Relationship Between Repetitions and Selected Percentages of the One Repetition Maximum in Healthy Children

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The purpose of this study was to evaluate the relationship between repetitions and selected percentages of the one repetition maximum (RM) in apparently healthy children. The 1 RM strength was measured on 13 boys and eight girls (mean age 10.4 ± 1.2 years) on the Heartline chest press and the Nautilus leg press exercises. Subsequently, subjects were tested to determine the maximum number of repetitions that could be performed to volitional fatigue at 50% and 75% of their 1 RM for each exercise. The results for the trials on the leg press and chest press indicate that at 50% 1 RM, the subjects performed 87.2 ± 56.5 and 39.2 ± 19.4 repetitions, respectively, whereas at 75% 1 RM, the subjects performed 18.2 ± 11.0 and 13.4 ± 4.3 repetitions, respectively. As the percent 1 RM increased, it is not surprising that the number of repetitions performed significantly decreased (p < 0.05). However, the number of repetitions performed at 50% 1 RM on the leg press was significantly greater (p < 0.05) than at the same intensity on the chest press, suggesting that the number of repetitions performed at a given intensity may not be same for all exercises. Although additional study is warranted, these findings suggest that progressive resistive strengthening programs should be prescribed with a RM load as opposed to a percentage of the 1 RM.


Progressive resistive strengthening has been used as a treatment technique for children with neuromuscular disorders for many years,¹ and now an increasing number of apparently healthy children are participating in muscle strengthening activities.² Although strength training was previously deemed unsafe and inappropriate for children, youth strength training is now recognized as a safe and effective method of conditioning for children providing that appropriate training guidelines are followed and qualified supervision is present.³ A majority of the scientific research indicates that children can increase their muscular strength above and beyond growth and maturation, if the strength training program is of sufficient duration and intensity.³,⁴ Furthermore, youth strength training programs may favorably influence selected motor performance skills and preliminary evidence suggests that youth strength training may enhance sports performance and decrease the risk of injury.³,⁵

The development of progressive resistive strengthening programs for children requires the consideration of several factors, including the number of repetitions, number of sets, and frequency of training. For the child interested in enhancing muscular strength, a training regimen that requires a minimum of a single set of six to 15 repetitions performed two to three times per week is recommended.³ Although an intensity of at least 60% 1 RM seems necessary to stimulate strength gains in most adults,⁶ the minimal threshold required to stimulate strength development in children is undefined. Furthermore, the relationship between repetitions and selected percentages of the 1 RM remains unexplored in apparently healthy children.

Hoeger et al⁷,⁸ examined this relationship in adults and concluded that the number of repetitions that could be performed at a given percentage of the 1 RM was specific for a given exercise. For example, at 60% 1 RM adults performed an average of 34 repetitions on the leg press, whereas the average number of repetitions on the leg curl, in comparison, was 11.⁷ These researchers demonstrated that a given number of repetitions may not always be associated with a particular percentage of the 1 RM. Thus, the minimal strength threshold, when
expressed as a percent of the 1 RM, may vary among muscle
groups. This information is useful not only for the development
of recreational strength training programs, but also for the
rehabilitation of musculoskeletal injuries. The aforementioned
findings, however, are based on adults and, therefore, should
not be generalized to younger populations. Thus, the purpose
of this study was to determine the relationship between repet-
tions and selected percentages of the 1 RM (50% and 75%) in
children.

METHODS

Subjects

Twenty-one apparently healthy subjects (13 boys and
eight girls) between the ages of eight and 12 years volunteered
to participate in this study. Boys and girls were combined
because measures of muscular strength and the rate of strength
development during preadolescence are fairly similar between
sexes. Subjects and their parents were informed about the
benefits and risks associated with this study, and parental
written consent was obtained. All subjects received a medical
examination to evaluate their musculoskeletal status, docu-
ment preexisting orthopedic injuries, and assess maturity level
based on Tanner staging. No orthopedic limitations or con-
traindications for strength testing or training were present, and
all subjects were at Tanner stage 2. All volunteers were ac-
cepted for participation. No subjects had any prior experience
with strength training nor did any subject participate in any
other form of strength training during the study period. How-
ever, all of the subjects participated in recreational physical
activities, and 15 of the subjects were regularly involved in at
least one sport (soccer, softball, hockey, or basketball). De-
scriptive characteristics of the subjects are presented in Table

Testing Procedures

All subjects participated in two introductory sessions
within a one-week period for practice and orientation. During
this time, the subjects were taught how to perform the chest
press (Heartline Fitness Equipment, Gaithersburg, Md) and leg
press (Nautilus International, Independence, Va) exercises
with proper form and technique. The Heartline chest press is a
child-size machine, and the Nautilus leg press is an adult-size
machine. Because of the linear nature of the leg press machine
and the adjustability of the leg press seat, all children comfort-
ably fit into this piece of equipment and were able to properly
execute the desired motion.

The order of testing, chest press first then leg press or leg
press first then chest press, was randomized and balanced
among subjects. Before all testing procedures, subjects partici-
pated in a general warm-up period that consisted of 10 min-
utes of low-intensity aerobic exercise and stretching. Before
attempting a 1 RM, subjects performed six repetitions with a
relatively light load, then three to four repetitions with a
heavier load, and finally a single repetition with 95% of their
predicted 1 RM. Subjects then attempted a single repetition
with the perceived 1 RM load. If this weight was lifted with the
proper form, the weight was increased by approximately one
to four kg, and the subject attempted another repetition. The
increments in weight were dependent upon the effort required
for the lift and became progressively smaller as the subject
reached the 1 RM. Subjects rested at least two minutes be-
tween all 1 RM trials. A minimum of 48 hours later, a second
1 RM test was performed on the same exercise and the values
were used to determine the reliability of the 1 RM test.
Throughout all testing procedures, an instructor to subject ratio
of 1:1 was maintained. The heaviest 1 RM load lifted on either
testing day was recorded as the child’s criterion value of
maximum strength. The 1 RM was typically determined within
two to three trials during the second test. After the completion of both 1 RM
trials, the testing procedures were repeated on either the chest
press or leg press exercise.

Before each repetition, subjects performed a general
warm-up followed by one set of six repetitions with approxi-
mately 25% of their predetermined 1 RM. The subjects then
performed as many repetitions as possible at 50% of their 1 RM
on either the chest press or leg press exercise. The order of
testing for the repetition trials was also randomized and bal-
amed among subjects. At least 48 hours of rest separated all
tests. Strict form was required for the repetition to be accepted,
and the last repetition represented momentary muscular fa-
tigue. These procedures were then repeated on the chest press
and leg press exercises, whereby the subjects performed as
many repetitions as possible with 75% of their 1 RM measure.
The total number of repetitions performed on the chest press
and leg press at 50% and 75% 1 RM were collected over a period of
six weeks to minimize the risk of an overuse injury and max-
imize enjoyment for the subjects. No injuries occurred during the
study period.

Statistical Analyses

Intraclass correlation coefficients (ICC) were used to de-
termine reliability of the 1 RM chest press and 1 RM leg press
tests. Standard deviations and standard errors of measurement
(SEM) were also determined for these measurements. For the
main study, repetitions performed at 50% and 75% of the 1
RM on the chest press and leg press exercises were compared
using a repeated measures analysis of variance (ANOVA).
When significant differences were found, a Bonferroni post-
hoc test was used to determine differences among groups. The
alpha level was set at p = 0.05 and data are reported as group
means ± standard deviation. The analyses were carried out
using the SPSS Statistical Package (SPSS, Inc. Chicago, Ill).

RESULTS

The ICCs, SD, and SEM values are listed in Table 2. The
ICCs were high (0.93 - 0.98) indicating good measurement
reliability for the 1 RM chest press and leg press tests. The
weights lifted during the first and second 1 RM trials on the
chest press and leg press tests are outlined in Table 3. The
results for the repetition trials on the leg press and chest press
exercises indicate that at 50% 1 RM the subjects performed
87.2 ± 56.5 and 39.2 ± 19.4 repetitions, respectively,
whereas at 75% 1 RM, the subjects performed 18.2 ± 11.0 and

Table 1

| Boys (N) | 13 |
| Girls (N) | 8 |
| Age (year) | 10.4 ± 1.2 |
| Stature (cm) | 133.8 ± 13.6 |
| Weight (kg) | 46.4 ± 14.2 |

Table 2

<table>
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<th>Variable</th>
<th>ICC</th>
<th>SD</th>
<th>SEM</th>
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<td>-.98</td>
<td>.93 kg</td>
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CONCLUSION

The range of repetitions performed by the subjects in this study at selected percentages of the 1 RM is noteworthy. At 50% 1 RM the scores ranged from 16 to 200 and at 75% 1 RM the scores ranged from 6 to 43. These findings are consistent with Westcott and Baechle who reported a wide distribution of repetitions completed by adults at 75% 1 RM. Furthermore, Sale reported a large intersubject variability (particularly at lighter loads) in young adult men on the leg press and bench press exercises. The intersubject variability in our study may be related to several factors including genetics or nonheireditary factors such as previous sport experiences or nutrition that may have increased the activity of certain key enzymes or muscle substrate levels. It is also possible that the number of repetitions performed could be related to each child's ability or desire to work through his or her so-called “comfort zone.” Children who have a high motivation to compete may be able to exercise at a higher level and withstand the discomfort associated with muscular fatigue for a longer period of time. It is important to consider that in our study all 1 RM tests and repetition trials were performed on the same chest press and leg press exercise. Therefore, our findings are not confounded by a lack of testing specificity. However, 1 RM testing on the leg press exercise was challenging for some of our subjects because of the starting position. It was difficult for some children to start the weight moving because of the initial inertia they had to overcome while performing this exercise with the proper technique. Although our results indicate that the subjects lifted about 1.8 times body weight on the leg press exercise (mean weight lifted was 83.6 kg), it is possible that our 1 RM leg press scores underestimated their true 1 RM strength. Thus, the repetitions performed on the leg press exercise at 50% and 75% 1 RM may actually have been performed at a lower percentage of the 1 RM.

DISCUSSION

An important finding from this investigation was that the number of repetitions performed by prepubescent boys and girls at a relatively low intensity (50% 1 RM) were not the same for the chest press and the leg press exercises. On the basis of this finding, it cannot be assumed that a given number of repetitions is always associated with the same percentage of the 1 RM. To our knowledge, no other study has investigated the dynamics of the relationship between repetitions and selected percentages of the 1 RM in children. The tendency for a child to perform more repetitions at a given intensity on an exercise which requires a relatively large amount of muscle mass is consistent, however, with results from adult studies.

Our results suggest that a 10 RM, for example, may not always be associated with 60% of the 1 RM. In fact, preliminary findings from our lab demonstrate that at 62% 1 RM children could perform approximately 21 repetitions on the chest press and 39 repetitions on the leg press (unpublished observations). Thus, if a child strength trained at 60% 1 RM, it seems that the emphasis of the program would be on increasing local muscular endurance rather than muscular strength. Furthermore, in the present investigation, the subjects performed 13.4 repetitions at 75% 1 RM on the chest press exercise, whereas Westcott and Baechle by comparison, reported that adults performed 10.5 repetitions on the same exercise at the same percentage of the 1 RM. Whereas a repetition range of eight to 12 has been suggested for adults, it seems that this prescription may need to be modified for younger populations.

Although speculative, it is possible that the minimal threshold—when expressed as a percentage of the 1 RM—may vary from one muscle or muscle group to the next, possibly related to the amount of muscle mass involved with each exercise. On the basis of this information, it seems that the prediction of the 1 RM in children from the number of repetitions performed on a given exercise may be difficult (at least at low intensities). Moreover, inasmuch as children are able to perform more repetitions at a relatively low intensity on a lower limb exercise, a strength training prescription would require that children perform a greater number of repetitions on the lower limb exercise than on the upper limb exercise. As previously suggested by Sale, it seems that the easiest method to prescribe a training load for children may be to first establish the repetition range (eg, eight to 12 repetitions) and then by trial and error determine the maximal resistance that can be handled for the prescribed range.

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REFERENCES


