Spherical Grip Strength in Children 3 to 6 Years of Age

Lisa Link, Shirley Lukens, Mary Ann Bush

Key Words: hand • pediatrics

Objective. The purpose of this study was to establish normative data on spherical grip strength of children 3 to 6 years of age with the Martin Vigorimeter.

Method. Two hundred twenty-five preschoolers in the Kalamazoo, Michigan, area were tested with standardized positioning and instructions. The mean of three trials for each hand was used as the grip-strength score. A repeated measure design was used and the right and left hands were alternated during testing to allow a 20-sec rest period between trials. Hand width also was measured in inches from the head of the second metacarpal to the head of the fifth metacarpal.

Results. Hand width and grip strength were significantly correlated for both the right (p < .0001) and the left hands (p < .001). Grip strength increased linearly across all of the age groups (p < .001). The results of paired t tests did not show a significant difference in grip strength between the right and left hands or between boys and girls. A table of mean grip-strength scores and hand width measurements along with their standard deviations is presented for clinical use.

Conclusion. The vigorimeter could be used to assess the grip strength of children with rheumatic disorders without putting excessive pressure on the joints or skin of the hand.

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O ccupational therapists use grip-strength measurements as one means of evaluating hand function (Pratt & Allen, 1989). This information may be used to determine the degree of disability and to document changes or improvement resulting from specific treatment methods (Ager, Olivett, & Johnson, 1984; Pratt & Allen, 1989). Grip-strength data could also be used to monitor specific hand disabilities such as rheumatoid arthritis, which causes progressive hand weakness (Agnew & Maas, 1991).

When working with children, occupational therapists look closely at hand function because it is related to childhood development and functional performance (Pratt & Allen, 1989). By age 3 years, children begin developing a tripod grasp, which is used when holding a pencil (Erhardt, 1974; Erhardt, Beatty, & Hertsgaard, 1981; Folio & Fewell, 1983). Engaging in writing activities and other fine motor tasks leads to the establishment of hand preference by age 6 years (Short-DeGraff & Palisano, 1988). During this preschool period, improvement in grip strength, manual dexterity, and bilateral coordination all contribute to the development and refinement of many prehensile skills such as unscrewing jars, buttoning clothes, stringing beads, tying shoes, zipping coats, cutting with scissors, and writing with pencils or crayons (Ayres, 1981; Short-DeGraff & Palisano, 1988).

Statement of the Problem

When assessing preschoolers for delays in fine motor skills, occupational therapists may have difficulty determining whether the delay is due to immature prehension patterns, incoordination, or a lack of grip strength (Robertson & Deitz, 1988). Normative data on grip strength in children are very limited, which makes it difficult for the therapist to distinguish between the grip strength of children with disabilities and that of children without disabilities (Robertson & Deitz, 1988).

Grip strength has been measured in children 5 years of age or older with an adult dynamometer and has been found to increase with age and to show a gender difference (Ager et al., 1984; Bowman & Katz, 1984; Fullwood, 1986; Mathiowetz, Wiemer, & Federman, 1986). However, the adult dynamometer is large and heavy, preventing some children from getting their whole hand around the device in order to achieve an optimal grip (Dewey, Child, & Ruml, 1920; Johnson, 1925). Additionally, in some children, the device can cause excessive stress on the joints in the hand, leading to discomfort during squeezing (Melvin, 1977). This stress could affect the child's performance on the second and third trials.

Other researchers have modified the dynamometer for small hands, having recognized the drawbacks of using the Jamar Hand Dynamometer1 with children, and

1Manufactured by Elmed Incorporated, 60 West Fay Avenue, Addison, IL 60101.
again reported an increased grip strength with age and a sex difference (Dunn, 1993; Jacklin, Maccoby, Doering, & King, 1984; Parizkova & Adamec, 1980). Unfortunately, occupational therapists often cannot use the normative data collected from these modified devices because the devices are not commercially available, and no validity or reliability studies exist on them (Robertson & Deitz, 1988).

Literature Review

Standardized Testing Protocol

Mathiowetz et al. (1986) and Dunn (1993) pointed out that previous studies using the dynamometer varied in terms of the handle position used, arm position, number of trials, amount of rest between trials, and the type of verbal instruction given. In regard to handle position, some researchers adjusted the Jamar Dynamometer to fit each person’s hand (Ager et al., 1984; Kellor, Frost, Silberberg, Iverson, & Cummings, 1971), whereas others placed it on the second position as suggested by the American Society for Surgery of the Hand (Bowman & Katz, 1984; Mathiowetz et al., 1986; Smith & Benge, 1985). Inconsistency in handle position makes it difficult to compare the results from different studies. Variations in arm position ranged from allowing the subject to rest the forearm on the table (Ager et al., 1984) to allowing the elbow to rest on the table with the wrist off (Fullwood, 1986). Kellor et al. (1971) allowed subjects to flex or extend their arms as long as the body was not touched. Balogen, Akomolafe, and Lateef (1991) found that arm position does affect performance on tests measuring grip strength. Subjects standing with arms extended scored the highest, followed by those standing with arms flexed. Subjects who sat with their elbows flexed scored the lowest. The American Society of Hand Therapists has suggested that clinicians and researchers use the following standardized position: sitting, with shoulder adducted and neutrally rotated, elbow flexed at 90°, and the forearm and wrist in neutral (Bowman & Katz, 1984; Mathiowetz et al., 1986).

Other factors that varied from study to study were the number of trials and the amount of rest between trials. Some researchers used two trials, taking the highest score (Kellor et al., 1971). Broadhead (1975) allowed a rest period between the two trials, whereas Bowman and Katz (1984) took two trials for each hand, allowing a short rest while switching hands.

Other researchers recorded the average of three trials for each hand (Ager et al., 1984; Jacklin et al., 1984) whereas some had subjects alternate hands for each trial (Dewey et al., 1920; Johnson, 1925). Montazer and Thomas (1991) reported that repeated grip strength decreases over time due to fatigue and that performance on the first trial differs significantly from subsequent trials. Reddon, Stefanyk, Gill, and Renney (1985) suggested a 30-sec rest period between trials in order to allow enough time to restore energy. Trossman and Li (1989) reported that subjects who had a 30-sec rest period between trials did not differ significantly in terms of grip strength from those who had a 15-sec rest between trials.

Verbal instructions are the last factor to consider when administering a standardized assessment for measuring grip strength. With studies involving children, Dewey et al. (1920) and Johnson (1925) gave a brief description of the dynamometer before testing and urged the child before each trial to squeeze as hard as possible. Fullwood (1986) and Robertson and Deitz (1988) also gave verbal encouragement and a demonstration of the device. The American Psychological Association (1974) reported that verbal instructions can affect performance.

Spherical Grip Strength Evaluation

The Martin Vigorimeter1, a device developed in the late 1970s, is becoming increasingly popular with occupational therapists who must assess the grip strength of children (Robertson & Deitz, 1988). The instrument consists of a set of three rubber bulbs (small, medium, and large) and a dial that records the strength of spherical grasp. The lightweight rubber component, weighing approximately 6 oz (as compared to 1.5 lb for the dynamometer), may reduce joint and skin pressure on the hand while allowing for a better grip (Fike & Rousseau, 1982).

The Martin Vigorimeter involves spherical grasp, which is characterized by volar flexion, neutral wrist position, thumb in abduction and opposition, and fingers in abduction and flexion. Platt (cited in Level, 1984) stated that the rounded arch of the hand with the widespread position of the digits and thumb allows object manipulation to occur during the spherical grasp pattern. In contrast, the dynamometer involves a power grasp pattern, which is characterized by the thumb and digits in adduction, the fingers flexed, a flattened arch, and a narrow span of the digits. Platt (cited in Level, 1984) stated that manipulation of objects does not generally occur with the hook or power grasp pattern.

Unfortunately, the Martin Vigorimeter has limited norms and lacks a standardized testing procedure. A few researchers have developed norms for this device with adults (Fike & Rousseau, 1982; Thorngren & Werner, 1979). Fike and Rousseau (1982) used the medium bulb for women and the large bulb for men. During the testing procedure, the arm was extended. Three trials were taken for each hand; the measurement of the right hand taken first. There was no rest between trials. Thorngren and Werner (1979) tested the reliability and precision of the devices and found it to be very accurate for adults. Gianinni, Stillman, and Brewer (1984) found the adapted...

1Manufactured by Elmed Incorporated, 60 West Fay Avenue, Addison, IL 60101.
sphygmometer cuff to be more precise than the Martin Vigorimeter except with older boys. Krombholz (1989) and Level (1984) both used the device to study spherical grip strength in children between 6 and 9 years of age. Both reported a gender difference and that grip strength increased with age. Level (1984) also learned from her work with the device that the smallest bulb seemed to work best with all of the children in her study.

Only Robertson and Deitz (1988) studied spherical grip strength in children younger than 6 years of age, using the Martin Vigorimeter with a standardized testing position and standardized verbal instructions. The one weakness of the study as noted by Robertson and Deitz was that the subjects were all white, primarily from a middle socioeconomic class, and from the Seattle, Washington area. Bowman and Katz (1984) and Mathiowetz et al. (1986) also noted that a limited sample size was a major weakness of their studies involving the grip strength of children. Replication of Robertson and Deitz's study, using the same standardized testing procedure with subjects from another part of the country, lends greater reliability and validity to this measurement instrument.

**Purpose of Study**

The present study expanded on the work of Level (1984) and Robertson and Deitz (1988) by using children aged 3 to 6 years, who did not have disabilities and were from culturally and socioeconomically diversified backgrounds. In addition to examining the relationship between grip strength and age and gender, this study also examined hand width, the length from the head of the second to the fifth metacarpal. Weiss and Flatt (1971) conducted a pilot study on 198 children without disabilities, finding digit length to be significantly related to pinch strength. Hand size may affect the child's ability to achieve an appropriate optimal grasp of the bulb, thereby affecting the accuracy of the grip-strength measurement. In this present study four hypotheses were examined:

1. Children aged 3 to 6 years demonstrate a significant increase in spherical grip strength with age.
2. In children aged 3 to 6 there is a significant difference in spherical grip strength between boys and girls.
3. In children aged 3 to 6 there is a significant difference in spherical grip strength between right and left hands.
4. In children aged 3 to 6 there is a significant difference in spherical grip strength based on hand size.

**Methodology**

**Sample**

In this study, a stratified sample of children between 3 and 6 years of age who attended preschool in the Kalamazoo, Michigan, area served as the population. The population categories examined in this study were gender, ethnicity, and socioeconomic status as reflected by the family household income. According to the United States 1990 census (as cited in Creating Economic Opportunity [CEO] Council, 1992), 223,411 people lived in Kalamazoo (51.8% female, 48.2% male). The racial distribution of children 3 years of age or older who were enrolled in preprimary school in Kalamazoo was as follows: 88% white, 9.76% black, 0.47% American Indian, and 1.8% Asian-Pacific Islander. The average household income for families in Kalamazoo was $31,060.

The percentage of subjects needed in each stratification cell was based on 1990 census data for Kalamazoo (as cited in CEO Council, 1992). (See Table 1).

All 35 preschools listed in the Kalamazoo phone book were contacted, and 15 agreed to participate in the study. Permission to conduct the study was granted from both Western Michigan University's Human Subject Institutional Review Board and the preschool directors before any contact was made with the sample population. Consent forms and questionnaires obtaining demographic information were provided for each child attending the identified preschools. The original sample consisted of 231 children. Grip-strength and hand width measurements were recorded for all volunteer subjects with parental or guardian consent.

After data collection, all coded data sheets reporting a history of physical or mental disability or a history of occupational therapy or physical therapy were removed from the study by the first author, leaving a sample of 225 participants. This method of selecting preschoolers without disabilities was used to protect confidentiality and to ensure that no child in a particular setting was left out of

**Table 1**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Desired percentage</th>
<th>Desired n for 225 subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys</td>
<td>48.2</td>
<td>109</td>
</tr>
<tr>
<td>Girls</td>
<td>51.8</td>
<td>117</td>
</tr>
<tr>
<td>White</td>
<td>88</td>
<td>199</td>
</tr>
<tr>
<td>Black</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Hispanic</td>
<td>Asian/Indian</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pacific Islander</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hispanic/Other</td>
<td></td>
</tr>
<tr>
<td>0–19,999</td>
<td>Household Income</td>
<td>33.3</td>
</tr>
<tr>
<td>20,000–49,000</td>
<td></td>
<td>75.33</td>
</tr>
<tr>
<td>50,000+</td>
<td>33.4</td>
<td></td>
</tr>
</tbody>
</table>

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testing. The children who participated in the study came from four types of preschools: 7 were private (36.9%), 5 were affiliated with religious organizations (50.7%), 1 was college based (7.1%), and 2 were community based (5.3%) (see Table 2).

**Apparatus**

The Martin Vigorimeter (also called the Hand CYNAMometer Pinch Gauge and the Dynamometer Pinch Gauge Combination) measures spherical grip strength. The instrument is available from a number of rehabilitation catalog companies. The Martin Vigorimeter is a pneumatic device with three sizes of rubber bulbs. The smallest bulb, with a diameter of 4 cm, was used because it was found to be the most effective with children (Level, 1984), and was also recommended by manufacturers for children. Robertson and Deitz (1988) stated that

The air pressure within the bulb is registered in kilopounds per square centimeter (1 kpsi = 98.1 kPa [kilopounds of air pressure] on a manometer via a rubber connection. The dial on the manometer has an arrow that rises and falls at the highest point of pressure exerted, and then maintains the reading to allow for accurate recording. (N = 48-64)

The arrow was set to a zero reading after each test, and the device checked for air leaks. The instrument is calibrated in both kPa's and bars, an international unit of pressure. The smallest bulb, with a diameter of 4 cm, was used because it was found to be the most effective with children (Level, 1984), and was also recommended by manufacturers for children. Roberson and Deitz (1988) stated that

Hand width was measured in inches from the head of the second metacarpal to the head of the fifth metacarpal. With the hand flat on the table, a tracing was made for accuracy. The pencil was used to mark the base of the second and fifth metacarpal on the paper. With a ruler, the distance between the two marks was measured in inches to establish hand width (see Figure 1).

**Researchers**

Four undergraduate senior occupational therapy students assisted with the testing of the subjects. The students attended a 1 hr training session using the Martin Vigorimeter. The session included a lecture and a hands-on component with both a written and practical exam given at the end of the session. Objectives for the training program were that the assistants were able to enhance their understanding of spherical grip strength, fill out the test forms accurately and completely, and follow the standardized operating procedures as established by the researcher. The four research assistants collected data on 59 children (26% of the data), and the primary investigator tested 166 children (74% of the data).

**Interrater Reliability Study**

The Pearson product-moment correlation coefficient is a common statistical test used to measure interrater reliability. Ottenbacher and Tomchek (1993) questioned this test because it measures linear associations but reveals little about interrater agreement. Bartko and Carpenter (1976) suggested that the interclass correlation is the best statistical measure to use with reliability studies.

Due to the difficulty in securing preschool subjects for all five researchers to test with a single instrument, the interrater reliability study was conducted with eight female occupational therapy students who ranged in age from 23 to 48 years. To accommodate the adult population, the testing protocol was altered slightly, and the medium bulb of the Martin Vigorimeter was used to test all subjects. Level (1984) found the medium bulb to be an appropriate size for women; this is also the manufacturer's suggestion. Each of the assistants rated all eight subjects in a predetermined, random order to help control for fatigue and order effect. The entire procedure took approximately 2 hr to complete.

In a typical reliability study, a random sample of K judges (K = number of judges) rates all of the N targets (N = number of measurements x number of subjects). The present study had 5 judges (K = 5) and 32 targets (N = 32). With this type of design, a subject x judges, two-way analysis of variance (ANOVA) is commonly used. The interclass correlation measure for a case two design is

**Table 2**

<table>
<thead>
<tr>
<th>Characteristics of Subjects</th>
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<table>
<thead>
<tr>
<th>Age (Year/Month)</th>
<th>Boys</th>
<th>Girls</th>
<th>White</th>
<th>Black</th>
<th>American Indian</th>
<th>Pacific Islander</th>
<th>Hispanic Other</th>
<th>Family Household Income for 13 Subjects ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3/5</td>
<td>7</td>
<td>9</td>
<td>14</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>3/6-3/11</td>
<td>20</td>
<td>18</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>4-4/5</td>
<td>23</td>
<td>29</td>
<td>48</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>4/6-4/11</td>
<td>28</td>
<td>28</td>
<td>45</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>5-5/5</td>
<td>25</td>
<td>26</td>
<td>46</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5/6-5/11</td>
<td>9</td>
<td>11</td>
<td>16</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>112</td>
<td>113</td>
<td>204</td>
<td>11</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>22</td>
</tr>
<tr>
<td>Percentage</td>
<td>49.8</td>
<td>50.2</td>
<td>91.1</td>
<td>4.9</td>
<td>4</td>
<td>1</td>
<td>1.8</td>
<td>10</td>
</tr>
</tbody>
</table>

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represented as follows (BMS = between targets, WMS = within targets, JMS = between judges, EMS = residual):

$$\text{ICC (2, 1)} = \hat{p} = \frac{\text{BMS} - \text{EMS}}{\text{BMS} + (K - 1) \text{EMS} + K (\text{JMS} - \text{EMS})/n}$$

Shrout and Fleiss (1979) reported that a $p$ value of .75 or above is very reliable (see Table 3). For the present study, $p = .99649$. A confidence interval was not considered because of the high $p$ value.

**Procedure**

Letters requesting permission to test the child and a questionnaire providing demographic information were sent to parents or guardians. The letters explained the purpose and significance of the study and how the child would be tested. All children who had parental or guardian permission and who gave verbal assent participated in the study.

Before testing the children individually, the researcher gave a brief orientation to the entire preschool class. After this initial orientation, the researcher accepted each child individually into a quiet room or area with child-sized tables and chairs, which was used for the data collection within each preschool. The child was welcomed and was asked to sit at the table. The researcher briefly reiterated the importance of grip strength within the child's own play and demonstrated the appropriate position the child must maintain during the testing. The standardized position used by Robertson and Deitz (1988) and Level (1984) was also used in this study: Shoulder adducted and neutrally rotated, elbow flexed at 90° and resting on the table surface, forearm in neutral, and wrist in 0 to 30° of extension. The smallest bulb was positioned in the child's palm with the air tube extending out between the child's thumb and index finger, and with the child's fingers wrapped around the bulb so that as much of the surface of the fingers touched the surface of the bulb as possible. The thumb was also checked to see that it was in opposition to the middle and ring fingers.

The researcher demonstrated how the child must exhale during the procedure to control for the Valsalva maneuver.

After agreeing to participate in the study, the child was instructed to "squeeze the ball as hard as you can." As the child began to squeeze, the researcher said, "Squeeze harder . . . harder . . . let go . . . good job." The scores were recorded on the data sheet and the dial on the device was reset to the zero mark. Only trials where the standardized position was maintained were recorded on the data sheet. To maintain confidentiality and to control for possible competition effects between children, each subject was not told the number of kilopounds he or she squeezed.

A total of six measures were taken, three for each hand. The mean of the three trials was used as the child's grip-strength score for that hand. Right and left hands were alternated to offset the effects of fatigue and to allow a 20-sec rest between trials. To control for the effect of order, half of the children in each age and gender group had the right grip measurement taken first, and half had the left taken first. After all six trials were completed, the width of the child's hand from the head of the second metacarpal to the head of the fifth metacarpal was measured with a ruler. The child was then given a sticker as a reward for participating in the study.

**Research and Statistical Design**

The following factors were controlled during data collection: testing position, length of time between trials, order in which hands were tested, and the amount and type of social reinforcement given. These were the same factors

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**Table 3**

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Abbreviation</th>
<th>DF</th>
<th>MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Targets</td>
<td>BMS</td>
<td>51</td>
<td>9492.5494</td>
</tr>
<tr>
<td>Within Targets</td>
<td>WMS</td>
<td>97</td>
<td>7.1542</td>
</tr>
<tr>
<td>Between Judges</td>
<td>JMS</td>
<td>4</td>
<td>2.17</td>
</tr>
<tr>
<td>Residual</td>
<td>EMS</td>
<td>93</td>
<td>0.8240</td>
</tr>
</tbody>
</table>

$p = .99649$
controlled for by Robertson and Deitz (1988). The time of
day of testing could not be controlled for because the
children participating in the study attended their pre­
school on different days and at different times. The ex­
perimenter-subject gender effects were held constant be­
cause the five experimenters (one researcher and four
assistants) were women.

A repeated measure design was used with four mea­
surements taken for each hand, the right and left grip
strength and the right and left hand width. Descriptive
statistics provided group means and standard deviations
for both right and left hands separately. The mean scores
for right and left grip strength were plotted against age in
order to provide a visual picture of grip strength across
time. Paired t tests were computed to identify any
strength differences between boys and girls and right and
left hands. The Pearson product-moment correlation was
computed to identify whether a correlation existed be­
tween hand width and grip strength. The SPSSx (1990)
statistical software package was used during data analysis.
The significance level for the statistical tests was set at
p < .05.

Results

Findings supported the first hypothesis, that children
aged 3 to 6 years do demonstrate a significant increase in
spherical grip strength with age ($r_{223} = .65, p < .001$). Grip strength increased for both the right and left hands across all of the age groups (see Figure 2). Hand width also tended to increase linearly with age ($r_{220} = 0.57, p < .001$).

The fourth hypothesis, which stated that children
aged 3 to 6 years demonstrate a significant difference in
spherical grip strength based on hand width, was also
supported. Both right ($r_{220} = 0.57, p < .001$) and left
($r_{220} = 0.59, p < .001$) hand width and grip strength
were closely associated with one another. Additional
Pearson correlation tests were computed to see whether
a significant difference between hand width and grip
strength existed within each age group (see Table 4). A
significant difference was found in four of the seven age
groups.

The second hypothesis, which stated that children
aged 3 to 6 years demonstrate a significant difference in
The Correlation of Hand Width and Grip Strength for Each Age Group

<table>
<thead>
<tr>
<th>Age Group (Year/Month)</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 5/0-5/5</td>
<td>( r(4) = .59, p = .1387 )</td>
<td>( r(4) = .21, p = .4290 )</td>
</tr>
<tr>
<td>2. 5/0-5/11</td>
<td>( r(3) = .47, p = .0039 )</td>
<td>( r(3) = .27, p = .1085 )</td>
</tr>
<tr>
<td>3. 4/0-4/5</td>
<td>( r(51) = .34, p = .0055 )</td>
<td>( r(51) = .38, p = .0051 )</td>
</tr>
<tr>
<td>4. 4/0-4/11</td>
<td>( r(44) = .12, p = .4277 )</td>
<td>( r(44) = .37, p = .0104 )</td>
</tr>
<tr>
<td>5. 5/0-5/5</td>
<td>( r(48) = .34, p = .0149 )</td>
<td>( r(48) = .41, p = .0030 )</td>
</tr>
<tr>
<td>6. 5/0-5/11</td>
<td>( r(18) = .50, p = .0059 )</td>
<td>( r(18) = .08, p = .0003 )</td>
</tr>
</tbody>
</table>

*p < .05
**p < .01
***p < .001

Hand strength based on gender, was not supported for both the right (\( r [223] = 1.61, p > 1095 \)) or the left hand (\( r [223] = 1.29, p > .1970 \)). These results provided support for combining data for boys and girls.

The third hypothesis, which stated that a significant difference existed between the right and left hand in terms of spherical grip strength, also was not supported (\( r [223] = 1.18, p > .2373 \)). Specific means and standard deviations for grip strength and hand width for both the right and left hands are reported in Table 5. The average increase in mean grip strength for each 6-month interval was 4.43 kPa for the right hand and 4.14 kPa for the left hand.

Discussion

Several past studies showed that grip strength of children 5 years of age or older increased linearly with age (Ager et al., 1984; Bowman & Katz, 1984; Broadhead, 1975; Fullwood, 1986; Jacklin et al., 1984; Level, 1984; Mathiowetz et al., 1986; Parizkova & Adamec, 1980). The present study supports the findings of previous studies that reported that grip strength increases linearly with age in children 3 to 5 years old (Dunn, 1993; Robertson & Deitz, 1988).

Numerous studies have also reported a difference in grip strength based on gender, with boys having a stronger grip strength than girls (Ager et al., 1984; Bowman & Katz, 1984; Fullwood, 1986; Jacklin et al., 1984; Krombhohz, 1989; Mathiowetz et al., 1986; Parizkova & Adamec, 1980). Robertson and Deitz (1988) and Dunn (1993) did not find such a gender difference when they tested children younger than 7 years of age. The present study, which involved children from a similar age group (3 to 6 years of age), also did not find a difference between boys and girls. Gender differences in terms of spherical grip strength may not be evident in children this young. Therefore, the results of this study provided support for Robertson and Deitz (1988), who combined the data for both boys and girls.

Establishment of hand preference occurs by age 6 (Short-DeGraff & Palisano, 1988). Therefore, the effect of hand dominance on grip strength was not examined in this study. Several researchers have found a difference between right-hand and left-hand grip strength (Bowman & Katz, 1984; Dunn, 1993; Robertson & Deitz, 1988; Weiss & Flatt, 1971). In this study, the difference between right-hand and left-hand grip strength was nonsignificant.

Weiss and Flatt (1971) found that the length of the digits of the hand were significantly related to pinch strength. They also measured hand width, but they did not report any findings relating hand width to hand strength. In the current study, it was found that grip strength was significantly related to hand width.

In the present study, a strong effort was made to obtain a stratified sample that would represent the population of preschool children in the Kalamazoo area. The stratification plan was closely followed, but unfortunately only 10 black children were tested, instead of the desired 19 children needed for the stratification cell. One limitation of this study was the small sample size for the youngest (n = 16) and the oldest (n = 20) age groups. Only 137 of the 225 families whose children participated in the study reported their family household income. Parents from higher socioeconomic classes seemed more willing to disclose this information.

The same standardized testing position and verbal instructions followed in the Robertson and Deitz (1988) study were used in the present study. This ensured consistency throughout the study and allowed the results of the present study to be easily compared with the data from the Robertson and Deitz (1988) study. The mean scores in this study were consistently lower than the mean scores in the Robertson and Deitz (1988) study (see Figure 2). These findings may be due to the use of a stratified sample, unlike the Robertson and Deitz (1988)

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Correlation of Hand Width and Grip Strength for Each Age Group</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Age Group (Year/Month)</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>1. 5/0-5/5</td>
</tr>
<tr>
<td>2. 5/0-5/11</td>
</tr>
<tr>
<td>3. 4/0-4/5</td>
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<tr>
<td>4. 4/0-4/11</td>
</tr>
<tr>
<td>5. 5/0-5/5</td>
</tr>
<tr>
<td>6. 5/0-5/11</td>
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</tbody>
</table>

*p < .05
**p < .01
***p < .001

Table 5
Means and Standard Deviations for Grip Strength and Hand Width

<table>
<thead>
<tr>
<th>Age Group Year/Month</th>
<th>N</th>
<th>Left Grip Strength</th>
<th>M</th>
<th>SD</th>
<th>Right Grip Strength</th>
<th>M</th>
<th>SD</th>
<th>Right Hand Width</th>
<th>M</th>
<th>SD</th>
<th>Left Hand Width</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/0-5/5</td>
<td>16</td>
<td>13.89</td>
<td>4.12</td>
<td>15.70</td>
<td>5.08</td>
<td>2.22</td>
<td>0.15</td>
<td>2.20</td>
<td>0.16</td>
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</tr>
<tr>
<td>5/0-5/11</td>
<td>39</td>
<td>18.64</td>
<td>6.52</td>
<td>18.21</td>
<td>7.95</td>
<td>2.26</td>
<td>0.19</td>
<td>2.23</td>
<td>0.18</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>4/0-4/5</td>
<td>55</td>
<td>25.80</td>
<td>6.45</td>
<td>22.25</td>
<td>6.24</td>
<td>2.31</td>
<td>0.15</td>
<td>2.30</td>
<td>0.15</td>
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<td></td>
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<tr>
<td>4/0-4/11</td>
<td>47</td>
<td>27.69</td>
<td>6.77</td>
<td>27.15</td>
<td>6.30</td>
<td>2.43</td>
<td>0.15</td>
<td>2.41</td>
<td>0.16</td>
<td></td>
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</tr>
<tr>
<td>5/0-5/5</td>
<td>50</td>
<td>30.99</td>
<td>7.97</td>
<td>29.70</td>
<td>7.92</td>
<td>2.52</td>
<td>0.19</td>
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<tr>
<td>5/0-5/11</td>
<td>20</td>
<td>36.03</td>
<td>8.45</td>
<td>34.35</td>
<td>8.48</td>
<td>2.54</td>
<td>0.15</td>
<td>2.50</td>
<td>0.12</td>
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</table>

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study, which used a sample of white children who were primarily from a middle socioeconomic class. Other possible explanations could include instrument differences or the testing of subjects individually versus in groups. The children in this study were tested individually. Robertson and Deitz (1988) noted that competition could affect the performance of a child during the grip-strength test.

In the present investigation, a formal interrater reliability study found a significant consistency between the five raters (p = .969). Interrater reliability data and a standardized testing protocol will provide other therapists with a reliable means of measuring spherical grip strength in children. In her 1993 study, Dunn used 12 data collectors and stated that a major limit of the study was a lack of interrater reliability data. Robertson and Deitz (1988) controlled for this factor by using only one data collector.

The testing instrument used in the present study appeared to have major advantages over other instruments. The bulbs of the Vigorimeter seemed easier for the children to grasp than those of the Jamar Hand Dynamometer. The Vigorimeter also appeared nonthreatening to the younger children. The rubber bulbs resembled a small rubber ball, an object that is familiar to the children. Some children commented that the Vigorimeter looked like a blood pressure measuring device seen in a physician’s office. The Vigorimeter measures grip strength in smaller increments than the Jamar Dynamometer, which measures grip strength in pounds or kilograms. This difference was important because some of the younger, smaller children could squeeze only 2 or 3 kPa. Despite its high cost of approximately $340, the device could have a wider clinical application than a less expensive device made by the therapist. Normative data and reliability or validity studies are limited on modified grip-strength measuring devices (Robertson & Deitz, 1988).

Conclusion

Dunn (1993) used a modified sphygmomanometer to compare the grip strength of normal children and that of children who had rheumatic disorders. Future studies involving the Vigorimeter could involve the same comparisons. The Vigorimeter could be used to assess the grip strength of children with rheumatic disorders without putting excessive pressure on the joints or skin of the hand. Future studies also could involve the collection of normative data on adults, using the Martin Vigorimeter. This instrument may have a wide clinical application for use with adults having carpal tunnel syndrome, arthritis, or peripheral nerve injuries.

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References


