Effects of Two Different Strength Training Modes on Motor Performance in Children

Sean P. Flanagan, Lloyd L. Laubach, George M. De Marco, Jr., Cesar Alvarez, Scott Borchers, Emily Dressman, Claire Gorka, Mary Lauer, Andy McKelvy, Melissa Metzler, Jodie Poeppelman, Carrie Redmond, Mike Riggenbach, Sarah Tichar, Kellie Wallis, and Dawn Weseli

Keywords: adaptation window, body weight training, machine weight training, weight training

For many years, strength training for children was considered ineffective due to insufficient levels of androgens and unsafe due to potential damage to the epiphyseal growth plate. However, current research suggests that children can safely make significant gains in strength, with additional motor performance, health-related, and psychosocial benefits (Faigenbaum, 1995; National Strength and Conditioning Association [NSCA], 1996). As a result, the American Academy of Pediatrics (1990) and the NSCA (1996) proposed that children could safely perform strength training, provided the program was appropriately planned and supervised. In fact, the Surgeon General’s Report on Physical Activity and Health (U.S. Department of Health and Human Services, 1996) also encouraged children ages 6 years and older to enhance and maintain muscular strength and muscular endurance.

Research has shown that children can gain and maintain muscular strength using a wide variety of methods. Strength gains have been reported using both adult- and child-sized weight machines, free weights (Ozmun, Mikesky, & Surburg, 1994), hydraulic machines (Weltman et al., 1986), pneumatic machines, isometric contractions, wrestling drills, modified pull-ups, and calisthenics (Duda, 1986; Faigenbaum, 1993; Faigenbaum et al., 1996). This research supports the notion that children can increase strength using a variety of methods.

Additionally, it is believed that improvements in the neuromuscular system, and not hypertrophy of the contractile proteins in skeletal muscle fiber, are primarily responsible for the strength gains in children (Ramsay et al., 1990; Ozmun et al., 1994). Because most of the children’s strength studies have not shown a corresponding increase in fat-free mass with an increase in strength, it is believed that increased motor unit activation, coordination, recruitment, and firing rate are all responsible for increased strength (Ramsay et al., 1990; Ozmun et al., 1994; NSCA, 1996). Therefore, specificity of training may play an extremely important role here.

However, despite findings indicating increases in strength (Payne, Johnson, Morrow, & Dalton, 1997), improvements in performing selected motor tasks have remained more difficult to demonstrate. One study reported no change in the vertical jump (Faigenbaum et al., 1996), whereas another reported an increase in the standing long and vertical jumps (Duda, 1986), and a third reported an increase in the vertical jump with no change in the standing long jump (Weltman et al., 1986). These results may have been due to differences in training modes, duration, load, or quality of instruction. Due to the specific nature of neuromuscular coordination, it may be that children using machine weight-training exercises may not experience a positive carryover effect on performance tasks where the external load is minimal (e.g., running, jumping, and throwing). Therefore, it is our hypothesis that training children to move their own bodies in increasingly complex ways may be as, or even more, beneficial to improving certain performance tasks than training with machine weight training.
There were two purposes to this study. The first was to determine the effect of strength training on children’s ability to run, jump, and throw. The second was to determine the effects of different strength training modes on the actual performance outcomes of the participants.

Method

Participants

The participants were 58 third-grade students of whom 28 were boys and 30 were girls. None of the participants had previous experience with strength training. Consent was obtained from participants, parents or guardians, and school administrators for participation in accordance with institutional review board procedures. Participants were assigned to one of three groups based on their availability.

The first group \( (n = 14) \) was the Machine-Trained Group. Means and standard deviations for their age, height, and weight were as follows: \( M_{age} = 8.75 \) years, \( SD = 0.46 \); \( M_{height} = 136.37 \) cm, \( SD = 4.39 \); \( M_{weight} = 37.44 \) kg, \( SD = 7.06 \). At a local fitness center the Machine-Trained Group used child-size, plate-loaded weight machines (FUTURE FORCE®, Lincoln, NE). This group was recruited using flyers posted at the facility and word of mouth; they trained after school hours.

The second group \( (n = 24) \), the Body Weight-Trained Group, used their body weight as resistance and increased the complexity of the exercise as overload. Means and standard deviations for their age, height, and weight were as follows: \( M_{age} = 8.64 \) years, \( SD = 0.49 \); \( M_{height} = 136.02 \) cm, \( SD = 6.68 \); \( M_{weight} = 32.42 \) kg, \( SD = 8.64 \). The Body Weight-Trained Group participated in the study as part of their regular school physical education program.

The third group \( (n = 20) \), the Control Group, received no treatment. Means and standard deviations for their age, height, and weight were as follows: \( M_{age} = 8.65 \) years, \( SD = 0.49 \); \( M_{height} = 132.15 \) cm, \( SD = 6.58 \); \( M_{weight} = 32.54 \) kg, \( SD = 10.95 \). The Control Group also participated in the study as part of their regular school physical education program, comprising cardiovascular and motor-sport skill units. None of the control participants were permitted to maintain their normal daily activities, including participation in various youth sports (e.g., soccer, football, basketball, and gymnastics).

All training sessions were under the direction of a Certified Strength and Conditioning Specialist (NSCA, 1996) and were supervised by undergraduate students in the exercise science major. The instructor-to-participant ratio was 1:3 for the Machine-Trained Group and 1:5 for the Body Weight-Trained Group.

Training

For purposes of efficiency in training, students in the Machine-Trained Group were divided into three separate groups and trained on Tuesdays and Thursdays. All three groups performed the following exercises twice a week: (a) squat, (b) bench press, (c) pull-down, (d) military press, (e) biceps curls, (e) hammer curls, (f) triceps press-downs, and (g) curl-ups. The prescribed speed of training for the Machine-Trained Group was a 1:2 cadence. Resistance was increased based on the guidelines established by Faigenbaum (1993). During Weeks 1 through 3, participants performed one set of 10–15 repetitions each. During Weeks 4 through 8, participants performed two sets of 10–15 repetitions each. All loads were determined, tracked, and controlled by the adult instructor. During Weeks 8 through 10, participants performed three sets of 8–12 repetitions each. The initial load was determined during the initial training session by trial and error until the participants could lift a given load with volitional fatigue within the prescribed repetition range. All exercises were performed for the same number of sets, and a set ended with volitional fatigue. Participants rested approximately 1 min between sets. During each of the three training phases, the workload (i.e., the amount of weight lifted) was increased by 5 lb (2.27 kg) once participants were able to perform the upper limit of repetitions (i.e., 12–15) with proper form. Proper form was closely monitored to ensure that participants were safely overloaded. Increases in training load were restricted to 5-lb (2.27-kg) increments due to limitations posed by the FUTURE FORCE® equipment used during the study.

The Body Weight-Trained Group also trained 2 days per week (i.e., Mondays and Wednesdays). Participants performed the exercises using their own body weight as the resistance. The exercises were performed according to the protocols described in Table 1. The participants’ speed of training was not controlled. Interested readers are directed to Virgilio (1997) for more complete descriptions. These exercises were chosen to correspond with and target the same body parts as those in the Machine-Trained Group. For instance, both push-ups and bench press target the pectoralis major, anterior deltoid, and triceps. Both inchworm and hamstring curls target the hamstrings. These exercises were augmented with parachute drills that used air resistance. These drills require several children working together to perform locomotor movements, shape formations, and exercises that use the air captured by the parachute as resistance (Virgilio, 1997).

Instead of increasing exercise resistance, the exercises were modified to require greater muscular coordination and control over the participant’s own body weight. Due to the wide variation in the ability to perform certain exercises, participants varied in the number
of repetitions and sets performed. Their rest periods were also approximately 1 min between sets. Because the load, volume, and contraction speed differed between the two experimental groups, training time was standardized to 40 min per workout for both groups. As indicated, the Control Group participated in the study as part of their regular physical education program and met for 40-min class sessions on Mondays and Wednesdays.

**Testing**

All three groups were tested prior to the beginning of training (Week 0) and on completing the training period (Week 11). Participants within a group were tested in a round robin fashion and provided three attempts (Safrit, 1995). Each participant had approximately 10 min of rest in between each activity. The performance measures are described below.

**Two-Handed Medicine Ball Put.** Participants sat on the ground and attempted to put a 1-kg ball as far as possible from the center of the chest using both hands. Distance was measured to the nearest .5 cm.

**Standing Long Jump.** The participants stood behind a line with their feet apart, knees bent, and swung the arms back and forth to prepare for the jump. The participants then jumped forward, landing on one or both feet. Distance was measured to the nearest .5 cm.

**Shuttle Run.** Participants began at a starting line and ran 30 feet (9.14 m), where they picked up a block of wood and returned it to the starting line. Participants then ran back to the 30-foot (9.14-m) mark, picked up a second block of wood, and returned to cross the starting line. Time was measured to the nearest .001 s.

**Data Analysis**

Data were analyzed via a 3 x 2 (Group x Time) analysis of variance with repeated measures on the second factor. STATISTICA for Windows software was used to process the data. The independent variables were treatment (independent group with three levels: Machine-Trained Group, Body Weight-Trained Group, and Control Group) and time (dependent group with two levels, pre- and posttesting), and the dependent variables were the sit-

<table>
<thead>
<tr>
<th>Table 1. Description of select exercises for the body weight group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exercise</strong></td>
</tr>
<tr>
<td>Sea crawl</td>
</tr>
<tr>
<td>Crab crawl</td>
</tr>
<tr>
<td>Turtle walk</td>
</tr>
<tr>
<td>Inch worm</td>
</tr>
<tr>
<td>Treadmill</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Results of children's performance on the medicine ball put, long jump, and shuttle run</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skill</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Medicine ball put (cm)</td>
</tr>
<tr>
<td>Long jump (cm)</td>
</tr>
<tr>
<td>Shuttle run (s)</td>
</tr>
</tbody>
</table>

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
ting medicine ball put in centimeters, standing long jump in centimeters, and agility run in seconds. Scheffe’s post hoc analysis was used for means comparisons. An alpha level of .05 was used for all statistical tests.

To qualify for inclusion in the study, participants were required to attend a minimum of 90% (18 of 20) training sessions and both testing sessions. Consequently, data from only 8 of the Machine-Trained Group and 22 of the Body Weight-Trained Group were included in the final analysis. Scheduling conflicts among members in the Machine-Trained Group were the primary causes of dropout. The Body Weight-Trained Group comprised children from an intact, ongoing physical education class from which 2 members transferred to other schools. Boys and girls were combined within the same group, because they showed a similar rate of increase in muscle strength during the prepubertal years (Ozmun et al., 1994).

**Results**

Results are explicated in Tables 2 and 3. For the medicine ball put, there were significant main effects for both group, \( F(2, 47) = 29.25, p < .001 \), and time, \( F(1, 47) = 30.25, p < .001 \), with a significant interaction \( F(2, 47) = 6.87, p = .004 \). Scheffe post hoc analysis revealed that both experimental groups performed significantly better than the Control Group on both pre- and posttests, and the Machine-Trained Group performed significantly better than the Body Weight-Trained group on the pretest. However, the Body Weight-Trained Group was the only group to significantly improve between pre- and posttests, and they performed significantly better than the other two groups on the posttest.

Results of the long jump tests indicated main effects for both groups, \( F(2, 47) = 10.55, p = .002 \), and time, \( F(1, 47) = 10.69, p = .002 \), with no significant interaction, \( F(2, 47) = 1.76, p = .184 \). Scheffe post hoc analysis revealed that both experimental groups performed significantly better than the Control Group on both pre-

and posttests, and there was no significant difference between the two experimental groups on either test.

For the shuttle run, results indicate significant effects for group, \( F(2, 47) = 3.83, p = .028 \), and time, \( F(1, 47) = 19.56, p < .001 \), with no significant interaction, \( F(2, 47) = .25, p = .78 \). Scheffe post hoc analysis revealed that both experimental groups performed significantly better than the control group on both pre- and posttests, and the Machine-Trained Group performed significantly better than the Body Weight-Trained Group. There was no significant difference between the two experimental groups.

**Discussion**

Several implications can be drawn from these results. First, while the Machine-Trained Group displayed superior performance over controls and, in some cases, the Body Weight Group, they did not show significant improvement on any performance measure tested. This result might suggest that trained children, like adults (Fleck & Kraemer, 1997), possess a smaller adaptational window with higher levels of fitness. Therefore, a different training protocol may have been needed to generate significant performance gains. Alternatively, machine-based training may not provide a specific stimulus that will carry over to performance measures.

Second, while the Body Weight-Trained Group showed significant improvement in the medicine ball put, they did not show significant improvement in the long jump and shuttle run. Because the legs possess larger muscle mass due to developmental factors and are used more often in daily living activities, they may require a greater overload stimulus than the upper body (Stone & O’Bryant, 1987). The results might suggest that the exercises selected, while providing a sufficient overload stimulus to the upper body, failed to stress children’s lower bodies above what they encounter as part of their daily activities. Correspondingly, we speculate that a different protocol, one in which the movements were more specific to running, jumping, and throwing but with a greater amount of resistance, may provide optimal results. These protocols may involve weight vests, dumbbells, explosive lifts, or a combination of all three. Such protocols may also provide a means of strength training children who are too weak to perform even a basic movement such as a push-up.

Finally, this study has shown that children can safely engage in strength training when a program is properly designed and supervised; none of the participants missed a training day due to an injury occurring as a result of this study. Additionally, none of the students withdrew from participating because of an injury. These

<p>| Table 3. Within group pre-post differences in children’s performance in terms of percentage |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Machine trained</th>
<th>Body weight</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medicine ball put</td>
<td>4.0</td>
<td>12.0*</td>
<td>4.0</td>
</tr>
<tr>
<td>Long jump</td>
<td>9.0</td>
<td>4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Shuttle run</td>
<td>2.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*p < .05.
findings endorse those reported in other children’s strength training studies, which revealed that participation is possible with a minimum risk of injury.

The results of this study also hold several implications for future research. First, to negate problems caused by groups with elevated performances, this experiment should be repeated with groups that perform more similarly on the pretests. Second, the duration of the study should be longer. Ten weeks may not be sufficient to realize improvements in performance. Additional training time may have led to greater increases in performance in either or both the Machine-Trained Group and Body Weight-Trained Group. Third, it would be interesting to see the effect of training with dumbbells as another experimental group. This type of training could provide a greater overload than the Body Weight-Trained Group and a greater neuromuscular demand than the Machine-Trained Group and may lead to superior performance than what was seen in either experimental group in this study.

This study has shown that children can safely and effectively engage in strength training. The results support the notion that the size of the adaptation window for trained children, specificity of training, and overload are as equally valid for children as they are for adults. Further research, with a longer duration, different training protocols, control for randomization, and groups of similar fitness levels, could provide additional information on this subject.

References


Authors’ Note

The authors would like to thank the reviewers for their constructive criticism throughout the review process. This study was supported from a grant provided by the University of Dayton School of Education and Allied Professions. The authors wish to acknowledge Toni Moore, Andrea Benge, Mark Dahm, and Sheri Moro for their cooperation in this study. Please address all correspondence concerning this article to Lloyd L. Laubach, University of Dayton, Department of Health and Sport Science, 500 College Park, Dayton, OH 45469-1210.

E-mail: Laubach@udayton.edu