Comparison of the Effect of Various Weight Training Loads on Strength

RICHARD A. BERGER
Texas Technological College
Lubbock, Texas

Abstract
Seventy-nine male subjects were used in this study to determine which proportions of maximum strength (1-RM) used in training were as effective for increasing strength as training with the 1-RM. Three groups trained twice weekly with 66, 80, or 90 percent of the 1-RM, plus one weekly effort with the 1-RM. A fourth group trained three times weekly with the 1-RM; a fifth group, with 66 percent of the 1-RM; a sixth group, with the 1-RM only once weekly; and the seventh group acted as a control. After six weeks of training, the group that trained with two-thirds of the 1-RM three times weekly and the control group had mean strength scores which were significantly less than the means of the other groups.

Review of the Literature
Several studies have compared the strength improvement effects of various weight training programs, but training usually required the lifting of loads which were maximum for a designated number of repetitions. Only one study has compared the effectiveness of increasing strength by reducing the loads used in dynamic training so that maximum effort was not elicited every training session. Berger (1) compared two different weight training programs and found that training with 90 percent of the 10-RM (a load which can be lifted correctly ten times only using maximum muscular exertion) for ten repetitions twice a week and with the 10-RM once a week was just as effective for increasing strength as training with the 10-RM for ten repetitions three times weekly. This result was in agreement with the early work of Hettinger and Muller (2) who found that training isometrically with two-thirds of maximum isometric strength or more was just as effective for increasing strength as training maximally. However, a later study by Muller and Rohmert (4) found that training isometrically with maximum contractions every training session was more effective for increasing strength than training with submaximal contractions. Other studies have compared different isometric training programs using various proportions of the 1-RM (a load which can be lifted correctly one time only using maximum muscular exertion), but since the number of sets or bouts performed and the length of contraction time were not controlled in these studies, it was difficult to draw any conclusions regarding only the effects of the resistance loads on strength increases.

Purpose of the Study
No studies have compared several dynamic training programs involving training with different proportions of the 1-RM to determine whether differential strength effects would occur. The purpose of this study was to determine which proportions of maximum dynamic strength used in training were as effective for increasing strength as training with the 1-RM.
Procedure

Seventy-nine male college students enrolled in weight training courses were used as subjects. The ages of subjects ranged from 18 to 23 years and body weights from 118 to 215 lb. Their training involved two different phases which totaled nine weeks. The first training phase was three weeks long and was concerned only with increasing the leg strength of the subjects. This was achieved, as shown by the t of 3.32, significant beyond the .01 level. The same training program was followed by all subjects during the first three weeks. The second training phase of the study last six weeks and began immediately after the first phase. Just prior to the beginning of the second phase, the seven weight training classes were assigned by the use of random numbers to a specific training program. It was administratively impossible to assign subjects randomly to a particular group, but the enrollment of a subject in a particular weight training class was not due to a selective factor which would seriously bias the data. This was indicated by the analysis of variance, which showed that differences in mean strengths between groups were not significant before or after the three weeks of training (F = 1.13 and 1.48, respectively). All subjects were tested for 1-RM deep knee bend before and after each phase.

The deep knee bend was started in a squat position with the upper legs approximately parallel and feet in line, spaced between 12 in. to 15 in. apart. A barbell was placed behind the neck on the shoulders at a height of 42 in. from the floor. The legs were then extended until straight. Subjects were instructed to maintain a straight back throughout the lift. Since the starting height of the barbell was the same for all subjects, the angle of leg flexion at the start of the lift varied among subjects. Taller subjects assumed a lower squat position than shorter subjects and, thus, were generally able to lift less weight. Because of this, the presence of a greater proportion of tall subjects in an experimental group may have biased the results. The analysis of variance, however, showed that this was not a problem since there was no significant difference between experimental groups in mean height (F = .67).

The procedure for the determination of the maximum or 1-RM deep knee bend was similar for all subjects. Five repetitions were first performed with 135 lb., which was relatively light for all subjects. One repetition was then performed with a load that was 20 lb. below the previous 1-RM. After each successful single lift, the load was increased by 10 lb. until the maximum was attained. At least a 2-min. rest was taken between lifts. The only time this test procedure was not followed exactly was at the first testing for 1-RM, when the procedure was the same except that the weight was added to the barbell in larger or smaller increments until a near maximum load was approached. At that point, the load increments again amounted to 10 lbs. after each successful lift.

Two training sessions were given prior to the initial test in order to acquaint the subjects with the correct performance of the test. The first three
weeks of training involved the performance of one set of deep knee bends with a load that permitted six repetitions with maximum muscular exertion (6-RM). Three training sessions were held weekly with at least one day intervening between sessions. The resistance load of 6-RM was always maintained by increasing the load as strength increased.

The seven weight training classes were each assigned to one of the following programs:

Group I \((N = 11)\) performed one repetition with 66 percent of the 1-RM at each of two weekly training sessions. The third training session in the week was used to determine the 1-RM.

Group II \((N = 12)\) performed one repetition with 80 percent of the 1-RM at each of two weekly training sessions. The third training session in the week was used to determine the 1-RM.

Group III \((N = 12)\) performed one repetition with 90 percent of the 1-RM at each of two weekly training sessions. The third training session in the week was used to determine the 1-RM.

Group IV \((N = 10)\) performed one repetition with the 1-RM three times weekly at the training sessions. The new 1-RM was determined once weekly during one of the three sessions. At the other two training sessions, if a subject was unable to perform the 1-RM, slight assistance was given by two spotters to permit the load to be raised with maximum effort.

Group V \((N = 13)\) performed one repetition with 66 percent of the 1-RM at each of three weekly training sessions. The 1-RM was determined at three weeks and at six weeks.

Group VI \((N = 12)\) was trained only once weekly during which time the 1-RM was determined.

Group VII \((N = 9)\) did not perform any leg exercises during this period but was tested for 1-RM before and after six weeks.

**Statistical Analysis**

Significance tests were used to analyze only the data collected during the second training phase of the six-week period. The t test determined whether significant improvement in strength existed within groups during and after six weeks of training. Analysis of variance determined whether the mean changes in strength between groups at various weeks of training were significantly different. The data used for the analysis of variance were the differences between strength scores at the beginning of the six-weeks period and the scores after one week, two weeks, three weeks, four weeks, five weeks and six weeks of training. Groups V and VII were not included in the analysis of variance tests at weeks one, two, four, and five since they were not tested for 1-RM at those times.

**Results and Discussion**

The results of the t test within groups are presented in Table 1. The numbers recorded under the weeks of training refer to mean differences in strength from the beginning of the six-week training period up to each week of training. Groups I, II, IV, and VI increased significantly after all weeks of training. Group III did not show a significant increase in strength after
TABLE 1.—STRENGTH CHANGES WITHIN GROUPS

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>8.19*</td>
<td>14.54*</td>
<td>28.18*</td>
<td>24.45*</td>
<td>45.00*</td>
<td>39.09*</td>
</tr>
<tr>
<td>II</td>
<td>10.44*</td>
<td>20.43*</td>
<td>17.16*</td>
<td>19.61*</td>
<td>27.17*</td>
<td>34.64*</td>
</tr>
<tr>
<td>III</td>
<td>.41</td>
<td>10.83*</td>
<td>15.83*</td>
<td>17.50*</td>
<td>25.83*</td>
<td>27.50*</td>
</tr>
<tr>
<td>IV</td>
<td>8.50*</td>
<td>12.00*</td>
<td>16.00*</td>
<td>23.00*</td>
<td>27.00*</td>
<td>33.00*</td>
</tr>
<tr>
<td>V</td>
<td>5.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>6.66b</td>
<td>11.66b</td>
<td>10.00b</td>
<td>15.95*</td>
<td>20.00*</td>
<td>23.33*</td>
</tr>
<tr>
<td>VII</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-3.33</td>
</tr>
</tbody>
</table>

* Significant beyond the .01 level. b Significant beyond the .05 level.

one week of training, but did at each of the following weeks. Groups V and VII did not change significantly in strength after six weeks.

Significant increases in strength were expected in Group I, II, III, and IV. Muller (3), Rarick (5), and Taylor (7) concluded from isometric studies that training with two-thirds of maximum strength was effective for increasing strength. Berger (1) found that training with loads of 90 percent of the 10-RM for ten repetitions increased strength as significantly as training with the 10-RM. There was no evidence, however, that training dynamically once weekly with maximum effort, as was done by Group VI, would result in a significant increase in strength. Rose (6) found that in adult males who had reached a strength plateau, strength was maintained but not increased with a maximum isometric contraction once weekly for four weeks, once every two weeks for eight weeks, and once every month for sixteen weeks.

Analysis of variance disclosed that highly significant differences existed between group means after six weeks ($F = 6.64, P < .01$), but not at weeks one, two, three, four, or five. The $t$ test disclosed that at six weeks the only groups that differed significantly from all others in strength improvement were Groups V (66 percent of 1-RM) and VII (control). This was expected because of the insignificant change in dynamic strength recorded by these groups after six weeks of training.

Since Groups I, II, III, IV, and VI did not differ significantly from each other at six weeks, training once weekly with the 1-RM was considered as effective for increasing strength as either training twice weekly with various
proportions of the 1-RM, and once a week with the 1-RM, or three times weekly with the 1-RM. However, it can be seen from Table 1 that from the second week to the sixth week, Group VI increased less in strength than Groups I, II, III, and IV. A longer training period may have resulted in significantly greater improvement in Groups I, II, III, and IV than in Group VI.

Training with two-thirds of the 1-RM, three times weekly, without a weekly maximum effort, will not increase strength and may not be any more effective for maintaining strength than no training. This was shown by insignificant differences in strength improvement within and between Groups V and VII.

The results of this study were in agreement with the results obtained by Hettinger and Muller (2). These investigators concluded that training with two-thirds of maximum isometric strength or more, five days weekly, and the sixth day with maximum strength, was just as effective for increasing strength as training with maximum strength six days weekly. This conclusion was verified in the present study by the insignificant differences between Group I (66 percent MW, 1-RM F), II (80 percent MW, 1-RM F), III (90 percent MW, 1-RM F), and IV (1-RM MWF) in strength improvement at six weeks of training. In the study by Hettinger and Muller, emphasis was placed on the effects of various proportions of maximum strength in increasing strength without due consideration of the improvement in strength resulting from the one weekly maximum effort. The possibility existed that the one weekly maximum isometric contraction was more effective for increasing strength than the training with a proportion of maximum strength. Also, training with one weekly maximum effort may have been just as effective for increasing strength as training five days weekly with two-thirds or more of maximum strength plus one weekly maximum contraction. These possibilities were investigated in the present study. The highly significant difference between the means in Group V (66 percent of 1-RM) and Group VI (1-RM F) amounting to 21.03 lb., indicated that in a training program involving a contraction with two thirds of maximum twice weekly plus a weekly contraction with maximum effort, the greatest stimulus to strength improvement was due to the maximum effort. Further insight was gained from comparing a training program combining a twice weekly effort with two-thirds of maximum plus a once weekly maximum (Group I) effort with a training program involving only one maximum effort weekly (Group VI). The mean difference between these groups, although insignificant, was 15.76 lb. in favor of Group I (66 percent MW, 1-RM F). A continuation of this study beyond six weeks may have resulted in a significant mean difference between these groups. This was indicated by the smaller rate of strength increase in Group VI (1-RM F) than in Group I from the second week. The combination of training with two-thirds or more of maximum with a weekly maximum effort appeared to produce an interacting effect which resulted in a greater improvement in strength than the additive strength effects produced by a program of two-thirds of 1-RM three times weekly (Group V) and the 1-RM once weekly (Group VI).
The results of this study, which showed that training with two-thirds of maximum or more plus one weekly maximum effort (Groups I, II, and III) was just as effective for increasing strength as training maximally three times weekly (Group IV), contradicted the results found by Muller and Rohmert (4). They concluded that training maximally six days weekly was more effective for increasing strength than training with two-thirds or more of maximum strength five days weekly and maximally one day weekly. Their conclusion also contradicted Hettinger and Muller (2) who found that training with two-thirds of maximum strength five days weekly and one maximum effort weekly will increase strength as rapidly as training with maximum strength every day.

The comparison between the results of the present study and the results of the studies by Hettinger and Muller (2) and Muller and Rohmert was not entirely valid since isometric training was employed in one study and isometric training in the other two. The number of training sessions also varied. The present study involved training three times weekly while the other studies involved training six times weekly.

Conclusions

The following conclusions were drawn from the results of this study:

1. Significant increases in strength will occur after two weeks of training twice weekly with two-thirds or more of the 1-RM, provided at least one maximum dynamic effort per week is performed on the third weekly training session.

2. Training with two-thirds of the 1-RM for one set, three times weekly, will not increase strength in six weeks.

3. Dynamic strength will not be reduced in six weeks of no training.

4. The increase in strength resulting from a training program of one set with two-thirds of the 1-RM, twice weekly, and the 1-RM once weekly, is due primarily to the training with the 1-RM.

References


(Submitted January 23, 1964)