Isotonic Contractions Might Be More Effective Than Isokinetic Contractions in Developing Muscle Strength

Kenneth L Knight, Christopher D Ingersoll, and John Bartholomew

Problem: Isokinetic contractions are thought to be superior to isotonic contractions for developing strength because resistance during them is greater. Because isokinetic resistance is accommodating, however, it decreases with fatigue. It is constant during multiple repetitions, so an aggressive isotonic procedure should produce more force as the muscle fatigues, which would be an advantage in strength development.

Purpose: To compare force production in isokinetic and isotonic muscle contractions at the beginning and end of a set of fatiguing repetitions.

Methods: Subjects performed 25 maximal-effort isokinetic knee extensions at 60°/s. After 25–72 hours, they performed maximal repetitions isotonically using 70% of the isokinetic peak torque with speed set at a maximum of 300°/s.

Results: Peak force during the first 3 repetitions was greater isokinetically, but average force was similar. During the last 3 repetitions, isotonic force was higher than isokinetic force.

Conclusion: Muscle is more active as it nears fatigue during an isotonic contraction. These data support the hypothesis that isotonic contractions recruit extra motor units at the point of fatigue.

Key Words: rehabilitation, neural drive, fatigue


The basic theory of isokinetic strength training has remained virtually unchallenged since its inception in the 1960s, even though most conditioning programs use isotonic equipment. Many have assumed that isotonic equipment is better because it is less costly and more convenient to use with large groups. We suggest, however, that isotonic lifting also provides a greater stimulus for strength development, especially during rehabilitation.

Direct comparisons of strength development using isokinetic and isotonic techniques have been inconclusive. Some authors claim no difference among the techniques, some have favored isokinetics, and others have endorsed isotonics.

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Our clinical experience\textsuperscript{14} and research\textsuperscript{15-17} with the technique of daily adjustable progressive resistive exercise (DAPRE)\textsuperscript{18} has produced strength gains 6–8 times greater than those presented in the literature with either isokinetics\textsuperscript{4,7,9,19-22} or traditional isotonics.\textsuperscript{11-14,23-25} Perhaps the earlier comparisons failed to show the superiority of isotonic training because the isotonic programs they used were not vigorous enough.

The basis of isokinetics is that accommodating resistance provides greater resistance during an individual contraction because it is not limited by the sticking point\textsuperscript{7,26}; that is, a maximal load can be applied at any point throughout the range of motion.\textsuperscript{1,19} Therefore, the assumption has been that isokinetic training will lead to greater strength gains than isotonic training will. During multiple repetitions, however, as the muscle fatigues, isokinetic resistance decreases. With an isotonic contraction, on the other hand, because the resistance is constant, as the muscle fatigues it must either recruit additional motor units or fail to perform the complete repetition. If indeed the body recruits more motor units at the point of fatigue during isotonic training, this would represent a major advantage of isotonic over isokinetic strength training. Greater motor-unit recruitment during fatigue\textsuperscript{27-30} might be more important to developing strength than the greater resistance during early repetitions when the muscle is fresh.\textsuperscript{27}

This experiment was designed to test 1 aspect of this hypothesis, the force-producing capabilities of fresh and fatigued muscle under isotonic and isokinetic conditions.

**Methods**

Our experimental design was a $2 \times 2$ factorial with type of exercise (isotonic and isokinetic) and repetitions (first 3 and last 3) as independent variables. Peak and average force were dependent variables and were calculated by the standard software of the Kinetic Communicator Dynamometer (KinCom) using standard testing protocols, that is, protocols that are used daily to test athletes. The study was approved by the university’s Institutional Review Board.

**Subjects**

Eighteen men from Indiana State University (age = 24.2 ± 4.0 years, ht = 178.8 ± 6.1 cm, wt = 89.3 ± 25.5 kg) who were in good to excellent physical condition volunteered to serve as subjects for this study, and each gave informed consent. The sample included 1 nonathlete, 1 varsity athlete, and 16 recreational athletes. They exercised 51.7 ± 35.1 min/day for 3.2 ± 1.7 days/wk.

**Procedures**
For both testing sessions, subjects’ left thighs were strapped to the Kin-Com bench with Velcro® straps. The leg strap was attached 3 cm above each subject’s ankle joint (medial malleolus). The Kin-Com was then set up and operated according to the manufacturer’s standard procedures. Subjects were allowed to warm up on their own. This included some brief stretching, a few hops or jumping jacks, and a few repetitions of knee extension on the Kin-Com. Our goal was simply to allow the subjects to do whatever they felt they needed to do to prepare for the task. When ready, subjects performed 25 isokinetic repetitions of knee extensions at 60°/sec on a Kin-Com with as much force as they could exert. We computed each subject’s average peak force for the first 3 isokinetic repetitions. After 24–72 hours rest, subjects performed as many isotonic (force-mode) repetitions as possible on the Kin-Com with the speed set at 300°/sec and force set at 70% of their average peak force for their first 3 isokinetic repetitions.

We then computed peak and average force for the first and last 3 isotonic repetitions, the first 3 isokinetic repetitions, and the 3 isokinetic repetitions corresponding to the last 3 isotonic repetitions. For instance, if a subject performed 17 isotonic repetitions, we used the forces generated during repetitions 15–17 of both isotonic and isokinetic modes. We then compared the results from isotonic and isokinetic testing on these 4 variables (beginning and ending peak force and beginning and ending average force).

Statistical Analyses
Our statistical analysis included a multivariate analysis of variance with repeated measures followed by post hoc analyses with univariate F tests (1-way analyses of variance). A probability level of P < .05 was selected for all tests.

Results
Subjects performed 14.9 ± 5.2 repetitions during isotonic testing (Table 1). Overall, there was a significant interaction effect between type of exercise (isotonic vs isokinetic) and repetitions (first 3 vs last 3; $F_{2,16} = 27.3, P < .001$), so the data were interpreted on the basis of the univariate tests.

Isokinetic force decreased with fatigue (21% after 15 repetitions), whereas isokinetic force remained essentially constant after 14 repetitions (Table 1). Isokinetic force was about 8% greater than isotonic force during the first 3 repetitions ($F_{2,16} = 4.7, P = .035$) and 15% less during the last 3 repetitions ($F_{2,16} = 10.4, P = .001$). This was true for both peak force (first 3 repetitions: $F_{1,17} = 6.57, P = .02$; last 3 repetitions: $F_{1,17} = 21.6, P < .001$) and average force (first 3 repetitions: $F_{1,17} = 7.84, P = .01$; last 3 repetitions: $F_{1,17} = 8.41, P = .01$).

Discussion
Our results agree with previous reports that peak torque and work decrease
during repeated isokinetic contractions\textsuperscript{32,33} and that force remains constant during repeated isotonic contractions.\textsuperscript{29} So our hypothesis that muscle force is greater during isotonic than during isokinetic contractions as muscle fatigue nears is supported. We feel that these data are consistent with the hypothesis that during rehabilitation isotonic training is more effective than isokinetic training and that they explain previous results of rapid strength gains\textsuperscript{14-16} during training with the DAPRE technique\textsuperscript{14,18} (Table 2).

The ability to maintain force production as the muscle fatigues represents a major advantage of isotonic strength training and appears to be more important in developing strength than the greater force produced during early repetitions when the muscle is fresh, as with isokinetics.\textsuperscript{27} We are not agreeing with the suggestion that fatigue is the cause of strength development\textsuperscript{34,40} but, rather, suggesting that once enough motor units fatigue that the remaining ones are incapable of lifting the unchanging force, inhibited ones are brought back on-line in order to continue lifting the weight. Consequently, the neural inhibition induced by the injury is reduced and the neural drive begins to return to its preinjury state. This occurs, however, only to the extent that the patient continues repetitions against a fixed force as active motor units fatigue. If the patient stops at the first sign of fatigue, isotonic training has no advantage over isokinetic training. The patient must be strongly encouraged to continue lifting after he or she normally would stop.

With traditional isotonic training, patients perform a set number of repetitions and therefore might not create the conditions (fatigue) wherein additional motor units are recruited. This explains the moderate increases in strength (<2%/day)\textsuperscript{11-14,23-25} with traditional isotonic training, which are considerably less than the 18% to 36% per day\textsuperscript{14-16} with the DAPRE technique.

The DAPRE technique\textsuperscript{14,18} is a prime example of an aggressive isotonic

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### Table 1  Isokinetic and Isotonic Peak and Average Force (mean ± SD)

<table>
<thead>
<tr>
<th>Force</th>
<th>Condition</th>
<th>First 3 repetitions</th>
<th>Last 3 repetitions*</th>
<th>First 3/Last 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak</td>
<td>isokinetic</td>
<td>539.9 ± 112.0</td>
<td>425.7 ± 106.1</td>
<td>79%</td>
</tr>
<tr>
<td></td>
<td>isotonic</td>
<td>503.0 ± 92.3</td>
<td>502.3 ± 106.2</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>isotonic/isokinetic</td>
<td>93%</td>
<td>118%</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>isokinetic</td>
<td>342.9 ± 78.2</td>
<td>269.8 ± 84.4</td>
<td>79%</td>
</tr>
<tr>
<td></td>
<td>isotonic</td>
<td>313.2 ± 63.1</td>
<td>305.1 ± 65.9</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td>isotonic/isokinetic</td>
<td>91%</td>
<td>113%</td>
<td></td>
</tr>
</tbody>
</table>

*Subjects performed 14.9 ± 5.2 repetitions isotonically.
Table 2  Strength Development With the DAPRE Technique

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Training sessions</th>
<th>Days/wk</th>
<th>Subjects*</th>
<th>Exercise</th>
<th>Repetitions</th>
<th>Weight (kg)</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knight/1980</td>
<td>9</td>
<td>3</td>
<td>21 men</td>
<td>knee extension</td>
<td>6.7 ± 1.8</td>
<td>41.4 ± 8.0</td>
<td>230%</td>
</tr>
<tr>
<td>Ingersoll, Knight/1991</td>
<td>9</td>
<td>3</td>
<td>10 women</td>
<td>knee extension</td>
<td>6.2 ± 2.8</td>
<td>32.0 ± 5.5</td>
<td>164%</td>
</tr>
<tr>
<td>Cordova et al/199</td>
<td>15</td>
<td>3</td>
<td>14 women</td>
<td>leg press</td>
<td>111.7 ± 15.1</td>
<td>64%</td>
<td></td>
</tr>
<tr>
<td>Wadey &amp; Knight/1989</td>
<td>20</td>
<td>5</td>
<td>6 men, 6 women</td>
<td>knee extension</td>
<td>87.4 ± 24.9†</td>
<td>54%</td>
<td></td>
</tr>
</tbody>
</table>

*Uninjured college students; except Knight 1980, which included knee/medial collateral and meniscus patients.
†Maximal voluntary isometric contraction tension (ft-lb).
strengthening program. Subjects are encouraged to complete as many repetitions as possible during the third and fourth sets, thus enhancing the possibility of performing repetitions beyond normal fatigue. The athletic trainer or therapist expends great effort to verbally motivate the patient to properly complete repetitions after he or she begins to fatigue. Resistance is adjusted for the fourth set, based on the number of repetitions performed on the third set. The patient again performs maximal repetitions, with encouragement. Thus there are 2 opportunities to “rescue” inhibited motor units, and as a result, recovery of neural drive is optimized.

Our use of 70% of the average peak force during the first 3 isokinetic repetitions for our isotonic lifting was the result of pilot testing. Less than this was not challenging enough to our pilot subjects, whereas they could not lift greater resistance more than 3–4 times.

In this study we only examined changes in force production and interpreted our results in light of related research by others. In order to tie all these concepts together, future research must assess motor-unit recruitment and peak force during isokinetic and aggressive isotonic training.

References

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