 1979; Moritani & DeVries, 1979; Smith, 1974). Resistance training has resulted in increased strength, improved functional performance in tasks such as running, jumping, and throwing, increased speed of movement, and improved force-time characteristics of muscle contraction (Clarke, 1960; Pipes & Wilmore, 1975; Rasch & Morehouse, 1957; Smith, 1964; Viitasalo & Komi, 1978).

Isokinetic resistance training is made possible by mechanical devices such as the Cybex II, which keep the limb motion in a near constant predetermined velocity. Resistance from the isokinetic device is developed in proportion to the force applied. Thus, increased acceleration is met by increased resistance. A maximal volitional effort is met by maximal resistance throughout the range of motion. More specifically, isokinetic resistance exercise has been found an excellent and safe type of training to increase both strength and speed of movement in reciprocal movement patterns (Halling & Dooley, 1979; Pipes & Wilmore, 1975; Sherman, Pearson, Plyley, Costill, Habansky, & Vogelgesang, 1982). Additionally, measurement with the device used in this study, Cybex II, has been found to be very reliable (Murray, Harrison, & Wood, 1982).

Resistance training is currently being used by athletes with cerebral palsy. Athletes train to compete in weight-lifting, a recent sanctioned event in the Cerebral Palsy Games. However, adherents of certain therapeutic treatment approaches feel that weight-training may be detrimental for individuals with cerebral palsy (Bobath, 1971). The potential detrimental effects include additional increases in resting muscle tone, increased abnormal posturing positions, and decreased range of motion. Studies have demonstrated that subjects with cerebral palsy do show strength gains with systematic resistance exercise (Healy, 1957; Meditch, 1961). However, no studies have examined the effects of systematic resistance exercise on movement function in individuals with cerebral palsy.

Improved motor function can also be achieved with repetitive practice trials with no resistance (Hobart, Kelley, & Bradley, 1975; Kottke, 1980; Payton & Kelley, 1972; Person, 1958). The training results in more efficient muscle activity as evidenced by electromyographic recordings after a series of repetitive practice trials. All of the repetitive practice studies were done with neurologically normal subjects. No such research has been done with individuals with cerebral palsy. The combination of the known neuromuscular problems in cerebral palsy and the demonstrated improvements in neuromuscular performance following repetitive practice with no resistance in noninvolved individuals suggests a need for experimental research in this area.

The present study was designed to evaluate the effects of isokinetic resistance exercise and repetitive movement exercise with no resistance on subjects with cerebral
palsy. Change in movement time (milliseconds) and time rate of torque development were selected as the dependent variables since they demonstrate the key reciprocal relationship between any agonist and antagonist muscle group.

**Methods**

**Subjects**

The subjects used in this experiment were children and adolescents with varying degrees of cerebral palsy, ranging in age from 10 to 20 years; they were matched according to type and severity of cerebral palsy according to the classification system employed by the National Association of Sport for Cerebral Palsy (NASCP). The classification scale developed by the NASCP is used to determine a person’s general functional movement ability. The scale is subdivided into eight classes, with classification being dependent on range of motion, motor control movement ability, and speed of movement. The classification procedure involves the comparison of the functional profile of the subject to the profile described within one of the eight classes. A registered physical therapist and a NASCP-certified classifier administered the scale. Following the classification, the matched experimental subjects were randomly selected to either experimental group. A matched control group was selected to approximate the experimental groups on the basis of the NASCP classification scale (see Table 1).

During the course of the study, each subject continued to participate in regularly scheduled school activities which included physical education, physical therapy, occupational therapy, speech therapy, and typical school classes. Subjects using medication prior to the experiment continued to use the medication recommended by their physician. Any change in antispasmodic medication during the study resulted in deletion of data from the analysis.

<table>
<thead>
<tr>
<th>Class</th>
<th>IR Type</th>
<th>NR Class</th>
<th>Type</th>
<th>Control Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spastic</td>
<td>1</td>
<td>Mixed</td>
<td>Spastic</td>
</tr>
<tr>
<td>2</td>
<td>Spastic</td>
<td>3</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
<tr>
<td>3</td>
<td>Spastic</td>
<td>3</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
<tr>
<td>3</td>
<td>Spastic</td>
<td>3</td>
<td>Spastic</td>
<td>Mixed</td>
</tr>
<tr>
<td>5</td>
<td>Spastic</td>
<td>5</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
<tr>
<td>6</td>
<td>Athetoid-ataxic</td>
<td>5</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
<tr>
<td>6</td>
<td>Spastic-athetoid</td>
<td>6</td>
<td>Athetoid</td>
<td>Spastic</td>
</tr>
<tr>
<td>7</td>
<td>Mixed</td>
<td>7</td>
<td>Spastic</td>
<td>Mixed</td>
</tr>
<tr>
<td>7</td>
<td>Spastic</td>
<td>7</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
<tr>
<td>7</td>
<td>Spastic</td>
<td>8</td>
<td>Spastic</td>
<td>Spastic</td>
</tr>
</tbody>
</table>
Treatments

Two different experimental exercise programs were used in the study: isokinetic exercise (IR) and repetitive movement exercise without resistance (NR). Subjects in the control group (C) continued to follow daily school therapy schedules, received no experimental treatment, and were tested on the same protocol as those in the experimental groups.

The movement used to study the effects of resistance exercise on cerebral palsy was elbow extension. This movement results in the primary isolation of the triceps brachii muscle which acts as an antagonist to the forearm flexors, which are frequently affected in cerebral palsy. Positioning and stabilization to permit isolation of the triceps brachii muscle was achieved by use of a special exercise platform, which had adjustable wooden blocks positioned on either side of the subject’s upper arm to reduce extraneous medial or lateral movement of the elbow (see Figure 1). A velcro strap was used to prevent any anterior-posterior movement of the elbow. The subject’s arm was carefully positioned to ensure horizontal axis alignment with the elbow joint and the accessory arm of the dynamometer.

The subjects in the isokinetic exercise group (IR) were seated next to the exercise platform in either a straight-backed wooden chair, their wheelchair, or a specially designed adjustable chair to accommodate their individual needs for posture and control. Using the dominant arm, each subject performed 3 sets of 10 repetitions per set, 3 days per week for 6 weeks, using a Super Mini-Gym Model 180, Mini Gym, Inc. Each repetition was performed at maximal speed and therefore theoretically at maximal resistance. The maximal speed of the Super Mini-Gym was preset at approximately 90° per second. Each
exercise session was supervised by the primary researcher or a registered physical therapist. The subjects were given verbal encouragement during each session. A charting system was used to document attendance and effort.

The subjects in the repetitive exercise group (NR) followed the identical protocol as the isokinetic exercise group, except that repetitions were performed without resistance. Each subject performed 3 sets of 10 repetitions, 3 days per week for 6 weeks.

Instrumentation and Evaluation

The dependent variables of interest in this study were movement time and rate of torque development. Movement time was tested on three separate sessions. The testing sessions included pretest, interim test, (3 weeks) and posttest (6 weeks). Ten scores were recorded for each testing sequence, with a mean score recorded in milliseconds. The movement time analyzer used to measure time of hand movement during 90° of elbow extension was a modified Automatic Performance Analyzer Model 631 (Dekan Timing Device). Photosensitive switches connected to the analyzer were mounted 90° apart on a specially designed platform signaling the beginning and ending of movement. Each subject’s arm was positioned by the experimenter and then the movement was initiated and completed by each subject.

The rate of torque development of elbow extension was evaluated using the Cybex II Isokinetic System. The instrument works by applying accommodating resistance to the limb equivalent to the muscular force output of the subject. The device applies accommodating resistance when the subject has accelerated to the preset velocity. The Cybex II Isokinetic System was linked with a Cybex II Dual Channel Recorder which simultaneously recorded torque (foot-pounds) and joint position angle. The chart speed of the recorder was preset at 25 mm/second and the position angle degree set on 150°. The rate of torque development was measured during the pretest and again at the posttest following 6 weeks of exercise training. No torque data were recorded on an interim basis, due to a limited availability of testing equipment. The constant velocity was established at 90°/second. The measurements taken were inserted into trigonometric functions to calculate accurately the height of the torque curve at 0.2 seconds. The measurement taken in millimeters was from the initiation of movement to the point on the graph at 0.2 seconds of movement. This height was then converted to ft.-lbs. using the Cybex II grid D in which 1 mm = 3 ft.-lbs.

The subjects were tested in a seated position with seat height adjusted to their requirements. Wheelchair-bound subjects remained in their wheelchairs for testing. The dominant arm was placed on the exercise testing platform and secured with adjustable blocks. The starting position for testing was with the arm and shoulder flexed and secured, with the hand pronated grasping the accessory arm of the dynamometer. Each subject’s elbow was aligned to the horizontal axis of the dynamometer, and the accessory arm adjusted to each subject had a comfortable grasp. Three to five submaximal practice trials were administered to evaluate seat position, arm position, and the subject’s understanding of the object of the task. Three maximal trials were then performed with the highest torque recorded used for the analysis.

Results

The dependent measures of movement time during elbow extension and torque (ft.-lbs.) in 200 ms during elbow extension were measured and analyzed separately. A $3 \times 3$ split
Table 2
Movement Time Cell Means and Standard Deviations for Groups by Time (A x B)

<table>
<thead>
<tr>
<th></th>
<th>B₁ (pre)</th>
<th>B₂ (post₁)</th>
<th>B₃ (post₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IR</strong></td>
<td>Isokinetic treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>0.226</td>
<td>0.163</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.120</td>
<td>0.055</td>
</tr>
<tr>
<td></td>
<td>(N = 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NR</strong></td>
<td>Repetitive treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>0.208</td>
<td>0.172</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.067</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>(N = 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CG</strong></td>
<td>Control group</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>0.202</td>
<td>0.201</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.073</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>(N = 10)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All values are in milliseconds.
p < .05

plot ANOVA with repeated measures on the last factor was used to determine significant F ratios with the movement time data. Analysis of covariance (ANCOVA) covarying on the pretest score was used to analyze the torque data. All calculations were computed using the Statistical Package for Social Sciences (SPSS) (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975).

Movement Time Data

The means of the movement time data (Table 2) show a decrease in movement time for both experimental groups while the control group demonstrated no change. The isokinetically trained group showed a statistically significant change in movement time $F(4, 54) = 4.03$, $p < .05$. Follow-up testing using a Tukey HSD post hoc analysis further showed that significant differences occurred between the pretest and interim test (3 weeks), and between the pretest and posttest (6 weeks) for the isokinetic group (IR) only. The mean and standard deviation values are shown in Table 2.

Time Rate of Torque Development

The time rate of torque development data were collected at the pretest session and again at the end of the 6-week training program (Table 3). The analysis of covariance found significant differences, $f(2, 26) = 11.019$, $p < 0.05$, between the groups. The subsequent Tukey HSD indicated the differences occurred between the isokinetic group (IR) and the other two treatment groups (NR, C). The mean and standard deviation for these values can be found in Table 3.

Discussion

The results of the study indicate that in these subjects with cerebral palsy, significant differences did occur in speed of movement and time rate of torque development in the
Table 3
Means, Standard Deviations, and Analysis of Covariance: Torque Data

<table>
<thead>
<tr>
<th>IR isokinetic treatment</th>
<th>NR repetitive treatment group</th>
<th>CG control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Posttest</td>
<td>Pretest</td>
</tr>
<tr>
<td>n = 10 for all groups</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scores in ft./lbs.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 9.39 | 13.80 | 9.96 | 9.96 | 4.29 | 3.00 |
| 6.87 | 16.77 | 7.56 | 5.28 | 7.59 | 6.87 |
| 14.70 | 16.77 | 6.87 | 6.87 | 0.00 | 0.00 |
| 8.82 | 8.82 | 6.87 | 6.87 | 3.00 | 3.00 |
| 3.00 | 9.96 | 7.56 | 8.82 | 18.60 | 16.60 |
| 6.12 | 8.82 | 4.29 | 3.00 | 9.96 | 9.96 |
| 10.47 | 21.72 | 6.87 | 6.87 | 14.70 | 14.25 |
| 3.00 | 9.39 | 8.22 | 8.22 | 9.96 | 9.39 |

*M 7.74 | 12.30 | 7.38 | 7.59 | 9.18 | 8.70 |

| SD | 3.30 | 4.53 | 1.41 | 2.13 | 5.46 | 5.37 |

n = 10 for all groups

Such neurological adaptation could have occurred in several mechanisms which have particular importance for individuals with cerebral palsy. Synchronization of motor unit recruitment, an important neuromotor mechanism, results from the ability to simultaneously contract a greater number of motor units and thereby increase the production of force. It also affects time rate of force development, resulting in maximal force production in a shorter period of time (Brouha, 1974; Milner-Brown, Stein, & Yemm, 1973; Milner-Brown, Stein, & Lee, 1975). Subjects in this study did exhibit increased production of torque as a function of the training.

Reciprocal inhibition is a key neural mechanism that deals with the relationship of agonist and antagonist muscle. Cerebral palsy disrupts the ratio of excitatory and inhibitory impulses from the afferent nerves, resulting in cocontraction of the agonist and antagonist (Sahrrnann & Norton, 1977). Resistive exercise training has been shown to result in a decrease of cocontraction in elbow flexion and extension in normal subjects (Patton & Mortensen, 1970). Although it was not tested directly in this study, the improved torque and speed of movement would suggest an improved reciprocal inhibition relationship.

The improvement in strength and speed of movement in individuals with cerebral
palsy in the isokinetic resistance group has important implications for training. Although
the repetitive exercise group evidenced an increase in movement speed, it was not signifi-
cant and showed no change after the 3-week testing session. The isokinetic group did show
a significant change in movement speed during the first 3 weeks and continued to improve
from the 3-week to 6-week testing sessions even though the change did not reach statistical
significance during this time period. The findings suggest that the isokinetic training had
a positive facilitative effect on both torque development and speed of movement in a group
with neurological complications specifically involving these abilities. The application of
resistance through the full range of motion, coupled with the emphasis of rate of move-
ment, produced a training effect in individuals with cerebral palsy similar to that found
in exercise programs in nonhandicapped subjects (Henry, 1960; Jorgensen, 1976; Komi,
1979; Pipes & Wilmore, 1975; Smith, 1964).

The findings indicate that individuals in this study made gains similar to a non-
handicapped population group following systematic isokinetic resistance exercise. This
improvement may have important consequences in rehabilitation programs for individuals
with cerebral palsy. Although caution must be used in drawing conclusions from experimen-
tal data with small groups, these data certainly present some interesting implications for
further study on improving functional performance of individuals with cerebral palsy.

Recommendations for further research include: (a) matching the subjects on more
variables (i.e., age, sex, EMG analysis); (b) collection of data over more repeated measures
for both movement time and torque, a limiting factor of this research due to availability
of measuring equipment; (c) collection of data with the aid of microprocessors; (d) varia-
tion of the speed of isokinetic training; and (e) single subject design experiments compar-
ing the effects of isokinetic training on the various types of cerebral palsy.

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