Trunk Flexion in Healthy Children Aged 3 to 7 Years

MARSHA B. LEFKOF

I tested 80 male and 80 female subjects between the ages of 3 and 7 years on two exercises of isometric trunk flexor muscle strength (half-hold hooklying position and supine flexion position) and one exercise of isotonic trunk flexor muscle strength (hooklying sit-ups) to establish normative data for trunk flexor musculature capabilities. Measurements included the length of time the half-hold hooklying and supine flexion positions were maintained and the number of repetitions of sit-ups. I found no significant differences between the sexes in performance of the isometric tests. I did find, however, a significant difference between age groups for half-hold hooklying and supine flexion tests \( p < .0001 \), indicating that the ability to perform isometric trunk flexion improves with age. Height was another significant variable contributing to test results \( p < .0001 \). Children were able to perform sit-ups consistently at age 6 years only; the male subjects performed an average of 20 more sit-ups than the female subjects \( p < .04 \). I discuss in this article the possible contribution of neuromuscular maturation and physical growth to the development of normal trunk flexion. The results may be useful to clinicians to assess abnormal trunk flexion accurately in children aged 3 to 7 years.

Key Words: Abdomen, Child development, Muscles, Physical therapy.

Normal sensorimotor development has been hypothesized to result from the interaction between stabilization of proximal body parts and movement of the distal parts.\(^1\) Proximal stability of the trunk, according to Stockmeyer, is accomplished by opposing forces of the intervertebral extensor muscles with the deep flexor muscles of the anterolateral abdominal wall.\(^1\) The interaction of these muscles largely provides the background postural stability from which coordinated movement of the distal body parts can develop. The relationship of the intervertebral muscles to normal sensorimotor development has been discussed extensively.\(^1,2\) The role of the trunk flexor muscles, however, has not been explored thoroughly.

The abdominal muscle group, which includes the rectus, obliquus externus, obliquus internus, and transversus abdominis muscles, contracts bilaterally to cause anterior approximation of the pelvis with the thorax.\(^3,4\) This combined action results in a posterior tilt of the pelvis and ventroflexion of the thorax on the pelvis. The abdominal muscle group assists in ventroflexion of the head from the supine position by stabilizing the thorax so that the neck flexor muscles are able to contract bilaterally to flex the head forward.\(^5\) Contraction of the neck flexor and abdominal muscles causes complete spinal flexion. During performance of a sit-up, once the trunk is in total flexion, the iliacus muscle contracts bilaterally to flex the pelvis forward on the femur to result in movement of the trunk to a vertical position.\(^3\)

The trunk flexor muscles contribute to the attainment of important motor patterns throughout development. Flexion in the supine position is an early total flexion pattern that may help the child learn to lift his head, trunk, and limbs against gravity in the supine position\(^6,7\); it is accomplished by the neck and trunk flexor muscles in combination with the flexor musculature of the extremities. Anterolateral abdominal activity stabilizes the trunk as the young child develops the ability to lift his head from the supine position\(^4,5\) and aligns the thorax with the pelvis for correct posture in the on-elbows, quad-ruped, sitting, and stance positions.\(^5,7\)

Accurate assessment of abnormalities in the child's muscle activity requires knowledge of the average motor capabilities for that child's age. Currently, normative data on isometric trunk flexor muscle strength in the 3- to 7-year age group is unavailable. Norms for isotonic abdominal strength are available only for a child 6 years of age or older.\(^8,9\) Evidence of the age at which children are able to perform consistently isometric trunk flexion against gravity is unavailable. A recent study of isotonic strength in preschool girls reported that the subjects were able to perform sit-ups consistently at age 6 years.\(^10\)

The purpose of my study was to compile normative data on isometric and isotonic trunk flexor musculature capabilities in children 3 to 7 years of age. I attempted to provide a frame of reference to which the clinician can compare trunk flexor muscle capabilities of children with disorders of normal movement and posture.

**METHOD**

**Subjects**

Parental consent forms were distributed to approximately 30 children in each of four classrooms in an elementary school and to all the children in five day-care centers. Approximately 50% of the elementary school students and 20% of the day-care center students returned signed forms, totaling 164 students with permission to participate in the study.
These students then were screened for evidence of gross motor abnormalities. The examiner observed each child's ability to walk without significant gait deviations and to perform gross motor skills appropriate for his or her age. Their medical and educational records also were reviewed to eliminate from the study those children with a history of special needs intervention. One hundred sixty children were considered to have normal gross motor skills and participated in the study.

Subjects were divided into four groups of 20 boys and 20 girls within age intervals of 3 to 4 years, 4 to 5 years, 5 to 6 years, and 6 to 7 years. All 6-year-old subjects and 16 of the 5-year-olds attended the elementary school. The 3-year-old and 4-year-old children and 4 of the 5-year-olds attended five different day-care centers. The children enrolled at the elementary school and three of the day-care centers were from predominately white, lower middle class, laborer families. The children attending the two other day-care centers were from white, upper middle class, professional families.

**Procedure**

I selected groups of three children at random from among the total number of subjects in each classroom. The groups were taken to the test room, where the test procedure was explained to them and they were informed that they would receive a sticker (reward) when they finished the activities. Height and weight measurements were taken. The children waited in the room with me during the testing of the other children. While waiting to be tested, the children were allowed to play with toys.

All tests were performed on a sit-up board: a padded plywood platform with an ankle strap to secure the feet. One child was asked to perform one test movement at a time. The examiner first demonstrated the test movement and then asked the child to assume the position independently. The tests were administered randomly to each subject; the exception was the half-hold hooklying test, which was given to all subjects before the supine flexion test. A period of between 1 to 10 minutes of rest was provided to each subject between tests. While one subject was resting, the examiner would ask another child to perform a test movement so that the subjects were rotated after each test. All subjects were asked to perform the three tests. The score of a child's performance was recorded on a data sheet immediately after each test.

**Protocol**

Isometric test I: Half-hold hooklying position. The subject was placed in the supine position, arms extended anterior to the trunk. Knees were flexed to 90 degrees, which the examiner measured with a goniometer. (The arms of the goniometer were aligned with the longitudinal axis of the thigh and the lateral malleolus of the ankle; the midpoint of the goniometer was aligned with the lateral surface of the knee joint.) Both feet were flat on the sit-up board and secured by a strap across the dorsa of the feet. The child then raised his head slowly, followed by his shoulders and upper chest. The examiner said, “Hold it,” when the child's scapulae were entirely off the board. The examiner determined that the child had reached this position when the inferior angle of the scapulae could be palpated. The examiner placed the child in the test position if the child was unable to assume the position independently. The child was instructed, “Hold it [the position] as long as you can.” Performance was

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**TABLE 1**

<table>
<thead>
<tr>
<th>Test-Retest Reliability Scores</th>
<th>Half-Hold Hooklying</th>
<th>Supine Flexion</th>
<th>Hooklying Sit-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (yr/mo)</td>
<td>Mean (X)</td>
<td>s (s)</td>
<td>Mean (X)</td>
</tr>
<tr>
<td>3/0 to 3/11</td>
<td>.51</td>
<td>.52</td>
<td>.99</td>
</tr>
<tr>
<td>4/0 to 4/11</td>
<td>.78</td>
<td>.46</td>
<td>.63</td>
</tr>
<tr>
<td>5/0 to 5/11</td>
<td>.91</td>
<td>.80</td>
<td>.63</td>
</tr>
<tr>
<td>6/0 to 6/11</td>
<td>.20</td>
<td>.86</td>
<td>.58</td>
</tr>
<tr>
<td>Total Sample</td>
<td>.75</td>
<td>.86</td>
<td>.83</td>
</tr>
</tbody>
</table>

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**TABLE 2**

<table>
<thead>
<tr>
<th>Means and Standard Deviations of Half-Hold Hooklying and Supine Flexion Test Results and t-test Results Between Boys and Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Half-hold hooklying position</td>
</tr>
<tr>
<td>Supine flexion</td>
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<tr>
<td>Supine flexion</td>
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<td>Supine flexion</td>
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</tbody>
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**TABLE 3**

<table>
<thead>
<tr>
<th>Means and Standard Deviations of Hooklying Sit-up Test Results and t-test Results Between Boys and Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hooklying sit-up</td>
</tr>
<tr>
<td>Hooklying sit-up</td>
</tr>
<tr>
<td>Hooklying sit-up</td>
</tr>
<tr>
<td>Hooklying sit-up</td>
</tr>
</tbody>
</table>

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* Scores measured in seconds.  
** NS = not significant at .05 level.
measured from the moment the examiner said, “Hold it,” to the moment the child’s head and chest began to lower from the position.

**Isometric test II: Supine flexion posture.** The child was placed in the supine position, arms crossed over his chest; knees were flexed to 90 degrees according to goniometric measurement. The examiner gave the command, “Roll into a ball.” The child then flexed his neck and upper trunk and simultaneously flexed his hips to bring his knees to his chest. The examiner said, “Hold it,” when the child was unable to further flex his head, upper trunk, and hips. The examiner checked the position by manually moving the child’s head, knees, and hips to achieve greater flexion. The position was correct if the examiner was unable to flex these body parts further. The examiner placed the child in this position if he was unable to assume supine flexion independently. This procedure should not have affected the results because the test was designed to measure the isometric contraction of the trunk flexor muscles at the end point of range only. Performance was measured from the moment the examiner ascertained that the position was correct to the moment the child’s head and extremities began to lower from the position.

**Isotonic test: Hooklying sit-ups.** The child was in the supine position and arms were extended anterior to his trunk, knees were flexed to 90 degrees according to goniometric measurement, and the feet were flat on the sit-up board and secured with a strap across the dorsa of the feet. The examiner gave one of two commands, either “Bring your nose to your knees” or “Sit up without using your hands,” depending on the child’s level of understanding.

The child attained upright sitting by flexing first his neck, then his upper trunk, and finally his lower trunk. The child was permitted to move at his own rate of speed. The upright position was attained when the examiner observed the child’s head and trunk in a plane perpendicular to the sit-up board. Each child was asked to perform two tasks: First, three trials were permitted for him to attain upright sitting. Second, if the child was able to attain upright sitting once, the examiner gave the instruction, “Do as many sit-ups as you can.” Performance was timed from the moment the sit-ups were initiated to the moment the child stopped. The number of sit-ups performed and the number of seconds during which the child was performing the sit-ups were recorded. If the child was unable to perform one complete sit-up, he received a score of zero for this test.

Test-retest reliability was obtained by random selection of five subjects from each age interval. These subjects were retested one week following the original test session. Reliability scores were computed for the entire population and for individual age intervals on each test (Tab. 1).

**Data Analysis**

Normative data and Student’s *t* tests were computed from test scores of male and female subjects at age intervals of 3, 4, 5, and 6 years. A one-way analysis of variance (ANOVA) was used to determine the effects of age, height, and weight on the scores of half-hold hooklying and supine flexion tests. A two-way ANOVA was computed on hooklying sit-up test scores to obtain the effects of age, sex, and interaction of age and sex on test results. A linear regression analysis was performed on height, weight, and sex variables. Multiple regression data showed that 6-year-old boys averaged 20 points more than 6-year-old girls on the hooklying sit-up test (*p* < .001). Because a significant difference was obtained between the scores of 6-year-old boys and girls on the hooklying sit-up test, a two-way ANOVA was used to analyze the data (Tab. 5). Significant effects were found for age (*p* < .001) and for age by sex (*p* < .05), not for sex. Multiple regression data showed that 6-year-old boys averaged 20 points more than 6-year-old girls on the hooklying sit-up test (*p* < .001).
### TABLE 6
Linear Regression Analysis Results for Contribution of Height to Isometric and Isotonic Test Scores for Boys and Girls Aged 3 Through 6 Years

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-hold hooklying Height</td>
<td>40,247</td>
<td>1</td>
<td>40,247</td>
<td>55.67</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Error</td>
<td>96,153</td>
<td>133</td>
<td>723</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TOTAL</td>
<td>136,400</td>
<td>134</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supine flexion     Height</td>
<td>14,807</td>
<td>1</td>
<td>14,807</td>
<td>43.72</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Error</td>
<td>45,044</td>
<td>133</td>
<td>339</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TOTAL</td>
<td>59,851</td>
<td>134</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hooklying sit-ups  Height</td>
<td>22,659</td>
<td>1</td>
<td>22,659</td>
<td>53.51</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Error</td>
<td>56,740</td>
<td>134</td>
<td>423</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TOTAL</td>
<td>79,399</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1.** Percentage of children aged 3 to 7 years able to perform half-hold hooklying, supine flexion, and hooklying sit-ups.

The subjects were able to perform consistently the half-hold hooklying test at age 4 years and the supine flexion and hooklying sit-up tests at age 6 years (Fig. 1). Variations were noted in the quality of movement among some subjects, including asymmetrical movement of the trunk and extraneous flexion of the head and extremities (Fig. 2).

A significant correlation was found between scores on the half-hold hooklying and supine flexion tests at all age levels and for each sex; the exception was the 4-year-old girls (Tab. 7).

### DISCUSSION

The average scores for each test were found to be considerably higher than averages listed for comparable movements in currently used motor development scales. Currently available average scores for isotonic trunk flexor muscle strength include the Frostig Movement Skills assessment, which requires boys at age 6 years to perform an average of 7.62 hooklying sit-ups and 6-year-old girls to perform 7.98 hooklying sit-ups. The Learning Accomplishment Profile calls for 5 sit-ups at age 6 years. For measurement of isotonic trunk flexor muscle strength, Ayres says to “expect little” from children under 6 years on performance of the supine flexion test; children over 6 years are expected to maintain supine flexion for 20 to 30 seconds. Average scores for the half-hold hooklying test were available for adolescent children only. The differences between the above scores and the scores resulting from my study may reflect several factors not controlled by me.

Differences may exist in the test procedure used in my study and the methods of the authors cited above. These authors gave little information on how they obtained their data. Motivation was observed by the examiner to be an important factor influencing the results. The children competed amongst themselves for the highest scores on each test. They also wanted to please the examiner to receive a sticker. Thus, the test results may have been higher than if each child were tested without other children in the room and without a reward.

Fatigue may have affected some children’s performances. Several children reported neck discomfort after the test session. This discomfort was particularly evident if the half-hold hooklying position was performed before the supine flexion test. On the retests, these children may have performed poorly because of the anticipation of pain.

Behavior appeared to be an influential factor in the results of the retests. Many of the 5- and 6-year-old children quickly lost interest in the retests and had to be persuaded to continue their participation. The 3- and 4-year-old children, on the other hand, tended to perform better on the retests because they had enjoyed the initial testing session and, in particular, were motivated to receive another reward.

The difference in performance of the tests between age intervals suggests that trunk flexor muscle capabilities improve with age. This finding is consistent with previous reports of developmental trends in performance of motor skills in young children. The ability to perform prone extension, the pattern of...
total extension of the spine and extremities that is antagonistic to supine flexion, has also been reported to show improvement with age.\textsuperscript{20}

Several factors are thought to contribute to the improvement of motor ability with age. Body proportions change as a young child grows. At age 2 years, the ratio of head to body size is 1:5; by age 6 years, the ratio is 1:7.\textsuperscript{21} This change indicates that a child lifts less total body weight when flexing his trunk against gravity as he grows older. Maximal isometric strength has been demonstrated to correlate significantly with cross-sectional muscle mass.\textsuperscript{22} Muscle strength has been found to correlate with height in children,\textsuperscript{23,24} a factor that is related to muscle length.\textsuperscript{25} Both muscle mass and height increase with age.\textsuperscript{21,26} Weight has been shown to be less of a predictor of muscle strength than are height and age.\textsuperscript{24}

The quality of motor performance has been demonstrated to improve with age; the tested movements were more precise and efficient and had less unwanted movement in older children.\textsuperscript{18,19} This increasing proficiency was thought to reflect the maturation of the nervous system.\textsuperscript{18} In my study, the 5- and 6-year-old children seemed to be more precise in their test movements; they used fewer extraneous or asymmetrical motions than the younger subjects. Bobath theorized that rotation about the longitudinal axis of the body is used by young children when rising from the supine to the sitting position until they develop the ability to sit up in a symmetrical pattern.\textsuperscript{27} This could explain the asymmetrical trunk movements I observed during the testing despite prior demonstration.

Performance on the half-hold hooklying position test correlated significantly with scores on the supine flexion tests for all age groups except 4-year-old girls. A strong correlation between the two tests suggests that either test may be used to determine isometric trunk flexion strength in this age group. Further testing is necessary to explain why the tests did not correlate in 4-year-old girls.

The pattern of movement used by each child appeared to influence performance of the isotonic abdominal test. During the testing, I observed that the children who scored the highest numbers of sit-ups used two additional movements: 1) hip extension prior to trunk flexion and 2) dorsiflexion of the ankles against the support strap during the sit-up. The initial hip extension may have helped to stabilize the lower end of the pelvis to provide distal fixation for the rectus abdominis muscle and to assist in tilting the pelvis posteriorly. Dorsiflexion of the ankles against the support strap provided a counterbalance to the child's high center of gravity. Children who did not dorsiflex their ankles exhibited considerable difficulty in performing sit-ups.

The subjects were asked to perform both isometric and isotonic tests to assess both static and dynamic trunk flexor muscle capabilities. Electromyographical studies of the abdominal muscles have indicated that the obliquus internus abdominis muscle was active during isometric trunk flexion contractions while the rectus abdominis and obliquus externus abdominis muscles were active during isotonic trunk flexion contractions.\textsuperscript{4,5} My finding that boys averaged 20 more sit-ups than girls at age 6 years may reflect proportional changes in body tissues. At this age, girls show a
Higher proportion of skin and subcutaneous tissue (fat) than do boys.7,6 Boys show a greater mean gain in breadth of bone and muscle tissue. The greater height and weight of boys may contribute to differences in performance.6 Disparate ability between the sexes in young children has been reported for other motor skills, such as ball throwing, ladder climbing, hopping, and skipping.17 Isotonic trunk flexion tests vary in the scores expected for boys and girls, as well. Contrary to my findings, the Frostig Movement Skills assessment requires slightly higher average scores for girls at age 6 years.8 The President’s Council on Youth Fitness test requires adolescent boys to perform twice as many sit-ups as their female counterparts.29

Behavioral factors also may have influenced the isotonic test results. Several of the girls terminated the test movements soon after they complained of fatigue or neck discomfort. Most of the 6-year-old boys, on the other hand, appeared to be motivated to perform longer than the girls; they expressed a desire to compete for the highest scores. Their behavior might have reflected cultural influences or differences in prior training. Further research is indicated to determine the effects of training and cultural mores on motor performance in early childhood.

CONCLUSIONS

One hundred sixty children between the ages of 3 and 7 years were tested to define the average isotonic and isometric strength capabilities of the trunk flexor musculature. By age 3 years, 95% of the children with normal motor development were able to perform isotonic trunk flexion contractions against gravity. By age 6 years, all the subjects also were able to perform isotonic trunk flexion contractions against gravity.

The average scores on the isometric and isotonic trunk flexor muscle tests were found to be considerably higher than scores from currently available motor assessments. A significant difference in the performance of the isotonic and isotonic trunk flexor muscle tests was found among age groups; this difference suggests that trunk flexion strength improves with age. Height correlated positively with test scores. Performance of the isotonic trunk flexion test was significantly different between the sexes at age 6 years; the boys scored an average of 20 points more than the girls. No significant differences were found between the sexes on either isotonic test or on the isotonic test in the younger age groups. The children consistently performed the isometric tests at a younger age than they performed the isotonic test. The younger groups also exhibited more extraneous movement during the tests than did the older groups.

Future studies should include large samples of children from a variety of socioeconomic, ethnic, and racial backgrounds to validate the findings of my study. Previous training of the children should also be considered as a variable. These studies could include younger children to ascertain the age at which children can first perform isotonic trunk flexion against gravity. Further analysis of the trunk flexor muscles in the developing child is essential to gain a more complete understanding of the contribution these muscles make to developmental motor patterns. Finally, normative data should be compiled on a wide array of important motor functions in children aged 3 to 7 years to develop objective and quantifiable criteria for proper assessment of preschool children with possible motor abnormalities.

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