Grip and Pinch Strength: Norms for 6- to 19-Year-Olds

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Grip and Pinch Strength: Norms for 6- to 19-Year-Olds

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Key Words: hand • hand strength testing • manual strength • motor skills • tests

The purpose of this study was to establish normative data for 6- to 19-year-olds on four tests of hand strength. The Jamar dynamometer was used to measure grip strength and a pinch gauge was used to measure tip, key, and palmar pinch. A sample of 231 males and 240 females from the seven-county Milwaukee area was tested, using standardized positioning and instructions. Results of this study indicate that increases in grip and pinch strength coincide with increases in chronological age, that males are stronger than females in all age groups, and that hand dominance does not significantly affect hand strength scores. Normative data collected in this study were slightly higher than norms from previous American and Australian studies.

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The collection of reliable and valid evaluation data depends on the use of accurate test instruments that have standardized procedures for their administration. In addition, normative data assist in interpreting evaluation results and in setting realistic treatment goals. Mathiowetz, Weber, Volland, and Kashman (1984) recently developed standardized procedures for grip and pinch strength evaluations which were reported to be reliable and accurate. Grip and pinch strength norms have been collected for adults 20 to 75 years old and older (Mathiowetz, Kashman, Volland, Weber, Dowe, & Rogers, 1985), but there are no such norms for 6- to 19-year-olds that are based on these standardized procedures.

Review of the Literature

Grip Strength Evaluation

Ager, Olivett, and Johnson (1984) recently reported grip strength norms for children aged 5 to 12 years ($N = 474$). They evaluated grip strength by adjusting the Jamar dynamometer to fit the hand, allowing flexion at the metacarpophalangeal joints. Another recent study also using the Jamar dynamometer reported norms for 240 Australian children aged 5 to 12 years (Fullwood, 1986). The dynamometer was set at the smallest setting for subjects aged 5 to 8 years and at the second smallest setting for subjects aged 9 to 12 years. Kellor, Frost, Silberberg, Iverson, and Cummings (1971) also used the Jamar dynamometer in their study of 250 adults aged 20 to 84 years and adjusted it to fit the subject's hand. Previous studies have shown that grip strength varies with different handle positions (Bechtol, 1954; Fess, 1982). Norms based on several positions make it difficult for a clinician to decide which position to use and how to interpret a patient's performance. If inconsistent positions are used to assess progress in treatment, a change in grip reading may be erroneously interpreted as an advance or a decline in progress (Fess, 1984).

In the study by Ager et al. (1984), subjects were instructed to rest their forearm on a table and to exert one maximal effort first with the right hand and then with the left hand. Fullwood (1986) instructed subjects to sit with their elbow on a table but their wrist off the table. One trial was recorded for each hand. Kellor et al. (1971) gave subjects two opportunities to exert their most forceful grip with each hand, and the two highest measurements were recorded. Subjects were permitted to flex or extend their elbows provided that neither the dynamometer nor their arm touched their body. The American Society of Hand Therapists (ASHT) suggests standardized arm positioning for hand strength tests. Specifically they recommend that patients sit with their shoulder adducted

Table 1
Characteristics of Subjects: Age, Sex, and Hand Dominance (*N* = 471)

Age	No. of Males	Dominance		No. of Females	Dominance	
		Right	Left		Right	Left
6–7	26	21	5	33	28	5
8–9	30	26	4	32	27	5
10–11	43	39	4	40	36	4
12–13	34	25	9	36	32	4
14–15	34	32	2	34	28	6
16–17	31	27	4	35	30	5
18–19	33	27	6	30	26	4
Total	231	197 (85%)	34 (15%)	240	207 (86%)	33 (14%)

and neutrally rotated, elbow flexed to 90°, and the forearm and wrist in neutral position (Fess & Moran, 1981). A recent study (Mathiowetz, Rennells, & Donahoe, 1985) clearly supports the ASHT recommendations that elbow position affects grip strength. The results of two conditions, elbow flexed to 90° and elbow fully extended, showed a significantly stronger grip strength measurement in the 90° elbow flexed position than in the fully extended position. In another study, Mathiowetz et al. (1984) used standardized procedures (i.e., subject position and instructions) to assess the reliability and accuracy of grip and pinch strength evaluations. The highest test-retest reliability for each test was achieved when the mean of three trials was used.

None of the normative data studies for grip strength (Ager et al., 1984; Fullwood, 1986; Kellor et al., 1971), except Mathiowetz et al. (1984) and Mathiowetz, Kashman, Volland, Weber, Dowe, and Rogers (1985), reported that specific verbal instructions were given to subjects during the evaluations. Fullwood gave subjects verbal encouragement during the evaluation, but it is not clear what type of verbal encouragement or whether it was consistent for all subjects. It is believed that the verbal instructions can affect performance on evaluation tests (Davis, 1974).

Pinch Strength Evaluations

There are various operational definitions for the different types of pinch. Burmeister, Flatt, and Weiss (1974) defined palmar pinch as thumb pad to each individual finger pad, whereas Kellor et al. (1971), Ager et al. (1984), and Fullwood (1986) defined it as thumb pad to pads of the index and middle fingers. The latter definition was used in this study. Ager et al. defined lateral pinch as the pad of the thumb against the lateral surface of the index finger. Burmeister et al. and Fullwood defined lateral pinch as thumb against the radial side of the proximal interphalangeal joint of the index finger, whereas Kellor et al. defined it as the pad of the thumb against the radial side of the index finger between the distal and proximal interphalangeal joint. The ASHT (Fess & Moran, 1981) referred to the latter as key pinch and defined tip pinch as thumb tip to index finger. The recommendations of the ASHT, developed to avoid further confusion over terminology, were followed in this study.

Burmeister et al. (1974) established pinch strength norms in 5- to 13-year-olds and assessed the relationship between hand size and pinch strength. The forearm of each subject was pronated while pinch

Table 2
Average Performance of Normal Subjects on Grip Strength (lb)

Age	Hand	Males			Females		
		Mean	*SD*	Range	Mean	*SD*	Range
6–7	R	32.5	4.8	21–42	28.6	4.4	20–39
	L	30.7	5.4	18–38	27.1	4.4	16–36
8–9	R	41.9	7.4	27–61	35.3	8.3	18–55
	L	39.0	9.3	19–63	33.0	6.9	16–49
10–11	R	53.9	9.7	35–79	49.7	8.1	37–82
	L	48.4	10.8	26–73	45.2	6.8	32–59
12–13	R	58.7	15.5	33–98	56.8	10.6	39–79
	L	55.4	16.9	22–107	50.9	11.9	25–76
14–15	R	77.3	15.4	49–108	58.1	12.3	30–93
	L	64.4	14.9	41–94	49.3	11.9	26–73
16–17	R	94–0	19.4	64–149	67.3	16.5	23–126
	L	78.5	19.1	41–123	56.9	14.0	23–87
18–19	R	108.0	24.6	64–172	71.6	12.3	46–90
	L	93.0	27.8	53–149	61.7	12.5	41–86

Note: The mean scores for individuals, aged 14 to 19 years, may be slightly low (0–10 lb lower than they should be) due to instrument error detected after the study.

strength was tested. Kellor et al. (1971) and Fullwood (1986) also tested pinch strength with the subject's forearm pronated, and only one opportunity was given to exert maximum effort. Ager et al. (1984) used the Preston pinch gauge, and one maximal force was exerted for each measurement. Fullwood and this study used the pinch gauge by B & L Engineering Co. because it has been reported to be more accurate than the Preston pinch gauge (Mathiowetz et al., 1984). For pinch strength evaluations, the ASHT recommended positioning the forearm in the neutral or midposition and recording the mean of three trials.

The purpose of this study was to establish grip and pinch strength norms for 6- to 19-year-olds and to describe the effects of age, sex, and hand dominance on hand strength.

Methods

Subjects

Subjects, 231 males and 240 females, who ranged in age from 6 to 19 years, attended schools in the seven-county Milwaukee area. All subjects were divided into seven 2-year age groups (see Table 1) and were free from disease or injury that could affect their upper extremity strength. Individuals with learning disabilities were excluded from the study.

Procedures

A brief interview preceded all testing to determine whether or not subjects met the criteria. This study was part of a larger study of hand strength and dexterity that included the Box and Block Test (Mathiowetz, Federman, & Wiemer, 1985). The hand strength testing followed the dexterity testing. Grip strength was tested first, followed by tip (2-point) pinch, key (lateral) pinch, and palmar (3-point pad) pinch. The operational definition of each type of pinch has been previously reported (Mathiowetz et al., 1984). For each test of hand strength, the subjects were seated with their shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in neutral position, and wrist between 0° and 30° dorsiflexion and between 0° and 15° of ulnar deviation (Fess & Moran, 1981; Mathiowetz et al., 1984). For each strength test, standard instructions were followed, and the scores of three successive trials were recorded for each hand (Ma-

Figure 1
A Comparison of Mean Key Pinch Strength Scores of Males and Females, Aged 6–19 Years

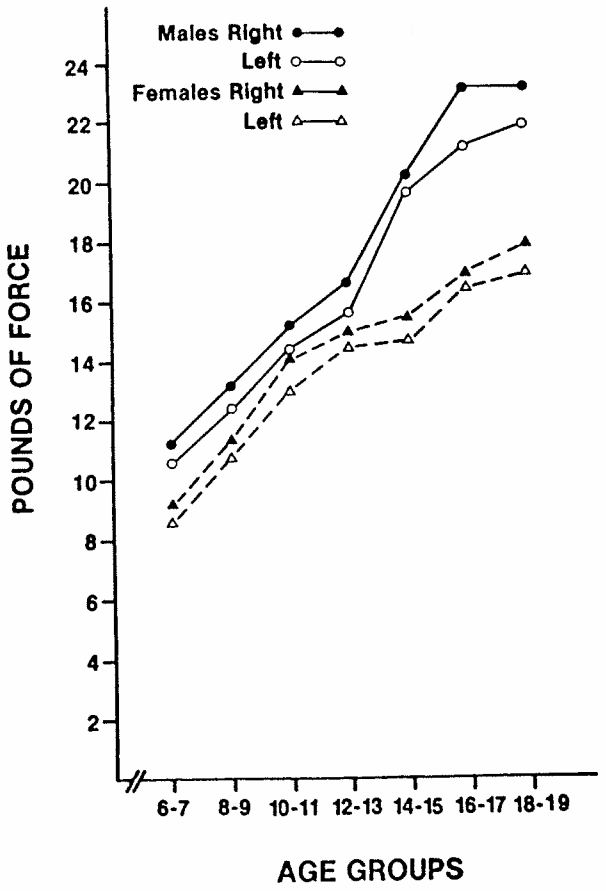


Table 3
Average Performance of Normal Subjects on Tip Pinch (lb)

		Males			Females		
Age	Hand	Mean	*SD*	Range	Mean	*SD*	Range
6–7	R	7.2	1.6	4–10	6.7	1.2	4–10
	L	7.1	1.4	5–11	6.1	1.5	3–10
8–9	R	8.6	2.2	6–17	7.6	1.4	5–10
	L	8.3	2.2	4–15	7.2	1.3	5–10
10–11	R	10.0	2.4	5–16	9.7	1.4	7–13
	L	9.5	2.3	5–16	9.4	1.7	6–12
12–13	R	10.5	2.5	5–14	10.6	2.2	6–17
	L	9.8	2.3	5–13	10.1	2.3	5–17
14–15	R	13.1	2.9	8–20	10.2	2.3	5–15
	L	12.6	3.0	6–18	9.5	2.4	4–17
16–17	R	15.0	2.7	11–21	11.9	2.3	9–19
	L	13.8	2.7	7–22	11.1	2.3	7–17
18–19	R	17.0	3.8	10–31	13.5	2.8	7–20
	L	16.1	3.8	11–29	13.4	2.9	8–20

Table 4
Average Performance of Normal Subjects on Key Pinch (lb)

		Males			Females		
Age	Hand	Mean	*SD*	Range	Mean	*SD*	Range
6–7	R	11.3	2.0	7–16	9.6	1.5	6–12
	L	10.6	2.1	4–15	9.1	1.5	5–11
8–9	R	13.1	2.6	9–18	11.6	2.6	8–23
	L	12.2	2.5	8–20	11.3	2.1	8–20
10–11	R	15.3	3.1	9–22	14.2	2.1	11–21
	L	14.5	2.9	9–22	13.3	2.0	11–19
12–13	R	16.6	2.9	11–22	15.2	2.6	11–22
	L	15.6	2.8	10–21	14.1	3.0	10–23
14–15	R	20.9	3.8	14–32	15.6	2.5	12–22
	L	19.9	3.7	12–26	14.8	2.7	7–22
16–17	R	23.3	3.4	14–31	17.3	3.0	12–27
	L	21.8	3.6	13–30	16.6	3.1	11–25
18–19	R	23.5	4.1	17–34	18.1	2.4	12–23
	L	22.9	4.0	14–33	17.2	2.5	12–22

thiowetz et al., 1984; Mathiowetz, Kashman, Volland, Weber, Dowe, & Rogers, 1985).

Equipment

The standard adjustable-handle Jamar dynamometer was used (Mathiowetz et al., 1984; Kirkpatrick, 1956) and was set at the second position for all subjects. It was held lightly around the readout dial by the examiner to prevent inadvertent dropping.

The B & L pinch gauge (0–60 lb), which measures tip, key, and palmar pinch, was held by the examiner at the distal end to prevent it from being dropped. Scores were read on the needle side of the red readout marker. The calibration of both instruments was tested periodically during the study (Mathiowetz et al., 1984).

Results

Descriptive data (see Tables 2–5) on male and female subjects indicate that hand strength increases with chronological age and that males are stronger than females on all tests for all age groups. A two-way analysis of variance, along with Scheffé post hoc procedures, showed that there were significant hand strength differences among the different age groups and different sexes for all four hand strength tests with the right and left hands (see Table 6). The Scheffé comparisons (see Table 7) more specifically show the hand strength differences among the age groups. In all cases there were significant differences in hand strengths between the 8- to 9-year-old and the 10- to 11-year-old age groups. There were no other consistent patterns of differences. However, the 10- to 11-year-old and 12- to 13-year-old age groups did not show significant hand strength differences in all cases. The pattern of scores in Figure 1 compares male and female key pinch strength scores for each age group. Male and females scores increase at a parallel rate from 6 to 13 years of age. However, the scores of 14- to 19-year-old males increased rapidly, whereas the scores of 14- to 19-year-old females increased gradually. This pattern of scores is also seen for tip pinch, palmar pinch, and grip.

To evaluate the effects of hand dominance, the average scores of right-handed subjects were compared to left-handed subjects using an independent *t*

Table 5
Average Performance of Normal Subjects on Palmar Pinch (lb)

		Males			Females		
Age	Hand	Mean	*SD*	Range	Mean	*SD*	Range
6–7	R	10.0	2.2	5–13	9.0	1.7	6–12
	L	9.2	2.0	5–13	8.4	1.4	6–11
8–9	R	11.6	2.3	7–17	10.7	2.1	8–17
	L	11.2	2.8	6–16	10.3	2.2	6–20
10–11	R	13.9	2.7	7–21	13.5	2.2	11–22
	L	13.2	2.9	8–23	12.6	2.0	10–17
12–13	R	15.5	3.6	8–26	15.4	2.6	11–23
	L	15.1	4.1	8–23	14.2	2.8	10–20
14–15	R	19.2	4.2	11–28	15.6	3.3	9–26
	L	18.8	5.0	10–33	14.7	3.4	8–25
16–17	R	22.2	5.0	17–39	17.8	3.9	12–27
	L	20.3	4.1	14–31	16.6	3.9	10–26
18–19	R	23.8	4.3	17–34	20.2	3.3	10–26
	L	23.4	4.5	16–34	19.0	3.0	14–25

Table 6
Two-Way (age × sex) Analysis of Variance for Each Hand Strength Test

Variables	*F* Values for Factors		
	Age ($df = 6$)	Sex ($df = 1$)	Age × Sex ($df = 6$)
Right grip	166.68**	146.68**	13.79**
Left grip	97.93**	101.67**	8.31**
Right tip	95.46**	60.19**	5.11**
Left tip	85.88**	51.49**	4.10**
Right key	119.48**	157.15**	7.59**
Left key	113.46**	144.69**	7.19**
Right palmar	125.51**	51.59**	3.81**
Left palmar	109.62**	60.39**	2.95*

* $P<.01$. ** $P<.001$.

test ($p<.05$ level of significance). There were no significant differences between right- and left-handed subjects on any of the hand strength tests. Consequently, scores of right- and left-handed subjects were combined in Tables 2 to 5.

Discussion

Previous studies on children (Ager et al., 1984; Bowman & Katz, 1984; Broadhead, 1975; Burmeister et al., 1974; Fullwood, 1986) have established that there is a positive relationship between hand strength and age. This was confirmed in this study for ages up through 19 years. Likewise the finding that male hand strength scores are higher than female scores was consistent with previous studies (Ager et al., 1984; Fullwood, 1986), except for Bowman and Katz who reported that male grip strength is significantly stronger in the left hand but not the right hand of 6- to 9-year-olds.

The nonsignificant effect of hand dominance was consistent with two recent studies (Ager et al., 1984; Fullwood, 1986). However, this contradicts findings of an earlier study (Burmeister et al., 1974), where the left hands of left-handed subjects were significantly stronger than the left hands of right-handed subjects for palmar and lateral (key) pinch. The contradictory results may be due to methodological differences or the small number of left-handed subjects in all of these studies.

That the mean scores in this study were consistently higher in all age groups than the mean scores of previous studies (Ager et al., 1984; Bowman & Katz, 1984; Burmeister et al., 1974; Fullwood, 1986) can be explained by various testing procedures that were used. For example, each study used different arm positions and verbal instructions and different numbers of trials for collecting data. The different age groupings might also be a factor. For example, the ages of Australian subjects (Fullwood) were recorded in years and months and then rounded off to the nearest year. It is assumed that these subjects were grouped approximately one-half year younger than the subjects in this study. Burmeister et al. grouped subjects by grade, whereas Ager et al. and this study grouped subjects by age. Different schooling experiences and cultural experiences (e.g., leisure habits, mobility, organized sports, etc.) may also affect scores. Regional differences (e.g., Denver versus Milwaukee) might also be a factor. Fullwood and Ager et al. used the same tester during the evaluations, whereas Burmeister et al. used an unknown number of volunteer therapists from different areas of the United States. Our study used eight testers trained to use standardized procedures that have high interrater reliability (Mathiowetz et al., 1984). The calibration of the dynamometer was checked in our study and in Fullwood's study. Burmeister et al. and Ager et al. did not report calibration of their instruments. Sampling error might also be a factor causing these higher scores. Within the schools selected, a sample of convenience was used in our study, whereas Fullwood and Bowman and Katz (1984) used random samples.

Grip Strength

Grip strength scores were consistently higher in this study than in two previous studies (see Figure 2), and data from this study were divided into 1-year age groups for easier comparison with similar data from previous studies (Ager et al., 1984; Fullwood, 1986). Fullwood's scores were generally higher than those of Ager et al. for 5- to 8-year-olds, whereas the scores

Figure 2
A Comparison of Mean Grip Strength Scores of Males and Females, Aged 5–13 Years

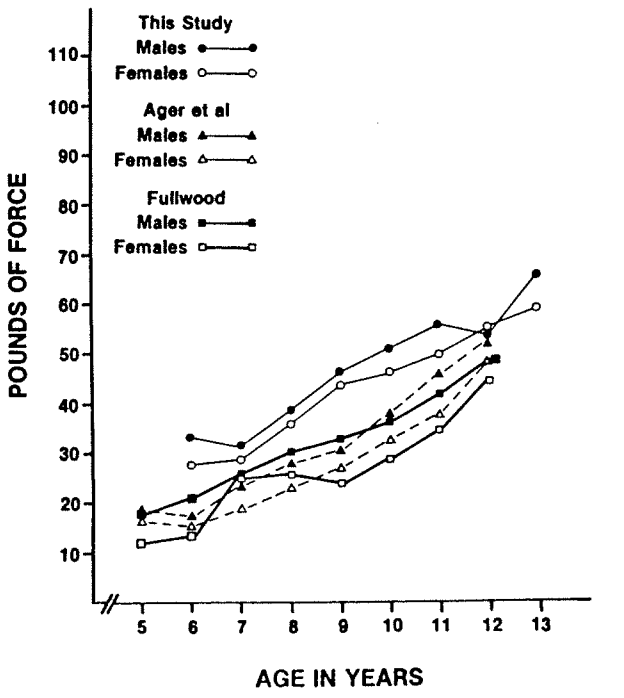


Table 7
Summary of the Scheffé Post Hoc Procedures for the Seven Age Groups

Variable	Age Group Comparisons
Right grip	1 2 < 3 4 < 5 < 6 < 7
Left grip	1 2 < 3 4 5 < 6 < 7
Right tip	1 2 < 3 4 5 < 6 < 7
Left tip	1 2 < 3 4 5 6 < 7
Right key	1 < 2 < 3 4 < 5 < 6 7
Left key	1 < 2 < 3 4 < 5 6 7
Right palmar	1 2 < 3 4 5 < 6 < 7
Left palmar	1 2 < 3 4 < 5 6 < 7

NOTE: Comparisons reported above are for adjacent age groups only. All other possible comparisons (e.g., 1 vs. 3, 1 vs. 7, etc.) were significant ($p<.05$).
Group 1 = 6–7-year-olds. Group 2 = 8–9-year-olds. Group 3 = 10–11-year-olds. Group 4 = 12–13-year-olds. Group 5 = 14–15-year-olds. Group 6 = 16–17-year-olds. Group 7 = 18–19-year-olds.
The symbol < indicates significant differences between age groups ($p<.05$) and underlining indicates no significant differences between age groups.

of Ager et al. were higher for 10- to 12-year-olds. Fullwood's grip strength scores were higher than the scores of Ager et al. in 6 out of 16 age comparisons. Although all three studies used the Jamar dynamometer, each study had different criteria for setting the handle size. This variable, as well as those previously mentioned, may have affected the results.

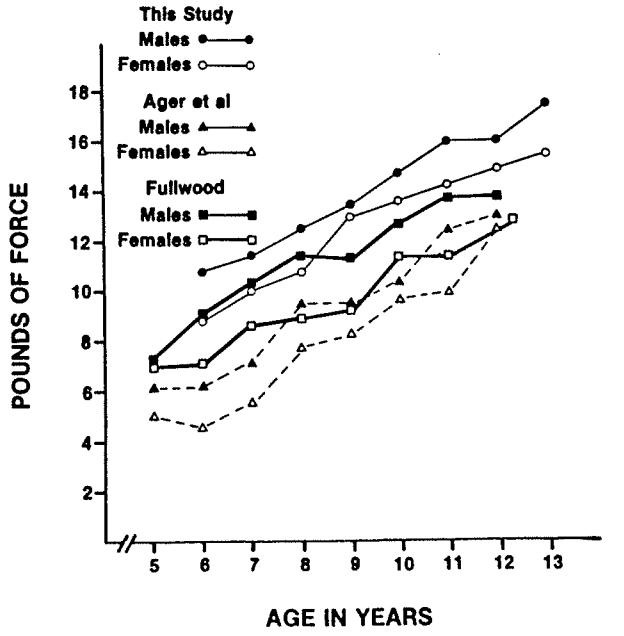
Pinch Strength

Pinch strength scores in this study were also higher for each age group than those scores of previous studies (Ager et al., 1984; Fullwood, 1986). This pattern is illustrated in Figure 3 for key pinch. The use of different pinch gauges (B & L Engineering versus Preston pinch gauge) could affect pinch strength scores. Fullwood calibrated the pinch gauge and reported that the error of the pinch meter recording below the true pressure applied was up to 10%. This might explain the lower scores in this study. The various operational definitions used for each pinch type could also affect the scores. Because of the many differences in these studies, conclusions should be made with caution.

This study has some limitations. A sample of hand strength of a Milwaukee area population may not be representative of hand strength throughout the United States. A study using the same standardized procedures in another area of the country is needed. Because of time and financial constraints, subjects were not selected randomly and the sample was relatively small. While testing tip pinch for this study, some subjects had difficulty maintaining the position as they were pinching (i.e., index finger or thumb would hyperextend and/or would slip off the pinch gauge). This difficulty has been reported by Mathiowetz, Kashman, Volland, Weber, Dowe, & Rogers (1985) and Swanson, Göran-Hagert, and DeGroot (1984). When these problems were encountered, subjects were tested as close as possible to the recommended position. The standard Jamar dynamometer was recently modified by moving the calibration screw to the center of the readout dial. The newer model was calibrated in the same way as previously reported (Mathiowetz et al., 1984). This slight modification was not anticipated to affect the scores, but when the newer model was compared to the older model (with the calibration screw off-center), it read significantly lower (Flood, Joy, & Mathiowetz, in press). Asimow Engineering identified insufficient lubrication as the cause of the lower scores. Since the new model was used in testing about 40% of the subjects, aged 14 to 19 years, only their scores were affected. Consequently, the grip strength norms for 14- to 19-year-olds (see Table 2) may be slightly lower. Therapists are cautioned to carefully check the calibration accuracy of the Jamar dynamometer. Additional research is needed to further check the calibration accuracy of the Jamar or alternate dynamometers. Future research is also needed to test the effect of forearm position (midposition versus pronation) on pinch strength.

To reliably use the normative data from this study, the following recommendations are made: (a) follow standard positioning and instructions; (b) use the average of three trials; (c) use the dynamometer and pinch gauge previously described; (d) check the calibration of the instruments regularly; and (e) use the same test instrument in pre- and posttesting.

Figure 3
A Comparison of Mean Key Pinch Strength Scores of Males and Females, Aged 5–13 Years



Summary

Standard positioning and instructions were used to establish grip and pinch strength norms for 6- to 19-year-olds. The conclusions of this study were in agreement with those of two similar studies; both grip and pinch strength increase steadily with chronological age, and males are consistently stronger than females within each age group. The differences in the reported normative data of the three studies were attributed to the different test procedures used for each study. The normative data reported in this study will provide therapists and physicians a means for comparing a patient's score with the scores of normal individuals of the same age and sex.

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