A Comparison of the Grip Strength of Children With Myelomeningocele to That of Children Without Disability

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The grip strengths of 108 children aged 6 to 19 years with myelomeningocele were measured and compared with previously published results for children without disability. The grip strengths of the 59 female subjects with myelomeningocele were significantly lower than those of the population without disability in all age groups except for the 12 to 15 years range. The 49 male subjects exhibited significantly lower grip strengths only up to age 12 years. Implications and recommendations for clinical treatment, effects of secondary neurological complications, limitations of the study, and topics of future research are discussed.

Throughout the 20th century, occupational therapists have become increasingly responsible for the objective evaluation of hand function and its effect on functional skills. One of the most important measures of hand function to consider is grip strength. The assessment of strength is often used as a baseline for treatment and as a way of measuring treatment progress. Grip strength norms for adults have been developed and used for over 30 years (Bechyl, 1954). The adult measures have been extensively studied (Mathiowetz, Weber, Volland & Kashman, 1984) for improvements to their reliability and validity, which are necessary for accurate and meaningful clinical assessments. Because of the difference in age, the adult measures are not applicable to the pediatric patient.

In the mid-1980s, two sets of investigators (Ager, Olivett, & Johnson, 1984; Mathiowetz, Wiemer, & Federman, 1986) developed pediatric grip strength norms that allowed the assessment of children based on grip strength. Both studies found that grip strength increases with age, that males are consistently stronger than females, and that hand dominance does not affect scores. Although these standards were developed from populations without disability, most occupational therapists use them to compare to special populations. Usually, these comparisons only show that the special population is different from the population without disability, hardly new or useful information. To date, only one study (Broadhead, 1975) has measured the grip strength in a population that was classified as mildly handicapped.

Neural tube defects (NTD) are among the most common congenital malformations. Many diagnoses fall into the category of NTD, including the various levels of spina bifida. Spina bifida occurs between the third and fourth weeks of gestation if the neural tube fails to close completely. The defect can occur at any level of the spinal cord. The severity can vary from no neural involvement (spina bifida cystica) to a completely open spine (rachischisis). The most frequently encountered type of NTD is myelomeningocele, which includes involvement of the bone, meninges, and spinal cord (Berkow & Fletcher, 1987; Brown, 1980; Cash, 1979). Myelomeningocele is highly associated with hydrocephalus and the Arnold-Chiari malformation (Brown, 1980).

Until recently, children with myelomeningocele had been thought to have normal use of the upper extremities because the neurological deficit was usually not caused by a spinal cord lesion high enough to involve the upper extremities. Thus, these children were subject to assessment of hand skills and grip strength based on standards developed for the population without disability. However, as far back as 1973, occupational therapists were noticing a difference in hand function with these children (Wallace, 1973).

Many people have failed to notice that an NTD is a defect in the development of the entire central nervous system.
system (Brown, 1980). If hydrocephalus develops after the closure of a spinal defect, there may be damage to the motor cortex, especially the pyramidal tracts, which results in upper extremity spasticity. A high percentage of these children also have a brainstem defect, called an Arnold-Chiari malformation, which can cause significant spinal cord above the level of the lesion that are not readily apparent during a routine physical examination (Begerer et al., 1986).

The purpose of this study is to describe norms of grip strength for children with myelomeningocele and to compare the grip strength of children with myelomeningocele to the norms generated in the study by Mathiowetz et al. (1986) to determine whether children with myelomeningocele have a statistically significant lower grip strength than those in the general population without disability. To the best of our knowledge, this is the first time that such a study has focused on the grip strength of children with myelomeningocele. It was hypothesized that a statistically significant difference ($\geq 1.64$) exists in the grip strength of the myelomeningocele group, divided by age and gender, as compared with that of the population without disability. The procedures to measure grip strength followed the methods of Mathiowetz et al. (1986) to more closely compare children with myelomeningocele and persons without disability.

Literature Review

Grip Strength in Children Without Disability

In the study by Ager et al. (1984), the grip strength of children 5 to 12 years of age was assessed with the adjustable Jamar dynamometer $^1$. The handle was adjusted to allow flexion at the metacarpophalangeal joints. Subjects rested their forearms on the table and were allowed to exert maximal effort once with each hand. Means and standard deviations were calculated. Results indicated that there is a steady increase in grasp strength that coincides with an increase in chronological age, that boys are stronger than girls, and that hand dominance is not a factor in grip strength.

Mathiowetz et al. (1986) reported grip strength norms for 470 children 6 to 19 years of age. Grip strength was evaluated with standards set forth by the American Society of Hand Therapists (ASHHT). The standard, adjustable-handle, Jamar dynamometer was used at the second position for all subjects. The dynamometer was calibrated to ensure correct measurements. The scores of three successive trials were recorded for each hand. Results were reponed by age and gender groups. The results of this study confirmed those found in the study by Ager et al. (1984).

$^1$Manufactured by J. A. Preston, PO Box 89, Jackson, Michigan 49201.

Upper Extremity Function in Children With Myelomeningocele

Numerous studies have documented that children with myelomeningocele suffer from a variety of fine motor difficulties. Grimm (1976) discovered that 14 out of 17 children had impaired hand function and 8 of the 14 had impaired tactile perception. In general, the higher the spinal cord lesion, the greater the hand dysfunction. In a study of children with myelomeningocele to determine the relationships among hand function, hydrocephalus, level of spinal cord lesion, and intellectual level, Sand, Taylor, Hill, Kosky, and Rawlings (1974) discovered that all children with hydrocephalus had deviant hand skills, as did a significant portion of children without hydrocephalus. Another study (Wallace, 1973) discovered that mobility was dependent on the level of the spinal cord lesion and how the severity of the hydrocephalus-induced spasticity affected upper extremity skills. Compared with the average scores of the formal evaluations of hand function performed on children without disability, the scores of children with myelomeningocele were an average of 41% lower (Turner, 1985). Mazur, Menelaus, Hudson, and Stillwell (1986) administered the Jebsen-Taylor Hand Function Test (Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969) to 143 people with myelomeningocele aged 8 to 35 years. On the whole, these subjects displayed impaired hand function, with higher level spinal cord lesions displaying the greater hand dysfunction. This study also demonstrated that the greater the number of shunt revisions, the greater the hand dysfunction.

Method

Subjects

All of the approximately 260 patients attending an interdisciplinary clinic for NTD and spinal cord injuries located at a major metropolitan pediatric hospital were included in the study. Part of this population's standard occupational therapy evaluation, conducted two to three times per year, is grip strength testing. For the purposes of this study, the grip strength of each subject was obtained during one of the regularly scheduled visits during a 2-year period. The data from patients who had diagnoses other than NTD, including lipocoeles and traumatic spinal cord injuries, along with patients younger than 6 and older than 19 years of age, were removed, leaving 49 males and 59 females, for a total of 108 subjects. Diagnoses included were myelomeningocele (with and without hydrocephalus) and caudal regression syndrome including sacral agenesis.

Procedure

As mentioned previously, clinical data, such as grip strength, manual muscle testing, coordination, perceptu-
al skills, and muscle tone, were evaluated after the completion of a standard verbal questionnaire dealing with activities of daily living and academic progress. The subjects were grouped into categories by gender and into 2-year age spans.

Bilateral grip strength was measured with the adjustable-handle Jamar dynamometer according to ASHT guidelines (Fess, 1982). Briefly, the procedure was as follows: the subject was seated with the shoulder adducted and neutrally rotated, the elbow flexed at 90°, and the forearm and wrist in a neutral position. The dynamometer was set at the second position for all subjects, identical to that used by Mathiowetz et al. (1986). The subjects were then verbally instructed to squeeze hard. A mean of three consecutive measurements was calculated to determine the grip strength.

The Jamar dynamometer was the instrument used to measure grip strength, not only because it was the one used by Mathiowetz et al. (1986), but also because it has been found to be the most reliable and accurate (+/-3%) instrument readily available (Mathiowetz, Weber, Volland & Kashman, 1984). The instrument was calibrated by the instrumentation technicians at the hospital to ensure accuracy. In an attempt to ensure validity and reliability of the measurements, one person, the first author, measured the grip strength of all subjects.

Results

Grip strength for the population without disability reported by Mathiowetz et al. (1986) and the average grip strengths measured in this study are shown in Tables 1 and 2. The data of Tables 1 and 2 clearly show that the mean grip strength of the group without disability is higher than that with myelomeningocele for all age groups except one (males, aged 14 to 15 years). Also in line with studies by others (Ager et al., 1984; Mathiowetz et al., 1986), the data indicate that grip strength increases with age and that males are consistently stronger than females.

In the male group, at ages 14 to 16 years, there is one anomaly in which the myelomeningocele group has a greater mean grip strength than the group without disability. This occurred because of a young man with a low-level spinal cord lesion (L5) and no other neurological deficits who participates in a body building program during his free time. This subject was retained in the data set to illustrate the wide variation in physical attributes in patients with myelomeningocele. Unfortunately, this age-gender group has only seven members, so the statistics for this group are significantly skewed because of this person.

Tables 1 and 2 also illustrate and duplicate important results of previous studies (Ager et al., 1984; Mathiowetz et al., 1986), that male and female grip strengths increase at approximately a parallel rate until about 12 to 14 years of age, after which the strength of males continues to increase and the strength of females tends to level off or increase at a much slower rate.

The range of grip strength reported in Tables 1 and 2 indicates greater variability in the study sample, with the low end tending to be much lower than that of the population without disability and the high end close to, or even below, the mean of the subjects without disability. The difference in the two populations is most pronounced with young males (below 12 years of age) and females in general, whereas the standard error of young adult males with myelomeningocele overlaps the standard error of the population without disability.

Tables 1 and 2 show that the standard deviation of grip strength is, in general, greater in the myelomeningocele group than in the group without disability, and that there is a wide difference in the standard deviations between the two groups. In the group without disability, the standard deviation tends to increase almost in proportion to age.

Table 1

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Hand</th>
<th>Subjects Without Disability</th>
<th>Subjects With Myelomeningocele</th>
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<tr>
<td></td>
<td></td>
<td>N</td>
<td>M</td>
</tr>
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<tr>
<td>18-19</td>
<td>L</td>
<td>33</td>
<td>105.0</td>
</tr>
</tbody>
</table>

Note: Data for children without disability from Mathiowetz et al. (1986). R = right, L = left.

*Denotes a statistically significant difference (|z| ≥ 1.64) between the subjects with myelomeningocele and the children without disability.
Table 2
Female Grip Strength for Children Without Disability and Subjects With Myelomeningocele

| Age (Years) | Hand | Children Without Disability | | | | Subjects With Myelomeningocele | | | |
|-------------|------|----------------------------|---|---|---|---|---|---|---|---|---|
|             |      | N  | M   | SD  | SEM | Range | N  | M   | SD  | SEM | Range | z-ratio |
| 6-7         | R    | 35 | 28.6| 4.4 | 0.8 | 20-39 | 11 | 15.9| 5.5 | 1.7 | 9-24 | -6.84^4 |
|             | L    | 35 | 27.1| 4.4 | 0.8 | 16-36 |    |      |      |     |      |         |
| 8-9         | R    | 35 | 35.3| 8.3 | 1.5 | 38-55 | 9  | 25.5| 10.9| 3.6 | 6-59 | -2.65^5 |
|             | L    | 35 | 33.0| 6.9 | 1.2 | 16-49 |    |      |      |     |      |         |
| 10-11       | R    | 40 | 47.9| 8.1 | 1.3 | 37-82 | 9  | 31.4| 15.6| 2.4 | 8-24 | -5.13^5 |
|             | L    | 40 | 45.2| 6.8 | 1.1 | 32-59 |    |      |      |     |      |         |
| 12-13       | R    | 36 | 50.6| 10.6| 1.8 | 39-79 | 9  | 30.4| 17.5| 3.5 | 10-67 | -2.36^4 |
|             | L    | 36 | 50.9| 11.9| 2.0 | 25-76 |    |      |      |     |      |         |
| 14-15       | R    | 34 | 58.1| 12.3| 2.1 | 30-93 | 8  | 47.1| 21.0| 4.6 | 9-66 | -1.64 |
|             | L    | 34 | 49.5| 13.9| 2.9 | 26-73 |    |      |      |     |      |         |
| 16-17       | R    | 35 | 67.3| 16.5| 2.8 | 23-12 | 10 | 50.1| 17.8| 5.6 | 17.86 | -2.70^4 |
|             | L    | 35 | 56.9| 14.0| 2.4 | 24-87 |    |      |      |     |      |         |
| 18-19       | R    | 30 | 71.6| 12.3| 2.2 | 46-90 | 3  | 47.2| 15.2| 3.8 | 32-62 | -2.70^4 |
|             | L    | 30 | 61.7| 12.5| 2.3 | 41-96 |    |      |      |     |      |         |

Note. Data for children without disability from Mathiowetz et al. (1986). R = right, L = left.

Denotes a statistically significant difference (|z| ≥ 1.64) between the subjects with myelomeningocele and the children without disability.

to age until about 16 years of age, when the standard deviations for males jump dramatically while those of the female subjects decrease slightly. In the group with myelomeningocele, there is no well-defined trend in the standard deviation, except that that of the male group increases at a much greater, if uneven, rate. There also seems to be a tendency for a larger standard deviation in the group with myelomeningocele, which can again be explained because of the small number of available subjects with myelomeningocele.

Data were further analyzed by calculating a z-ratio to determine the significance of the difference between the means of the population without disability and the group with myelomeningocele. A z-ratio was chosen for analysis because the study data were compared with published data without direct access to the raw data of the published study. Each age-gender mean value reported by Mathiowetz et al. (1986) was assumed to be the population value. The corresponding study sample by age-gender grouping was compared with the assumed population value with the z-test. A one-tailed test was used because it was hypothesized that the group with myelomeningocele would consistently show lower grip strength than the population without disability. The result of this analysis is shown in the last column of Tables 1 and 2. From this, one can conclude that the female sample group is statistically different with regard to grip strength in all age groups with the exception of the 12 to 15 years group. The male sample group is significantly different only up to 12 years of age. It appears that the male subjects with myelomeningocele catch up with the population without disability by age 12 years, whereas females with myelomeningocele continue to lag behind their counterparts without disability through their teenage years.

The F ratios were compared for the 14 sets of variances. Two of the 14 were significant. In one case the population variance was larger and in one case it was smaller. Given the numbers calculated, this is within the realm of chance. The size of the sample is used in calculating the standard error for the z-ratios. Because the sample size is small, the standard error of the mean is relatively large, as expected. There must be an exceptionally large difference between the population values and the sample values to obtain significance.

Discussion

Tables 1 and 2 illustrate that the population without disability and the group with myelomeningocele show statistically significant differences up to age 12 years for both males and females. At the 12 to 13 years age group, neither the male nor female components of the two populations are significantly different. Past the age of 12 years, the grip strength of the male population continues to be on a par with their counterparts without disability. The grip strength of females with myelomeningocele, however, lags behind that of the population without disability past the age of 12 and throughout the teenage years.

The mean grip strength was lower than that of the population without disability in all the subgroups of children with myelomeningocele except for the previously mentioned anomaly of the male 14 to 15 years age group.

It appears that grip strength tends to stabilize and follow the trends seen in the population without disability as the child with myelomeningocele reaches the teenage years. This may be due to less change taking place in their neurological systems. Before their teenage years, many children with myelomeningocele are subject to multiple shunt revisions, Arnold-Chiari decompressions, untheering of the spinal cord, scoliosis surgery, and other potentially traumatic orthopedic procedures that may influence
their upper extremity strength development.

The results of this study are similar to those obtained by other researchers (Anderson & Plewis, 1977; Brunt, 1980; Grimm, 1976; Hebert, 1987; Lottow, 1976; Mazur, Ayward, Colliver, Stacey, & Menglaus, 1988; Mazur et al., 1986; Sand et al., 1974; Sousa, Gordon, & Shurtleff, 1976; Turner, 1985; Wallace, 1973), indicating that children with myelomeningocele exhibit global impairment of hand function. The present study adds grip strength to the growing list of hand dysfunctions seen in children with myelomeningocele.

**Implications for Occupational Therapy**

Myelomeningocele is a serious birth defect involving the entire nervous system. The effect of the secondary neurological complications can be as devastating, or more, than the initial spinal lesion. These complications often have negative effects on hand strength, thereby limiting functional abilities. The functional areas most often affected are activities of daily living, fine motor skills (including those necessary for academic achievement, such as writing) and the use of mobility aids. However, it is often important to deduce the actual cause of the grip strength impairment. If the weakness is caused by secondary complications, neurophysiological approaches to the problem may prove more successful than a strengthening regime. Only if function is reduced because of weakness should grip strengthening be undertaken. Occupational therapy should include grip strengthening only if a weakness has been shown to limit functional skills and not for its own sake, that is, merely to achieve a level of strength established for the population without disability.

There are limitations in this study. Because the investigator performed all of the grip strength evaluations, it is possible that the investigator biased the experimental data, although care was taken to avoid such an occurrence. Such an occurrence is unlikely, because an objective instrument and a standard measuring technique were used. A more severe limitation was that the results, and in particular the statistical measures comparing the study group to the published norms, were affected by the limited size of the available myelomeningocele population.

Topics of future research in this area include a true matched study comparing subjects with myelomeningocele to those without disability, with a sufficiently large sample to dispel any doubts stemming from a too-small sample; an investigation of whether a strengthening program will actually be effective in improving the grip strength of a myelomeningocele population; a quantitative investigation of how reduced grip strength adversely affects functional skills; and an investigation of whether grip strength is affected by secondary neurological complications and of whether, if the secondary complications are significant, impairment can be predicted.

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