A Description of Grip Strength in Preschool Children

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Key Words: child development • grip strength • hand function

The purpose of this research project was to provide occupational therapists with preliminary descriptive data on the spherical grip strength of 3- to 5-year-old children using the Martin Vigorimeter. Three hundred and eighty boys and girls were tested. Standardized positioning and instructions were followed. The mean of three trials was used as the grip strength score for each hand. The right and left hands were alternated during testing to allow a 20-second rest between trials. A repeated measures design multiple analysis of variance was used to analyze the data. The findings indicated that the mean grip strength scores increased linearly with an increase in age (p < .001) and that the right grip strength score was greater than the left (p < .001). The descriptive data were reported separately for the right and left hands by age increments of 6 months. Two tables of mean grip strength scores and their standard deviations were generated for clinical use.

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O ccupational therapists commonly use hand strength measurements in assessing hand function to determine the degree of disability, appropriate treatment methods, and treatment effectiveness. Norms for comparing the hand strength measurements of the disabled child with that of the nondisabled child of the same age are very limited. Most of the work done in the area of grip strength has been with adults rather than with children. Work done with children has focused on children 5 years of age or older and has been performed with instruments (e.g., dynamometers) developed for adults (Ager, Olivett, & Johnson, 1984; Broadhead, 1975; Mathiowetz, Wiemer, & Federman, 1986; Montoye & Lamphiear, 1977; Montpetit, Montoye, & Laeding, 1967; Newman et al., 1984). It has long been recognized that these instruments are too large and heavy for small hands and thus are not optimum tools for measuring hand strength in young children (Dewey, Child, & Ruml, 1920; Johnson, 1925). Other researchers have recognized the limitations of these instruments and have developed modified dynamometers of their own for use with the young child (Jacklin, Maccoby, Doering, & King, 1984; Metheny, 1941; Parizkova & Adamc, 1980). Unfortunately, the results of these studies cannot be used by clinicians on a day-to-day basis since the testing instruments are not commercially available. Additionally, these studies focused on the nonmanipulative cylindrical grasp, as opposed to a more functional manipulative grasp, the spherical grasp, which incorporates thumb opposition.

Not until the late 1970s, when the Martin Vigorimeter (or Hand Cynamometer Gauge) was developed, was there an appropriate instrument for measuring the spherical grip strength of young children. Up to the present time, only limited norms or sketchy protocols for the clinical use of this device have been developed. Thorngren and Werner, in 1979, developed norms using the Martin Vigorimeter with adults, and Solgaard, Kristiansen, and Jensen, in 1984, evaluated the precision and reliability of the device for adults. They found it to be a very accurate instrument. Level, in 1984, was the first to compile descriptive data for children using the Martin Vigorimeter. She studied the spherical grip strength of children aged 6 years through 9 years. She also studied the effects on the grip strength of children of the three bulb sizes available for the Vigorimeter. She found that the smallest bulb (diameter 4 cm) was appropriate for all the children in her study. At this time, there are no norms or descriptive data for grip strength for children under the age of 6 that have been obtained by using commercially available instrumentation. Thus, the clinician is unable to compare the grip strength of the disabled child with that of the nondisabled child...
to make an accurate diagnosis of the problem, plan appropriate treatment, or measure the effectiveness of the treatment approach used.

The purpose of this study was to provide clinicians with preliminary descriptive data on the spherical grip strength of preschool children. By the age of 1 to 1½ years most children have established a fine pincer grasp, and by the age of 3½ to 4 years most children have established a tripod grasp of a pencil (Erhardt, 1974; Erhardt, Beatty, & Hertsgaard, 1981; Folio & Fewell, 1983). It is during the preschool years that children apply and refine these prehensive skills to the use of simple tools such as knives, forks, scissors, crayons, pencil and paper, shoelaces, zippers, buttons, and other devices (Ayres, 1981). Occupational therapists may be asked to evaluate and treat children who are having fine motor difficulties as demonstrated by their inability to adequately use these simple tools. It is often difficult for clinicians to make a differential diagnosis and determine if the child's difficulty is due to incoordination, immature prehension patterns, or lack of adequate strength. Additionally, occupational therapists frequently use hand strength measurements to assess treatment effectiveness.

This study expanded on the work of Level (1984) by broadening the age range for which grip strength values are available. Specifically, this study described spherical grip strength of normal (nondisabled) Caucasian boys and girls aged 3 to 5½ years. In order to determine how best to present these descriptive data, the following hypotheses were tested:

1. Children aged 3 to 5½ years demonstrate a significant increase in grip strength with an increase in age.
2. Children aged 3 to 5½ years demonstrate a significant difference between right- and left-hand grip strength.
3. Children aged 3 to 5½ years demonstrate a significant difference in grip strength based on sex.

Method
Sample
The original sample for this study consisted of 386 children who had parental permission to participate. Six of the subjects refused to participate or were unable to comply with the testing procedures, thus leaving a convenience sample of 380 participants. Criteria for inclusion in the study were that the child must be Caucasian, nondisabled, and between the ages of 3 and 5½ years. A nondisabled child was defined as one with no history of physical or mental disability as reported by the parent or guardian. The children who participated in the study came from three sources: (a) two large child-care chains in the greater Seattle area (n = 143, or 38%), (b) 10 community college-based parent cooperative preschools (n = 126, or 33%), and (c) 6 private preschools (n = 111, or 29%). All three sources represented lower to upper middle income families living primarily in suburban locations. Approximately 80% of the families from the child-care chains had two full-time working professional parents; and 58% of the cooperative preschool families had single incomes. See Table 1 for the composition of the sample.

Apparatus
The Martin Vigorimeter,1 also known as the Hand Cynamometer Pinch Gauge or the Dynamometer Pinch Gauge Combination, was used to measure the spherical grip strength of each child (see Figure 1). This instrument is a pneumatic dynamometer with three sizes of rubber bulbs (diameters of 4 cm, 5 cm, and 6 cm). Since the smallest bulb was found to be the most effective for young children's hands (Level, 1984), it was used for all children in this study. The air pressure within the bulb is registered in kilopounds per square centimeter (1 kp/cm² = 98.1 kPa) on a manometer via a rubber connection. The dial on the manometer has an arrow that rotates and stops at the

Figure 1. Child demonstrating the correct hand testing position for using the Martin Vigorimeter.

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Table 1
Composition of Sample (N = 380)

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = 3.00-3.50 years</td>
<td>33</td>
<td>35</td>
<td>68</td>
</tr>
<tr>
<td>2 = 3.51-4.00 years</td>
<td>40</td>
<td>37</td>
<td>77</td>
</tr>
<tr>
<td>3 = 4.01-4.50 years</td>
<td>47</td>
<td>34</td>
<td>81</td>
</tr>
<tr>
<td>4 = 4.51-5.00 years</td>
<td>43</td>
<td>41</td>
<td>84</td>
</tr>
<tr>
<td>5 = 5.01-5.50 years</td>
<td>38</td>
<td>32</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>201</td>
<td>179</td>
<td>380</td>
</tr>
</tbody>
</table>

1 The Martin Vigorimeter is available from A. J. Preston Corporation, 60 Page Road, Clifton, NJ 07012.
highest point of pressure exerted, and then maintains the reading to allow for accurate recording. The Martin Vigorimeter is calibrated in both kPa's and bars (1 bar = 98.1 kPa).

Procedures

Letters requesting permission to test each child were sent to parents or guardians. The letters explained the purpose and significance of the study and how the children would be tested. All children for whom permission was received, who agreed to participate, and who met selection criteria were included in the study. A quiet room or area with a child-size table and chairs was used for the data collection within each preschool. All children were seated in appropriately sized chairs that allowed their feet to be flat on the floor. The upper extremity to be tested was positioned so that the shoulder was adducted and neutrally rotated, the elbow was flexed at 90°, the forearm was neutral, and the wrist was in 0° to 30° of extension, maintained by resting the elbow and forearm on the table. The Vigorimeter bulb was positioned in the child's hand with the air tube extending out between the child's thumb and index finger and the child's fingers wrapped around the bulb with the thumb opposed to the middle or ring finger (see Figure 1). If a child was unable to maintain the standardized position for testing, he or she was shown the position again, placed in the position, and verbally encouraged to maintain the position. Only trials where the standardized position was maintained were included in the data. Three trials were taken on each hand. Right and left hands were alternated to offset the effects of fatigue and to allow a 20-second rest between trials. To control for the effect of order, half of the children in each age and sex group had the right grip measurement taken first, and half had the left taken first. Prior to each measurement the child was instructed: “Squeeze the ball as hard as you can.” As the child began to squeeze, the examiner said: “Squeeze harder . . . harder . . . let go . . . good job.” To maintain confidentiality and to control for possible competition effects between children, the children were not told the number of kilopounds they had squeezed. Following the completion of all six measures, each child was given a sticker as a reward for his or her participation in the study. A total of six measures was taken, three for each hand. The mean of three trials for one hand was used as the child's grip strength score for that hand.

Research and Statistical Design

This descriptive study controlled for the effects of (a) the testing position, (b) the length of time between trials, (c) the order in which the hands were tested, (d) the time of day of testing, and (e) the amount and type of social reinforcement. The experimenter-subject gender effects were held constant by the use of a single female experimenter.

A multiple analysis of variance (MANOVA) using a repeated measures design was chosen to analyze the research data. A MANOVA was chosen because several factors could be looked at simultaneously in one statistical analysis. Using a MANOVA reduced the possibility of making Type I errors, that is, of finding a significant difference between factors when in actuality there were none. The repeated measures design was chosen because there were two measurements for each child, a right- and a left-hand measurement. The MANOVA was used to determine if there was a significant difference in grip strength scores at the p < .05 level based on the child's age, sex, or the hand measured and whether any interactions existed between any of these factors. As part of the MANOVA, the effect of age on grip strength was looked at further by an orthogonal polynomial contrast and repeated contrasts.

Results

The results of this study supported two of the three research hypotheses:

1. Children aged 3 to 5½ years do demonstrate a significant increase in grip strength with an increase in age, and this relationship is linear.
2. Children aged 3 to 5½ years do demonstrate a significant difference between right- and left-hand grip strength.

The hypothesis stating that children aged 3 to 5½ years demonstrate a significant difference in grip strength based on sex was not supported. There was a significant difference in mean grip strength scores based on the ages of the subjects, F(4, 370) = 74.72, p < .001, but not based on sex, F(1, 370) = 3.30, p = .070. Additionally, there was no significant interaction between age and sex (p = .953). A significant difference between right- and left-hand grip strength means also was found, F(1, 370) = 18.75, p < .001. The direction of the difference between right and left means can be seen in Figure 2, with right scores higher than left scores. The orthogonal polynomial contrast indicated that the relationship between mean grip strength and age was linear, F(1, 370) = 296.60, p < .001. From the plotted mean grip strength scores it can be seen that strength increased with age, as indicated in Figure 2. The average increase in mean grip strength scores for each 6-month increase in age was found to be 4.75 kPa for the right hand and 4.25 kPa for the left hand. To analyze the age effect further, repeated contrasts between the age groups were done as a part of the MANOVA. Results indicated that each
age group was significantly different from each adjacent age group (at $p < .001$) and that no significant Age $\times$ Sex or Age $\times$ Hand interactions existed.

These results indicated that the descriptive data should be presented for right and left hands in age increments. By contrast, the finding of no significant differences between sexes provided support for combining data for boys and girls. When the descriptive data for boys and girls were examined by age group, it was found that in most cases boys were stronger than girls by 1 to 2 kPa. When considered from a clinical perspective the magnitude of the difference did not seem significant. Therefore, in view of both statistical and clinical considerations, the decision was made to present the tables with data combined for both sexes.

Table 2

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>$-3 , SD$</th>
<th>$-2 , SD$</th>
<th>$-1 , SD$</th>
<th>Mean</th>
<th>$+1 , SD$</th>
<th>$+2 , SD$</th>
<th>$+3 , SD$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00-3.50</td>
<td>5</td>
<td>11</td>
<td>17</td>
<td>23 ($\pm 6$)</td>
<td>29</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>3.51-4.00</td>
<td>13</td>
<td>18</td>
<td>23</td>
<td>28 ($\pm 5$)</td>
<td>33</td>
<td>38</td>
<td>43</td>
</tr>
<tr>
<td>4.01-4.50</td>
<td>11</td>
<td>18</td>
<td>25</td>
<td>32 ($\pm 7$)</td>
<td>39</td>
<td>46</td>
<td>53</td>
</tr>
<tr>
<td>4.51-5.00</td>
<td>14</td>
<td>21</td>
<td>28</td>
<td>35 ($\pm 7$)</td>
<td>42</td>
<td>49</td>
<td>56</td>
</tr>
<tr>
<td>5.01-5.50</td>
<td>15</td>
<td>24</td>
<td>33</td>
<td>42 ($\pm 9$)</td>
<td>51</td>
<td>60</td>
<td>69</td>
</tr>
</tbody>
</table>

Note. All strength scores are presented in kilopounds air pressure per square centimeter (kPa). The number in parentheses after each mean strength score is the standard deviation.

Ten means and ten standard deviations were thus generated. The specific means and standard deviations for each hand and each age group are reported in Tables 2 and 3.

The frequency distributions of the mean grip strength scores also were looked at statistically to determine the relative distributions of the research data compared with the expected distributions in the population at large. The research data did generate normal bell-shaped curves, with kurtosis and skewness values near zero, both when the mean grip strength scores were looked at together and when they were separated out by age and hand. Thus a $\pm 1 \, SD$ and $\pm 2 \, SD$ from the mean strength score does, in fact, represent approximately 68% and 95% of the normal population, respectively. These percentages therefore have been included in the mean hand strength tables (see Tables 2 and 3).

Discussion

Numerous studies have shown that there is a positive linear relationship between hand strength and age (Ager et al., 1984; Mathiowetz et al., 1986; Metheny, 1941; Newman et al., 1984; Parizkova & Adamec, 1980). This finding was further supported for ages 3 to 5½ years by this study. The right-hand/left-hand strength differences reported in the literature were also found in this study. Sex differences have been reported in previous studies (Ager et al., 1984; Jacklin et al., 1984; Mathiowetz et al., 1986; Metheny, 1941; Newman et al., 1984; Parizkova & Adamec, 1980), with boys demonstrating greater grip strength than girls. A significant sex difference was not evident from this research. Thus, the descriptive data were presented with the sexes combined, but separately for each hand and age group.

The major strength of this study is that it is the first known study of its kind to collect descriptive data on grip strength for children under the age of 5 years with an appropriate commercially available instrument. The data for this research will provide occupational therapists with a baseline of comparison for

Figure 2. Mean grip strength scores for each hand (kPa = kilopounds air pressure per square centimeter).
Table 3
Left-Hand Mean Grip Strength as Measured With the Martin Vigorimeter

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>-3 SD</th>
<th>-2 SD</th>
<th>-1 SD</th>
<th>Mean</th>
<th>+1 SD</th>
<th>+2 SD</th>
<th>+3 SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00-3.50</td>
<td>8</td>
<td>13</td>
<td>18</td>
<td>23 (+5)</td>
<td>28</td>
<td>33</td>
<td>38</td>
</tr>
<tr>
<td>3.51-4.00</td>
<td>12</td>
<td>17</td>
<td>22</td>
<td>27 (+5)</td>
<td>32</td>
<td>37</td>
<td>42</td>
</tr>
<tr>
<td>4.01-4.50</td>
<td>10</td>
<td>17</td>
<td>24</td>
<td>31 (+7)</td>
<td>38</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>4.51-5.00</td>
<td>16</td>
<td>22</td>
<td>28</td>
<td>34 (+6)</td>
<td>40</td>
<td>46</td>
<td>52</td>
</tr>
<tr>
<td>5.01-5.50</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40 (+10)</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>

Note: All strength scores are presented in kilopounds air pressure per square centimeter (kPa). The number in parentheses after each mean strength score is the standard deviation. Strength scores range from -1 SD to +1 SD in approximately 68% of all cases; -2 SD to +2 SD in approximately 95% of all cases.

evaluating and treating children. By using the Martin Vigorimeter, others can easily replicate this study. Additionally, this study has a much wider clinical application than would a study that used a device made by a researcher. Since the Martin Vigorimeter measures strength in kilopounds of air pressure per square centimeter, it provides smaller increments of measure than is possible with a device measuring strength in pounds. In addition, the provision of the three bulbs allows for measuring the small child’s hand with an appropriately sized instrument. The Martin Vigorimeter is very light, weighing approximately 6 oz, as compared with 1.5 lb, the average weight of a typical metal dynamometer.

A second major strength of the study is the use of a standardized position for testing and standardized verbal instructions. Both ensured consistency throughout the study besides providing therapists with a protocol for clinical use in testing children. The need by occupational therapy for more standardized protocols for pinch and grasp strength assessment was pointed out by Smith and Benge (1985). They recommended that the American Occupational Therapy Association develop and adopt standardized protocols and terminology for hand strength assessment.

The major weakness of the study lies in the area of sampling. The sample was limited to Caucasian children from the suburbs who had volunteered to participate and were attending preschool in the greater Seattle area. These children were primarily from a middle socioeconomic class. The results of this study should be generalized only to similar populations.

Additionally, the results of this study may be slightly elevated because the children were tested in small groups and not individually. Various researchers, as noted by Landers and McCullagh (1976) and Wankel (1984), have found that the presence of an audience facilitates performance in simple motor tasks. Thus, it is possible that the specific mean grip strength scores obtained in this study are slightly higher than what a clinician would find when testing children individually. Testing was done in small groups because child-care center regulations did not permit individuals unaffiliated with the center to take children individually to any part of the center.

This study was a significant first step in researching hand strength in the young child. Further research is needed to collect descriptive data on a broader population of children over a greater age range, from different racial groups, and from different socioeconomic backgrounds.

Acknowledgments

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