Comparison of Isometric Test Procedures to Assess Muscular Strength in Elementary School Girls

Frank E. Seagraves and Michael Horvat

The purpose of this investigation was to compare isometric test procedures (make vs. break tests by muscle groups) with elementary school girls, ages 9–11, using hand-held dynamometry. Fifty subjects in Grades 3 and 4 performed three trials on four muscle groups using each testing procedure following a preliminary session to allow familiarity with the instrumentation, test procedures, and test positions. Retest measurements were taken in 5–7 days with the order of the test procedures counterbalanced. Four $2 \times 2$ (Side × Test Condition) ANOVAs, with repeated measures on each factor, were used to analyze the data. Significant Side × Test Condition interaction effects were evident for knee extension, elbow flexion, and shoulder abduction. Except for the knee extension, the break test produced higher values than the make test in all muscle groups, which is in agreement with previous investigations.

There are two types of test procedures under the category of isometric strength tests: make tests and break tests. In the make or hold test, the subject exerts a maximal voluntary effort against a dynamometer or fixed external device (5). In a break test procedure, the subject performs a maximal voluntary effort against a dynamometer that is applied with an increasing counterforce by the examiner to exceed or “break” the isometric contraction of the muscle (5). At present, there is no consensus on the most appropriate test procedure to measure isometric strength.

Previously, research employing the use of hand-held devices to assess isometric muscular strength has established reliability, as well as standardization of testing procedures (3, 4, 5, 6, 7). The efficacy of hand-held dynamometry using a break test has been investigated by several researchers in children with healthy and diseased muscle (1, 2, 10, 11, 15). In most cases, testing procedures and positions are typically standardized on adults and therefore may not be generalized to preadolescent and adolescent populations. In previous research with children, it was reported that stabilization, experience, motivation, and discomfort were important factors in generating representative scores. Horvat

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and colleagues (9) suggested that the break test procedures used with children sometimes induced pain and discomfort, indicating that a make test procedure may be more appropriate for children.

Because of the disproportionate size, lower muscle strength, and comfort level, the make test may be more effective in assessing strength scores in children. In some instances, the strength of the examiner can alter the force generated to break the isometric contraction. For children, this may be problematic since the examiner's strength is considerably greater in most muscle groups and may affect generating a true score. In order to generate more representative scores, the make test procedure in which the investigator does not attempt to exceed the subject's effort may be more productive in the assessment of children.

Another variable that may occur while using hand-held dynamometry is the optimum time needed to generate the maximal force. In the break test, the time recommended to break the contraction is 1.0 to 2.0 s. This time is utilized to eliminate extraneous movements that may occur as the examiner applies a stronger application to break the contraction (4). In contrast, the make or hold test uses a longer time interval in which the subject pushes against the device. Bohannon has utilized the make test procedure consisting of a period of 4–5 s for muscle contraction that was compared to a 2-s break test in adults. This longer time advantage may allow children to gradually apply force to generate a maximal effort. The results reported by Bohannon between make and break tests indicated that neither test could be judged as superior if the investigator does not question the integrity of the effort (3).

Variations were apparent, with the break test producing higher values than the make test; however, it was concluded that both tests measured maximal voluntary contractions and that other factors such as comfort, contraction time, age, and relative muscle size should determine test use since one test did not exhibit superior reliability. For children, the comfort level and contraction time seem to be important in generating representative results, since a painful stimulus or extended attention may become factors in test performance. What still needs to be addressed is the lack of evidence in children on various isometric test procedures. Consequently, it was the purpose of this investigation to compare differences in two test procedures (make test vs. break test) to assess isometric muscular strength in elementary school girls.

**Methods**

**Instrumentation**

The Hoggan MicroFET (Hoggan Health Industries, Inc., Draper, UT) is a hand-held force evaluation device that has demonstrated inter- and intratester reliability coefficients of .95 and a failure rate of less than 0.5% in clinical tests (10). The device is a microprocessor-controlled hand-held transducer that measures eccentric muscle force accurately (in pounds) through multiplanes. Two test conditions were compared: the make or hold test and the break test. A make test is a procedure in which subjects exert maximal voluntary effort against the dynamometer while it is held stable by the examiner, and a break test is performed by the examiner generating a peak force that exceeds and breaks the contraction.
the isometric contraction of the subject (5). All 50 subjects performed a make and break test on each muscle group.

**Subjects**

Fifty girls in Grades 3 and 4, ages 9–11 \( M = 9.46 \) were selected from participants in a physical education class at a public elementary school in north Georgia. All subjects were screened for any orthopedic/health problems from school records, and written consent was obtained from the subjects, parents, and the University of Georgia Human Subjects Committee. All subjects were randomly selected from the approximately 100 children who returned signed consent forms to their physical education teacher.

**Testing Procedures**

One session before each test procedure was used to familiarize the subjects with the test positions, instrumentation, and to minimize the practice effect (8). During the practice session, subjects were allowed several trials in each position until they were able to perform the protocol without difficulty. The positions were modifications of suggested standard manual muscle-testing positions (12). Modifications were a result of previous research guidelines recommended by Horvat et al. (9) that indicated elementary children, because of their smaller stature and comfort level, had difficulty in positions involving lying prone, extending the straight arm in a horizontal plane, or flexing the hip 8 inches above the table top. The modifications made were to test in a sitting position as opposed to the prone position, bending the elbow 90° as opposed to straight abduction, and reducing the hip flexion from 8 inches to 4 inches.

Muscle groups were tested alternating body sides and upper and lower body muscle groups in the following order: knee extension, elbow flexion, hip flexion, and shoulder abduction. Results were recorded as the peak values generated to the nearest pound (Table 1). Consistency was ensured by (a) maintaining consistent instrumentation placement and body segment position, (b) positioning instrumentation so that the force plate was comfortable on the subjects, and

<table>
<thead>
<tr>
<th>Muscle group</th>
<th>Make test</th>
<th>Break test</th>
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<tbody>
<tr>
<td></td>
<td>Right M</td>
<td>Right M</td>
</tr>
<tr>
<td>Knee extension</td>
<td>38.99</td>
<td>38.31</td>
</tr>
<tr>
<td>Elbow flexion</td>
<td>27.77</td>
<td>27.08</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>18.08</td>
<td>17.61</td>
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Table 1: Means and Standard Deviations by Muscle Group and Test Condition in Pounds
(c) providing consistent verbal feedback. The examiner manually stabilized the body segment proximal to the limb site being tested. Each test score and test duration was recorded to the nearest pound and two tenths of a second, respectively. The testing and practice sessions were conducted in the same environment. All subjects were initially assessed on either a 2-s break or 5-s make test during two test sessions 5–7 days apart. The order of the test procedures were counter-balanced to counteract effects of learning, fatigue, or motivation on test performance. All tests consisted of three trials on each side with 20 to 30 s between each trial. Scores were based on the mean of three trials.

Results

Four 2 × 2 (Side × Test Condition) ANOVAs with repeated measures on each factor were used for statistical analysis (13, 14). The alpha was set at .05 for all ANOVAs, recognizing the possibility of inflating the Type I error rate. When statistically significant interaction effects were detected, the desired simple effects were tested at $\alpha = .01$. Mean values and standard deviation by muscle groups and test conditions are included in Table 1.

**Hip Flexion**

For hip flexion, Side × Test Condition interaction was not statistically significant, $F(1, 49) = 0.78$, $p = .38$. Therefore, there was no statistical evidence supporting make versus break test mean strength as a function of side. Neither was there any statistical evidence supporting right leg versus left leg mean strength differences, $F(1, 49) = 0.44$, $p = .514$. However, there was a statistically significant test condition effect, $F(1, 49) = 52.23$, $p = .0001$, indicating the break test ($M = 31.14$) produced mean strength values that were higher than the make test procedure ($M = 26.41$) for hip flexion.

**Knee Extension**

For knee extension, a Side × Test Condition interaction was statistically significant, $F(1, 49) = 84.40$, $p = .0001$. Examination of the cell means revealed that the subjects’ mean strength scores were more consistent from the right quadriceps ($M = 38.99$) to the left quadriceps ($M = 38.30$) when measured with the make test than when measured with the break test ($M = 34.73$ and $M = 42.13$, respectively). Analyses of the simple effects supported this observation, as no statistically significant differences in mean strength were detected between the right and left quadriceps when measured by the make test ($p = .1191$). However, there was a statistically significant difference detected in right and left knee extensor mean strength scores for the break test ($p = .0001$). Further, analyses of simple effects demonstrated that the break test produced significantly lower ($p = .0001$) scores than the make test on the right side, while producing significantly higher ($p = .0026$) mean strength scores than the make test on the left side.

**Elbow Flexion**

For elbow flexion, the Side × Test Condition interaction was not statistically significant, $F(1, 49) = 1.44$, $p = .24$, suggesting that make versus break strength
does not differ as a function of side (right or left elbow). However, there was a statistically significant test condition effect, $F(1, 49) = 21.50$, $p = .0001$, as well as statistically significant side effect, $F(1, 49) = 14.50$, $p = .0004$. Specifically, the subjects' mean strength scores on the break test ($M = 30.35$) were greater than their mean strength scores on the make test ($M = 27.42$). Furthermore, subjects demonstrated slightly higher mean strength scores on the right side ($M = 29.40$) than on the left side ($M = 28.38$).

**Shoulder Abduction**

The Side x Test Condition interaction for shoulder abduction was statistically significant, $F(1, 49) = 4.78$, $p = .03$, suggesting possible make versus break differences as a function of side. Based on the analyses of simple effects, the subject mean strength scores on the break test produced significantly ($p = .0001$) greater mean strength scores (2.29 lb greater) than their mean strength scores on the make test with respect to the right shoulder ($p = .0001$). Subjects also exhibited greater mean strength scores (3.08 lb greater) on the break test than the make test ($p = .0001$) on the left shoulder. It is possible to generalize that the subjects' mean strength scores on the break test are higher than the make test; however, it should be noted that the make versus break differences are greater, from a statistical standpoint, for the left shoulder than for the right.

**Discussion**

In an earlier investigation with children, Dawson and colleagues (7) indicated that the scientific literature on assessing strength is relatively sparse when applied to children, especially in females. Noteworthy absences were indicated in all aspects of strength assessment in children, including various types of testing methodology, equipment, and muscle groups evaluated (7).

The purpose of this investigation was to compare two isometric strength-testing procedures for assessing muscular strength in elementary school girls. Within this investigation the make test procedure produced values that were within 16–15% of each break test value. This is in contrast to an earlier investigation in which Bohannon (3) reported differences of 30% between make and break test procedures in adults.

Several factors may be apparent that contribute to the greater variance. First, Bohannon's investigation utilized an adult population, in contrast to the present investigation, which utilized elementary school girls. The smaller muscle mass and ability to generate force produced less of a variation between test procedures than with adults. Secondly, elbow flexion was the only group assessed by Bohannon (3), as opposed to four muscle groups in this study. For elbow flexion variations on the make test, procedures were approximately 10% of break values on the left and right sides. In addition, variation may be attributed to relative strength of individual muscle groups as a relatively strong muscle group such as the knee extensors may produce less consistent scores due to testing procedures and test duration. For example, on the break test, knee extension produced the greatest variation in mean strength scores. This muscle group also produced the highest mean strength value (see Table 1).
As Figure 1 graphically demonstrates, the break test procedure in each muscle group produced higher values on left and right sides than the make test procedure, with the exception of knee extension. The break test procedure on the right side produced a mean value that not only was lower than make test procedure but also seemed to vary greatly from the break test on the left side. Interestingly, this variability occurred on the strongest muscle group tested, which may account for the Side x Test Condition variation. Since the break test uses a procedure in which the examiner must overcome or break the isometric contraction, the relative strength of the muscle group during a short duration (1.0 to 2.0 s) may contribute to the variation. This is in agreement with the rationale stated earlier that the make test procedure, because of variations in testing procedures with the break test, may be more appropriate with younger children because of the differences in levels of strength between the subject and examiner. It is also easier to stabilize the muscle group in the make test. In addition, the comfort level of the younger subject may be compromised when the break test procedure is used because the examiner must exert force that is greater than the subject’s effort to break the isometric contraction.

One factor that is commonly addressed in children is that motivational level commonly varies and leads to inconsistencies in determining maximal strength values. The consistency of measures, with the exception of knee extension, indicate that students generated consistent efforts on each test. As stated previously, the order of the tests were counterbalanced to counteract effects of learning, fatigue, or motivation on test performance.

While it is apparent that higher values in most cases can be generated with the break test procedure, it is not known whether these represent true values or variations in the force applied to break the contraction. In this investigation, the examiner had conducted several hundred evaluations on children and adults,
indicating that these results were probably accurate. In cases where the examiner is inexperienced, there are often variations that can be attributed to the tester’s experience. Better reliability values are consistently evident in studies where testers possessed experience in using the testing device (4, 9).

In summary, the present investigation seems to support the contention that either test is a viable method to assess muscular strength in elementary school girls. A significant difference was indicated, with the break test producing higher values on all muscle groups except the knee extension. This is consistent with earlier investigations on adults, and it is noteworthy that this investigation further expands this research to elementary-age girls. The consistency of the values in both test procedures, with the exception of knee extension, may also be noteworthy since children present a group that is commonly difficult to assess. Depending upon the nature of the clinical or educational setting, it is apparent that a make test procedure may be more preferable since it is more comfortable, the procedures are easier for children to understand, and it allows proper stabilization procedures and an increased amount of time to sum the children’s efforts to generate force. Therefore, the make test may be more appropriate for generating usable and consistent results when assessing younger populations.

Further research is required to expand the knowledge base of hand-held dynamometry and the advantages it offers when assessing muscular strength. It is also necessary to develop standardized procedures and to compare various muscle groups, types of muscle contractions, and normative values across the age span. Hand-held dynamometry offers validity, reliability, and portability without burdensome, expensive equipment. Of utmost importance is the development of standardized procedures that would generate increased usability of scores. Additional research should pursue the advancement of standardized procedures with girls and boys, as well as test duration within various muscle groups.

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