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# The Ab-Adductometer: A New Device for Measuring the Muscle Strength and Function of the Thumb

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**ABSTRACT**: The purpose of this study was to present normative values for thumb abduction and adduction and also to present measures of reliability of the measuring system arising from the use of the Ab-Adductometer. With the Ab-Adductometer, we obtained abductor and adductor measurements of intrinsic muscle strength of the healthy hand thumb in 600 volunteers. Handgrip strength values were obtained with the Jamar dynamometer. Age and male—female specific reference ranges for the Ab-Adductometer and the Jamar dynamometer are presented. This study, with a very large number of volunteer subjects, 600, presents reference ranges for pure palmar adduction and abduction of the thumb. The results indicate that the Ab-Adductometer is a clinically useful device for the purpose of quantitatively measuring thumb adduction and abduction strength at various starting angles of thumb abduction relative to the plane of the palm. The device may be especially helpful in the evaluation of compressive neuropathies of the median or ulnar nerves such as carpal tunnel syndrome or cubital tunnel syndrome as well as for primary disease of the peripheral nerves that affect intrinsic muscles and for thumb function in proximal conditions such as tetraplegia and brachial plexopathy.
J HAND THER. 2007;20:311–25.

Despite great technological advancements in the field of hand surgery and hand therapy over the past 25 years, grip and pinch strength and manual muscle testing are the only commonly used ways to quantitatively measure muscle strength in the hand. Subtle variations in the assessment of these measurements are commonly used to make assessments of the strength and weakness in the hand that may be due to primary muscle pathology, nerve and motor endplate disease, or disorders of bone and joint. For the grip meter, these variations include varying the grip settings to invoke intrinsic vs. extrinsic motor units or a combination of both.[1,2] Also, variations in pinch such as tip, chuck, or key pinch are commonly used to mimic various activities of daily living. The data obtained from these measurements are extensively used in hand surgery/therapy research, daily clinical practice, and by the medico-legal and workers compensation communities as part of disability and return to work assessments.

The inherent limitation in these tests lies in the fact that both of these testing modalities evaluate muscle groups that are innervated jointly by the median and ulnar nerves. Grip strength is a composite function with contributions from all the palmar digits as well as synergistic firing of intrinsic and extrinsic digital flexors. The extrinsic flexors of the hand, the superficialis and profundus groups are dually innervated in the forearm; the intrinsic flexors, the interosseii the lumbricals to the fourth and fifth digits are primarily ulnarly innervated; and the radial two lumbricals are median innervated.[3,4] With pinch strength, the same issues exist.[2]

The simple act of pinch uses every thenar muscle to a greater or lesser extent. Recently, a study[5] focused on the relative contributions of the median and ulnar nerve to pinch and grip strength. This article explored the effect of selective median and ulnar nerve blocks at the wrist. This study, consisting of 21 subjects, focuses on the relative loss of grip and pinch strength

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doi:10.1197/j.jht.2007.07.010

from a starting control point without consideration for age or weight. There was a considerable loss of grip and pinch strength with selective median or ulnar nerve block; however, pinch and grip strength cannot specifically correlate with either median or ulnar nerve deficiency. Even the original normative values for pinch and grip presented by Mathiowitz et al.[1] show only a fair correlation to age and there was no mention of patients' weight as a factor. Thus, grip and pinch strength can only be used as relative values such as a baseline against which subsequent measurements over time can be compared.

Traditionally, the evaluation of the hand has focused on inspection of the thenar and hypothenar eminences for atrophy or more specifically for atrophy of the abductor pollicis brevis (APB) in median neuropathy and the first dorsal interosseus in ulnar neuropathy. Tests such as the Froment's sign[6] (adduction weakness and overcompensation by the flexor pollicis longus [FPL] and extensor pollicis longus [EPL]) and observable weakness to palmar abduction of the thumb are universally considered indicators of weakness due to pathology in the ulnar nerve and median nerve, respectively. The EPL is considered a weak thumb adductor and contributes to no more than 10% to the strength of that function.[7] Thus, it is generally recognized these maneuvers isolate the motor function of ulnar and median nerves. Unfortunately, these tests are qualitative only and are subject to observer bias. There currently exists no clinically useful way of quantitatively measuring thumb adduction and abduction jointly. An ability to do so would allow one to measure subtle weakness in specific muscle groups according to innervation and to track these measurements over time. This would be especially helpful in the evaluation of compressive neuropathies of the median or ulnar nerves such as carpal tunnel syndrome or cubital tunnel syndrome. Primary disease of peripheral nerves that affect intrinsic muscles such as Charcot-Marie-Tooth could be tracked in this manner. Thumb function in proximal conditions such as tetraplegia and brachial plexopathy could be followed. Isolated injuries to the median and ulnar nerve, either partial or complete, could be evaluated as a baseline and more importantly postoperative recovery could be assessed over time.[8]

## PURPOSE OF THE STUDY

The purpose of the study is to present normative values for thumb abduction and adduction and also to present measures of reliability of the measuring system arising from the use of the Ab-Adductometer, a new device, not yet commercially available, designed to assess pure palmar adduction and abduction of the thumb. Its design and concept will be illustrated and normative values, derived from 600 volunteers, for thumb adduction and abduction will be presented.

## INSTRUMENTATION

The device we used to measure thumb strength is the Ab-Adductometer. This is designed to quantitatively assess the human thumb's muscle ability to come out of the plane of the palm in a straight line in abduction and to retrace that path back to the palm in adduction (Figure 1). The device has three basic components: 1) A base that includes digital display, a 50 pound (lb) load cell, separate circuitry to determine direction of the force, a pound/kilogram converter, and a zeroing calibrator. The display is capable of tracking numerically the force created by the thumb in real time and can be frozen at peak force, 2) A vertical palm press to stabilize the metacarpals to isolate thumb function, and 3) A cross beam housing with an adjustable thread to vary the angle of abduction and a suspended force ring to house the thumb being tested. During each test of muscle strength, the position of the ring is fixed and there is no perceptible motion so that a true isometric contraction is performed. Grip strength was measured using a calibrated Jamar dynamometer in the "third handle position.[1]"

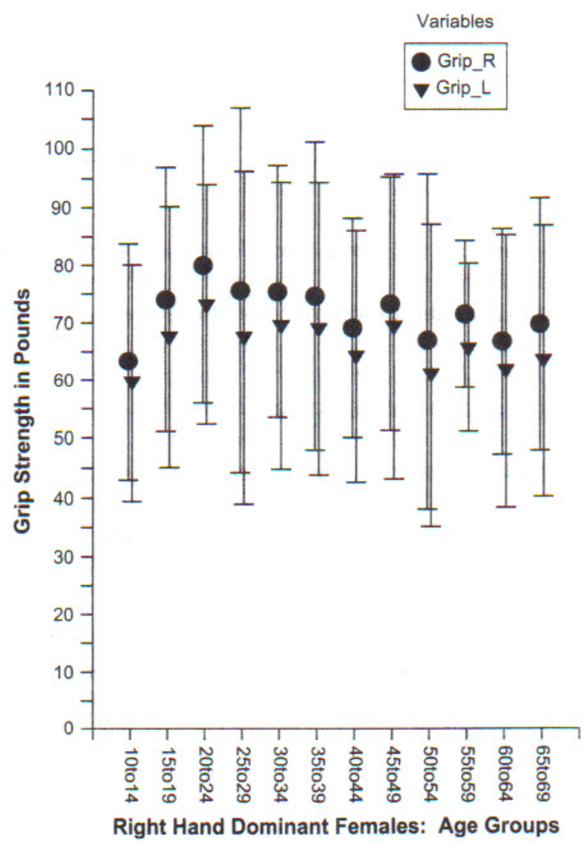


*FIGURE 1. Grip strength for right-hand–dominant females. Means and 95% confidence limits for right and left grip by age groups.*

## MATERIALS AND METHODS

### Subjects

Men and women were recruited to voluntarily participate in a measure of thumb strength using the Ab-Adductometer. There were 294 males and 302 females. Their ages ranged from 10 to 69 years. Subjects were recruited from a busy ophthalmology practice waiting room and were evaluated by a neutral examiner. Subjects were excluded from participation if they reported a previous or current history of hand injuries or hand surgery or if they reported the presence of any symptoms in their hands such as numbness, tingling, weakness, or pain. The hands were examined and seemed to be free of any gross anomalies, deformities, or disabilities. Informed consent was obtained from each subject.

### Muscle Testing

The subjects' name, age, gender, hand dominance, and weight were recorded. Hand dominance was determined by asking "Are you right handed or left handed?" The dominant hand was tested first.

Before each test run, the machine is recalibrated to zero. The subject's elbow rests on a cushion. The elbow is flexed to 90° and the forearm rotation is set at neutral. The wrist is extended to 30° so as to lock the palm and the thumb into the device. The palm of the hand is secured against a rigid flat bar by an adjustable padded vertical platform that is screwed into place by the threaded knob on the side. Digits 2 through 5 are locked in about 30° of flexion at the metacarpophalangeal joints. The proximal and distal interphalangeal joints are held in full extension. The thumb is encased in a fitted rigid plastic bushing placed at the level of the interphalangeal joint and then inserted into the metal ring (Figure 1). The force-ring distance from the upright palm restraint may be varied so that the thumb is positioned at 30°, 45°, or 60° palmar abduction. The static angle of thumb abduction is assessed with a manual goniometer. When the thumb pushes the force ring, either toward or away from the palm, the force is transferred to the ring, which in turn is attached to a screw (Figure 1). (During testing, the ring does not move and thus isometric thumb strength is measured.) This screw pushes or pulls a pivoted beam, which in turn pushes or pulls on the load cell. The load cell is supplied with a constant low voltage, which is set to zero when no force is present. When a force is applied, the load cell records the force whose value is read out on the digital display. The display is configured so that the subject could not see the numbers. Subjects rested for 1 minute between tests.

Readings on the Ab-Adductometer were taken only once, with the exception of 50 subjects from which multiple measures (three) were taken to assess the reliability of the device.

### Abbreviations

The abbreviations used are AB for abductor, AD for adductor, R for right hand, L for left hand, 45 for the 45° readings. Thus, ABR45 means abductor readings taken on the right hand at the 45° setting, etc.

### Data Analysis

There were 294 males and 302 females. Ages ranged from 10 to 69 years. Age was divided into 12 groups, each covering a five-year period and each containing more than 20 subjects.

For each age group, for each hand, and for each gender, we present basic statistics, mean, standard deviation, range, and confidence intervals for abductor and adductor readings. These will serve as normative values for the Ab-Adductometer. In addition, statistical graphs, box-and-whisker plots, and confidence interval charts present the reader with immediate visual appreciation tools for the nature and trend of the data.

## RESULTS

### Reliability

Sixty subjects, 32 females and 28 men, ranging in age from 18 to 60 years, were tested three times with 1 minute resting periods apart. Readings were taken for ABR45, ABL45, ADR45, and ADL45. The measure of agreement or reliability or within-subject repeatability used is the intra-class correlation coefficient (ICC), Bartko and Carpenter.[9] The ICC has an upper value of 1.0 for perfect agreement that is where for each subject the measures are identical. Its lower value is zero. The ICC's are 0.92 for ADL45, 0.89 for ADR45, 0.80 for ABR45, and 0.73 for ABL45. These are excellent values and fall within established guidelines reported by Landis and Koch,[10] where values of 0.81 to 1.00 are reportable as "Almost Perfect" and values from 0.61 to 0.80 as "Substantial."

### Correlations

We computed the correlations of age and height with GripR, GripL, ABR45, ABL45, ADR45, and ADL45. Although many reports for strength reference studies report values only by age groupings, we found that age actually has little association with the strength measures. For example, the correlation of age with GripR, GripL, ABR45, ABL45, ADR45, and ADL45 had the Pearson product moment correlations ranging from −0.1 to +0.03, not statistically significant. Contrastingly, the correlations of weight with

GripR, GripL, ABR45, ABL45, ADR45, and ADL45 ranged from 0.43 to 0.57, with statistical significance. Because there is such a strong relationship of weight with the strength measures and a very weak one with age, we propose that one may consider reporting and using normative strength values per weight groupings, rather than by age groupings as is most commonly done. In this report, we present normative values by both weight and age groupings for the interested reader.

The correlation of GripL and GripR with the four AB and AD readings ranged from 0.67 to 0.78, highly statistically significant. The correlation of the four AB and AD values among themselves ranged from 0.55 to 0.85, also statistically significant.

## Grip Strength by Age Groupings

Figures 1 and 2 illustrate grip strength in right-hand–dominant females and males per age groups. Grip strength in right-hand–dominant men increases to the 20- to 30-year period to a value of about 125 lb and then slowly decreases to about 90 lb by age 65–69 years. Within each age class, the grip can vary by as much as 35 lb. This holds true for right and left hands. For males, the average grip strength for all subjects is 105 lb for the right hand and 98 lb for the left. This 6-pound difference (95% confidence interval 5.5 to 7.1) is statistically significant because of the large group size. Paired t (274) = 15.4, $p < 0.001$.

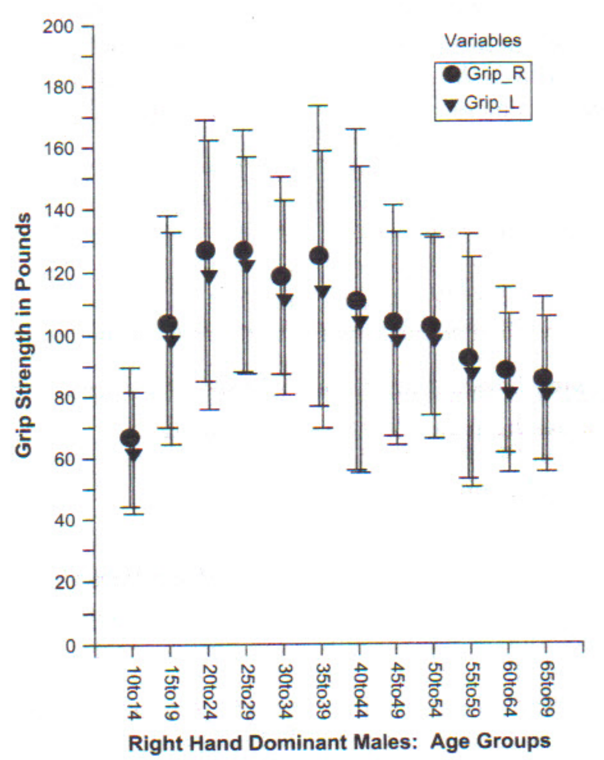


*FIGURE 2. Grip strength for right-hand–dominant males. Means and 95% confidence limits for right and left grip by age groups.*

For right-hand–dominant females, the grip strength curve is much flatter than males with averages from 60 to 80 lb. Within each age class, there is variability by as much as 30 lb. This holds true for right and left hands. For females, the average grip strength for all subjects is 72 lb for the right hand and 66.6 lb for the left. This 5.6-lb difference (95% confidence interval is 4.9 to 6.3) is statistically significant because of the large group size. Paired t (274) = 16.6, $p < 0.001$.

## Grip Strength by Weight Groupings

Figures 3 and 4 illustrate grip strength in right-hand–dominant females and males per weight groups. Grip strength in right-hand–dominant men increases from about an average of 70 lb for the lightest group to about 120 lb for the next to last weight group. In males, there is a slight unexplained drop in average grip strength for the 181- to a 190-lb group and a similar drop in the females for their 150- to 159-weight group.

The patterns observed in the weight group (Figures 3 and 4) illustrate more of a trend pattern for both men and women than that observed in the age group (Figures 1 and 2). We maintain here and below that there is a more predictable pattern of strength measures when viewed against weight groups rather

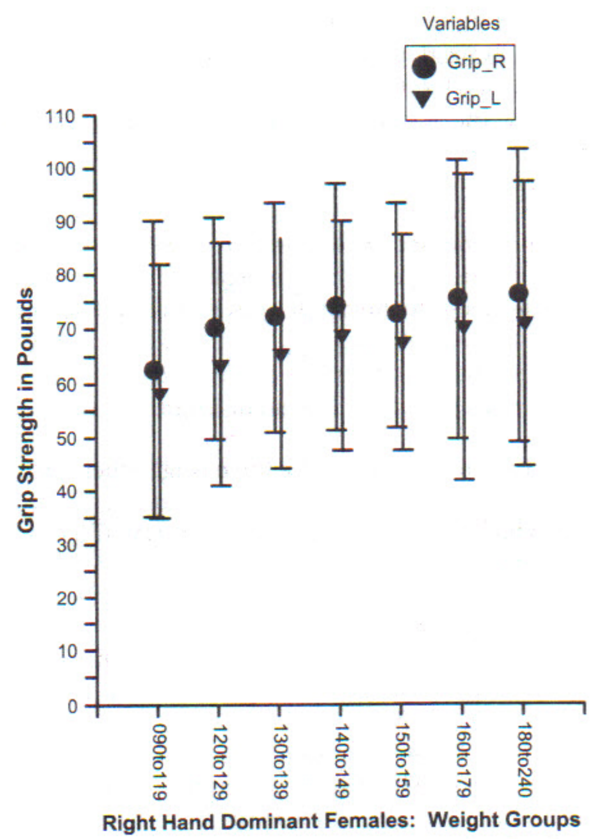


*FIGURE 3. Grip strength for right-hand–dominant females. Means and 95% confidence limits for right and left grip by weight groups.*

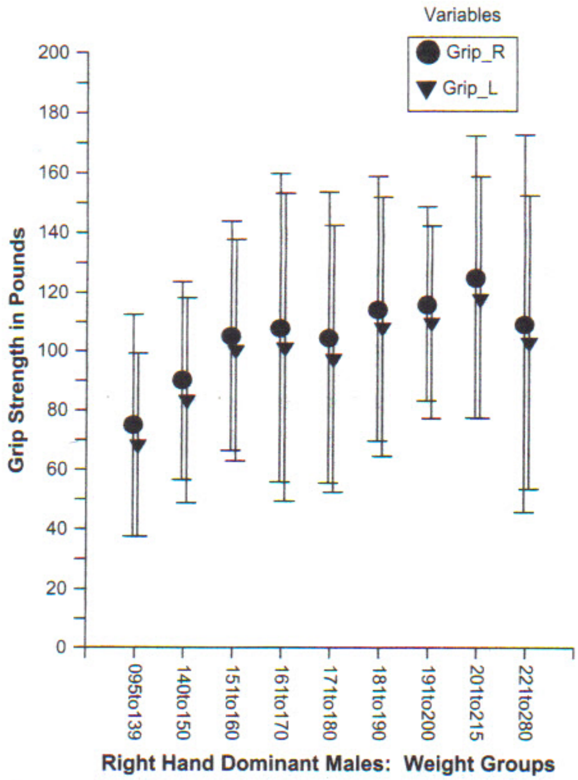


*FIGURE 4. Grip strength for right-hand–dominant males. Means and 95% confidence limits for right and left grip by weight groups.*

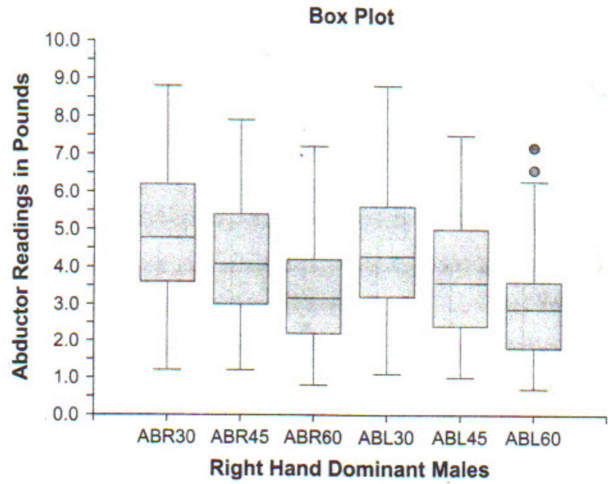


*FIGURE 6. Box and whisker plots showing median (center line of box), 25 percentile value, and 75 percentile value (lower and upper parts of the box, respectively) for male abductor readings. The lines, that is, the whiskers cover approximately 95% of the data. Graphs show decreasing abductor values as the angles increase.*

than age groups. This holds for grip and for the Ab-Adductometer as will be demonstrated below.

## Box and Whisker Plots for 30°, 45°, and 60° Settings

Figures 5–8 present the female and male right-hand–dominant abduction and adduction readings for the 30°, 45°, and 60° settings, for left and right hand for the total group size. The plots illustrate several points. For the abduction readings, Figure 5 for females and Figure 6 for males, the measure of strength decreases as the angle of thumb abduction increases. Males have higher abduction means than females.

In Figures 7 and 8, the females have lower means than the males but for the adduction strength readings, the mean values increase for both the left and right hands as the angle of thumb abduction increases. These figures played an important role in the decision to use and report the 45° settings. Clearly, the 45° setting is a middle value and is highly representative of the thumb's range. These figures

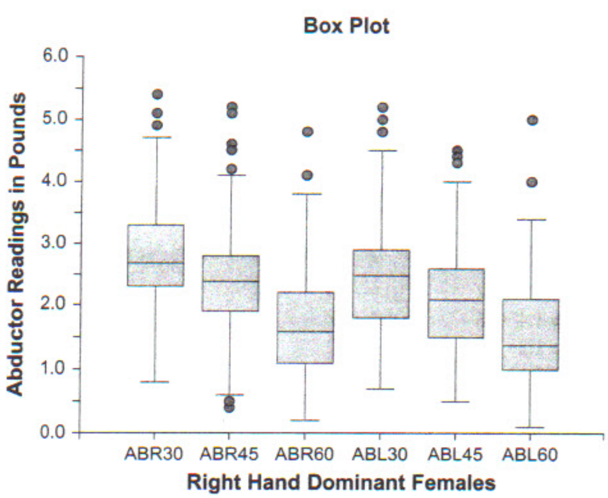


*FIGURE 5. Box and whisker plots showing median (center line of box), 25 percentile value, and 75 percentile value (lower and upper parts of the box, respectively) for female abductor readings. The lines, that is, the whiskers cover approximately 95% of the data. Graphs show decreasing abductor values as the angles increase.*

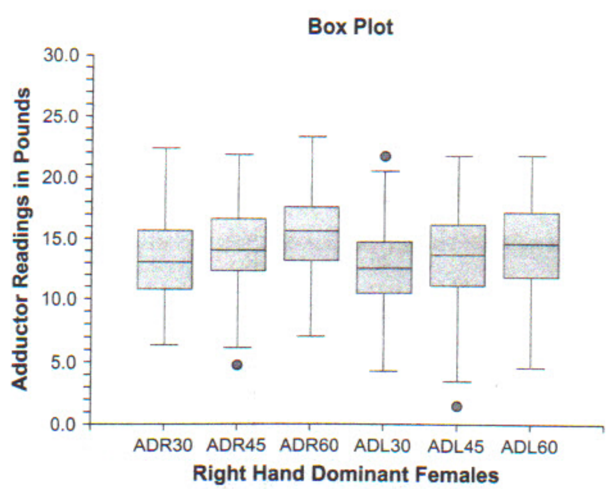


*FIGURE 7. Box and whisker plots showing median (center line of box), 25 percentile value and 75 percentile value (lower and upper parts of the box, respectively) for female adductor readings. The lines, that is, the whiskers cover approximately 95% of the data. Graphs show increasing adductor values as the angles increase.*

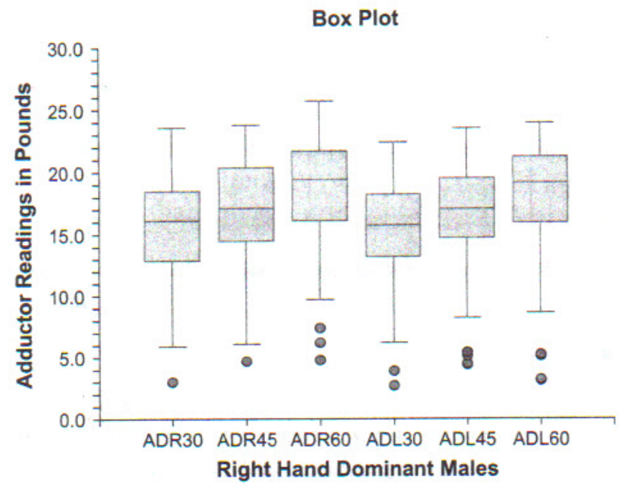


*FIGURE 8. Box and whisker plots showing median (center line of box), 25 percentile value, and 75 percentile value (lower and upper parts of the box, respectively) for male adductor readings. The lines, that is, the whiskers cover approximately 95% of the data. Graphs show increasing adductor values as the angles increase.*

also illustrate how important it is for investigators to report the position of the hand when tested and to have normative values for each possible setting. If only one setting is reported, it is still important to report that setting and to present normative values for that setting.

## Normative Values, Basic Statistics, and Graphs by Classic Age Groupings for the 45° Setting

Tables 1–4 present normative values for abductor and adductor readings by age groups, for right-hand–dominant subjects because right-hand–dominant subjects comprised more than 90% of the study and hence are the focus of the reports. Because we have 20 or more subjects per age groups, the means and ranges are quite representative.

Tables 1 and 2 present results for the females, for abductor and adductor measurements and Tables 3 and 4 report male abductor and adductor values by age groups. The unit of measure is pounds. The age groups were preselected but the number falling within each group exceeds 20 subjects with one exception. The range is the actual observed smallest and largest value within a particular age group. The last column, the weight range is the observed range of subjects' weights once the age group was preselected. One can note that there does not appear to be any particular trend of weight values as the ages increase.

Figures 9–12 present the means and 95% confidence intervals by age groups, for the female and male abductor and adductor values found in Tables

***TABLE 1.* Abductor Reference Readings (Unit lb) for Right-handed–Dominant Females 45° Setting**

| *Age Range* | *Number* | *Hand* | *Mean* | *SD* | *Range* | *95% Limits* | *Weight Range (yr)* |
|---|---|---|---|---|---|---|---|
| 10–14 | 24 | R | 1.91 | 0.58 | 1.1–3.2 | 0.8–3.0 | 90–130 |
| | | L | 1.98 | 0.65 | 1.1–3.1 | 0.7–3.2 | |
| 15–19 | 23 | R | 2.33 | 0.53 | 1.5–3.7 | 1.3–3.4 | 110–165 |
| | | L | 2.14 | 0.67 | 1.1–3.8 | 0.8–3.4 | |
| 20–24 | 24 | R | 2.53 | 0.94 | 1.0–5.1 | 0.7–4.8 | 118–185 |
| | | L | 2.04 | 0.68 | 0.8–3.9 | 0.7–3.4 | |
| 25–29 | 25 | R | 2.47 | 1.05 | 0.7–4.2 | 0.4–4.5 | 93–239 |
| | | L | 2.24 | 0.80 | 0.8–3.6 | 0.7–3.8 | |
| 30–34 | 22 | R | 2.41 | 0.64 | 1.0–3.7 | 1.2–3.7 | 125–198 |
| | | L | 2.3 | 0.87 | 0.5–3.7 | 0.6–4.0 | |
| 35–39 | 31 | R | 2.42 | 0.92 | 0.4–3.8 | 0.6–4.2 | 95–225 |
| | | L | 2.26 | 1.02 | 0.5–4.5 | 0.3–4.3 | |
| 40–44 | 21 | R | 2.44 | 1.10 | 0.6–5.2 | 0.3–4.6 | 127–220 |
| | | L | 1.96 | 0.96 | 0.6–3.6 | 0.1–3.8 | |
| 45–49 | 24 | R | 2.49 | 0.84 | 0.5–4.5 | 0.8–4.1 | 125–210 |
| | | L | 2.25 | 0.77 | 0.7–4.4 | 0.7–3.8 | |
| 50–54 | 20 | R | 2.38 | 0.70 | 1.1–3.8 | 1.0–3.8 | 130–210 |
| | | L | 1.92 | 0.51 | 1.1–2.7 | 0.9–2.9 | |
| 55–59 | 20 | R | 2.57 | 0.58 | 1.4–3.6 | 1.4–3.7 | 130–195 |
| | | L | 2.15 | 0.55 | 1.2–3.4 | 1.1–3.2 | |
| 60–64 | 20 | R | 2.26 | 0.67 | 1.1–3.4 | 0.9–3.6 | 130–240 |
| | | L | 1.82 | 0.67 | 0.8–3.3 | 0.5–3.1 | |
| 65–69 | 21 | R | 2.34 | 0.62 | 1.2–3.3 | 1.1–3.6 | 133–198 |
| | | L | 2.07 | 0.84 | 0.8–4.3 | 0.4–3.7 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand indicates whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

*TABLE 2.* **Adductor Reference Readings (Unit lb) for Right-handed–Dominant Females 45° Setting**

| *Age Range* | *Number* | *Hand* | *Mean* | *SD* | *Range* | *95% Limits* | *Weight Range (yr)* |
|---|---|---|---|---|---|---|---|
| 10–14 | 24 | R | 11.63 | 2.49 | 7.3–17.6 | 6.8–16.5 | 90–130 |
| | | L | 10.82 | 3.06 | 3.5–18.2 | 4.8–16.8 | |
| 15–19 | 23 | R | 14.34 | 2.59 | 11.4–21.2 | 9.3–19.4 | 110–165 |
| | | L | 12.77 | 3.29 | 8.3–21.2 | 6.3–19.2 | |
| 20–24 | 24 | R | 15.33 | 2.38 | 11.6–20.4 | 10.7–20.0 | 118–185 |
| | | L | 14.55 | 2.65 | 9.7–18.8 | 9.4–19.7 | |
| 25–29 | 25 | R | 15.35 | 3.77 | 7.9–21.9 | 8.0–22.7 | 93–239 |
| | | L | 14.79 | 3.64 | 9.2–21.3 | 7.7–21.9 | |
| 30–34 | 22 | R | 15.60 | 3.63 | 8.7–20.8 | 8.5–22.7 | 125–198 |
| | | L | 15.59 | 4.12 | 1.5–21.2 | 7.5–23.7 | |
| 35–39 | 31 | R | 14.10 | 3.54 | 7.5–21.7 | 7.2–21.0 | 95–225 |
| | | L | 13.86 | 3.75 | 6.3–21.7 | 6.5–21.2 | |
| 40–44 | 21 | R | 14.21 | 2.93 | 8.1–21.2 | 8.5–20.0 | 127–220 |
| | | L | 12.63 | 3.31 | 7.6–21.8 | 6.1–19.1 | |
| 45–49 | 24 | R | 14.82 | 3.18 | 6.5–17.8 | 8.6–21.1 | 125–210 |
| | | L | 13.35 | 4.01 | 4.3–19.1 | 5.5–21.2 | |
| 50–54 | 20 | R | 14.83 | 3.34 | 4.8–19.5 | 8.3–21.4 | 130–210 |
| | | L | 13.64 | 3.56 | 6.7–18.8 | 6.7–20.6 | |
| 55–59 | 20 | R | 15.98 | 2.37 | 12.1–21.3 | 11.3–20.6 | 130–195 |
| | | L | 14.82 | 2.85 | 6.0–19.8 | 9.2–20.4 | |
| 60–64 | 20 | R | 14.16 | 3.43 | 6.2–21.5 | 7.4–20.9 | 130–240 |
| | | L | 13.98 | 3.09 | 8.9–19.6 | 7.9–20.0 | |
| 65–69 | 21 | R | 13.52 | 2.12 | 10.1–17.5 | 9.4–17.7 | 133–198 |
| | | L | 13.41 | 2.74 | 9.5–19.5 | 8.0–18.8 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

*TABLE 3.* **Abductor Reference Readings (Unit lb) for Right-handed–Dominant Males 45° Setting**

| *Age Range* | *Number* | *Hand* | *Mean (SD)* | *Range* | *95% Limits* | *Weight Range (yr)* |
|---|---|---|---|---|---|---|
| 10–14 | 23 | R | 2.31 (0.56) | 1.2–3.3 | 1.2–3.4 | 95–140 |
| | | L | 2.00 (0.60) | 1.1–3.3 | 0.8–3.2 | |
| 15–19 | 22 | R | 3.94 (1.30) | 1.6–6.5 | 1.4–6.5 | 135–190 |
| | | L | 3.50 (1.30) | 1.7–6.6 | 1.0–6.0 | |
| 20–24 | 26 | R | 5.25 (1.21) | 3.0–6.8 | 2.9–7.6 | 125–215 |
| | | L | 4.27 (1.20) | 2.0–5.9 | 1.9–6.6 | |
| 25–29 | 24 | R | 5.28 (1.43) | 2.6–7.2 | 2.5–8.1 | 145–209 |
| | | L | 5.04 (1.43) | 2.2–6.6 | 2.2–7.8 | |
| 30–34 | 21 | R | 4.32 (1.07) | 2.5–6.5 | 2.2–6.4 | 138–225 |
| | | L | 4.14 (1.54) | 2.1–6.9 | 1.1–7.2 | |
| 35–39 | 25 | R | 4.81 (1.57) | 2.6–7.5 | 1.7–7.9 | 145–270 |
| | | L | 4.50 (1.47) | 2.2–7.5 | 1.6–7.4 | |
| 40–44 | 19 | R | 3.92 (1.31) | 1.8–6.5 | 1.4–6.5 | 130–230 |
| | | L | 3.60 (1.25) | 2.0–6.1 | 1.2–6.0 | |
| 45–49 | 25 | R | 4.62 (1.18) | 2.6–6.5 | 2.3–6.9 | 145–250 |
| | | L | 3.85 (1.26) | 1.8–5.8 | 1.4–6.3 | |
| 50–54 | 26 | R | 5.13 (1.70) | 1.7–7.9 | 1.8–8.5 | 148–290 |
| | | L | 4.33 (1.39) | 2.1–6.6 | 1.6–7.0 | |
| 55–59 | 20 | R | 4.01 (1.27) | 1.5–6.1 | 1.5–6.5 | 145–238 |
| | | L | 3.60 (1.30) | 1.3–5.6 | 1.0–6.2 | |
| 60–64 | 23 | R | 3.58 (1.27) | 1.8–5.6 | 1.1–6.1 | 139–245 |
| | | L | 3.06 (1.22) | 1.0–5.2 | .70–5.4 | |
| 65–69 | 21 | R | 3.52 (1.00) | 2.3–5.4 | 1.6–5.5 | 140–215 |
| | | L | 2.92 (0.86) | 1.8–5.0 | 1.2–4.6 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

*TABLE 4.* **Adductor Reference Readings (Unit lb) for Right-handed–Dominant Males 45° Setting**

| *Age Range* | *Number* | *Hand* | *Mean (SD)* | *Range* | *95% Limits* | *Weight Range (yr)* |
|---|---|---|---|---|---|---|
| 10–14 | 23 | R | 12.37 (1.55) | 10.2–15.7 | 9.3–15.4 | 95–140 |
| | | L | 12.56 (2.35) | 9.0–17.5 | 8.0–17.2 | |
| 15–19 | 22 | R | 17.22 (3.24) | 6.2–21.2 | 10.9–23.6 | 135–190 |
| | | L | 17.54 (3.75) | 5.1–22.2 | 10.2–24.9 | |
| 20–24 | 26 | R | 18.93 (2.81) | 13.2–22.8 | 13.2–24.4 | 125–215 |
| | | L | 18.45 (2.11) | 13.4–21.7 | 14.3–22.6 | |
| 25–29 | 24 | R | 20.37 (2.19) | 15.8–23.4 | 16.1–24.7 | 145–209 |
| | | L | 19.91 (2.11) | 16.2–23.2 | 15.8–24.0 | |
| 30–34 | 21 | R | 19.00 (3.09) | 12.2–23.0 | 12.9–25.1 | 138–225 |
| | | L | 17.90 (4.08) | 8.2–22.5 | 9.9–25.9 | |
| 35–39 | 25 | R | 19.10 (3.59) | 11.1–23.8 | 12.1–26.1 | 145–270 |
| | | L | 18.88 (2.97) | 10.8–23.5 | 13.1–24.7 | |
| 40–44 | 19 | R | 17.65 (4.19) | 4.7–22.8 | 9.4–25.9 | 130–230 |
| | | L | 16.16 (3.89) | 5.4–21.2 | 8.5–23.8 | |
| 45–49 | 25 | R | 19.94 (3.07) | 10.4–21.8 | 13.9–26.0 | 145–250 |
| | | L | 16.95 (2.62) | 10.7–21.2 | 11.8–22.1 | |
| 50–54 | 26 | R | 17.69 (2.59) | 11.6–21.2 | 12.6–22.8 | 148–290 |
| | | L | 17.39 (2.62) | 10.8–21.6 | 12.2–22.5 | |
| 55–59 | 20 | R | 16.02 (2.90) | 10.6–21.1 | 10.3–21.7 | 145–238 |
| | | L | 15.92 (2.85) | 11.8–21.2 | 10.3–21.5 | |
| 60–64 | 23 | R | 14.70 (2.96) | 6.1–18.2 | 8.9–20.5 | 139–245 |
| | | L | 14.2 (3.81) | 4.4–19.3 | 6.7–21.7 | |
| 65–69 | 21 | R | 15.02 (2.18) | 10.8–20.8 | 10.8–19.3 | 140–215 |
| | | L | 15.01 (2.04) | 10.4–18.7 | 11.0–19.0 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

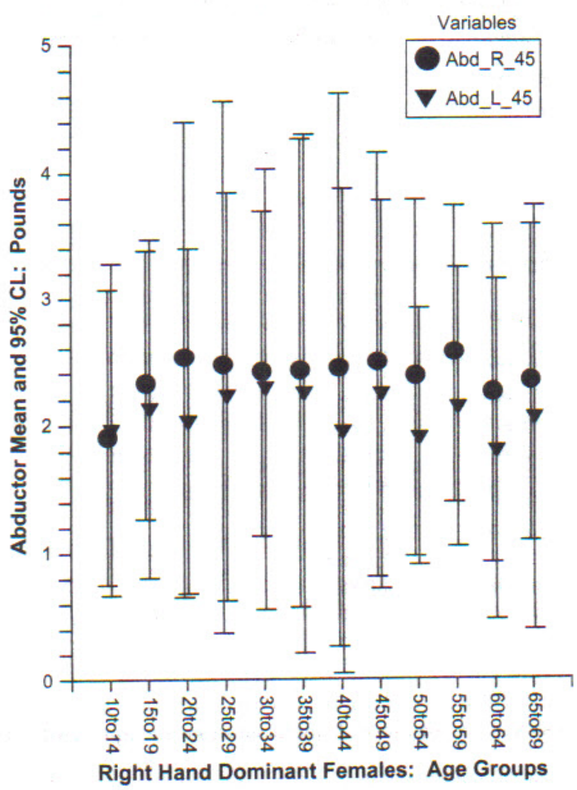


*FIGURE 9. Right- and left-hand abductor readings for right-hand–dominant females. Means and 95% confidence limits by age groups.*

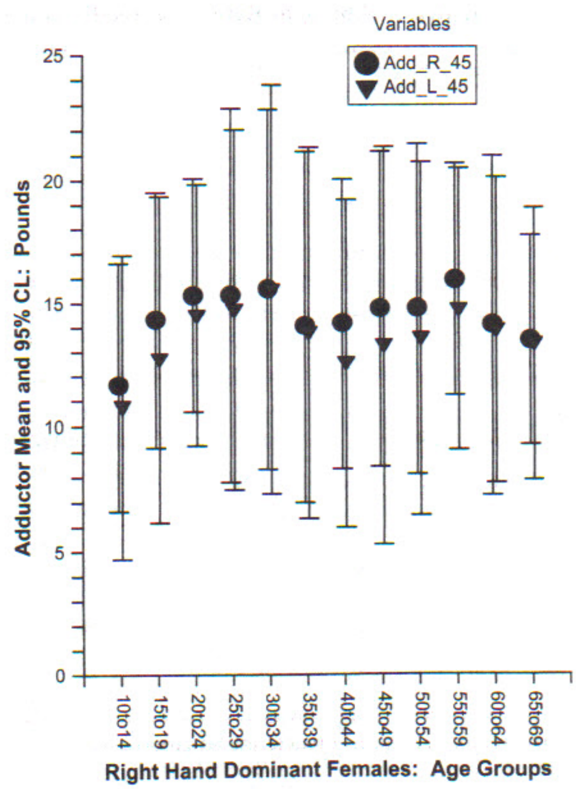


*FIGURE 10. Right- and left-hand adductor readings for right-hand–dominant females. Means and 95% confidence limits by age groups.*

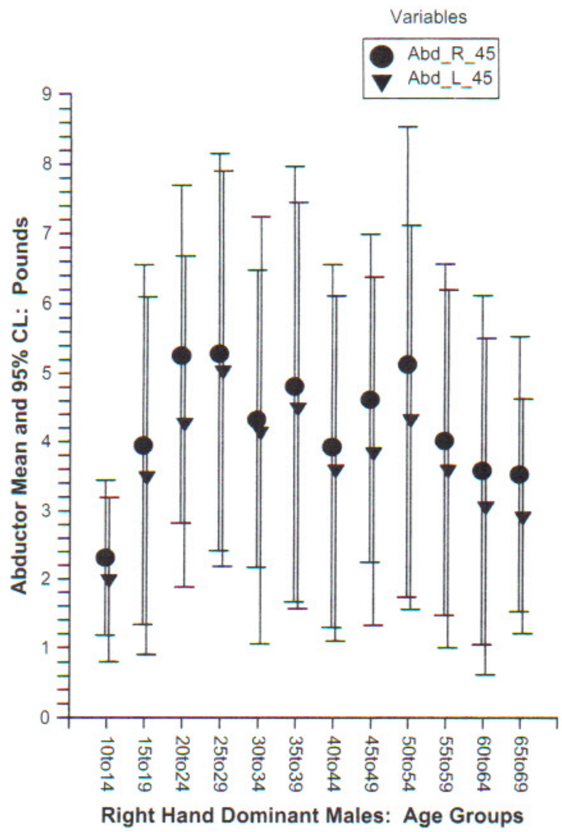


*FIGURE 11. Right- and left-hand abductor readings for right-hand–dominant males. Means and 95% confidence limits by age groups.*

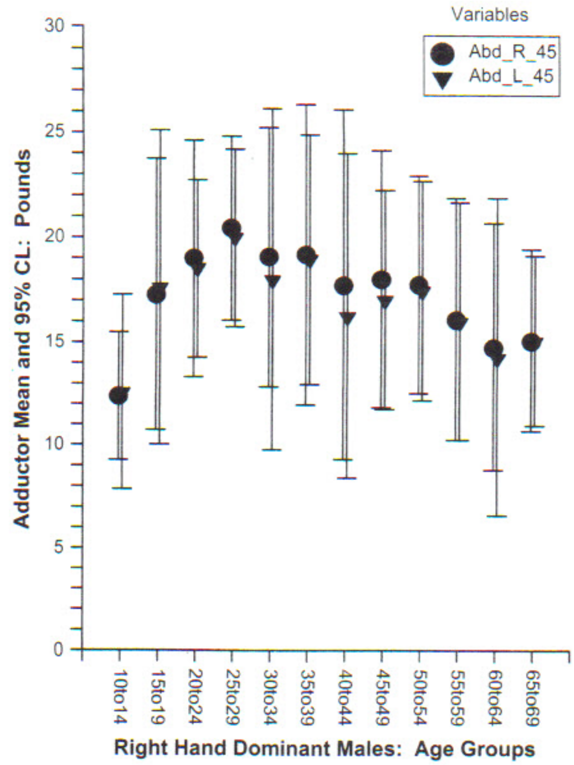


*FIGURE 12. Right- and left-hand adductor readings for right-hand–dominant males. Means and 95% confidence limits by age groups.*

1–4. Figures 9–12 illustrate the confidence intervals appearing in the tables. Note that in comparing Figures 9 and 10 with Figures 11 and 12, the females have lower mean values than the corresponding male values. In addition, the females have a basically flat profile of readings across the age groups. The males however, not only have greater mean levels, but also more fluctuation in the mean levels across the age groups and greater variability (more spread in the intervals) compared to the females.

Consistently, the right hand is stronger than the left hand. In all four cases male, female, abductor, and adductor, the difference is less than six-tenths of a pound. This difference because of the large group sizes (275) statistically significant ($p < 0.001$) but not likely to be clinically meaningful or important.

## Normative Values, Basic Statistics, and Graphs by Classic Weight Groupings for the 45° Setting

Tables 5–8 present normative values for abductor and adductor readings by weight groups, for right-hand–dominant subjects. The last column of the tables, the "Age Range" present the actual age ranges of subjects within the preselected weight groups.

For these weight groupings, it is Figures 13–16 that are particularly instructive. For both females and males, there is a steady and smooth increase in strength as weight increases, this however, being more evident in the female (Figures 13 and 14). For males, there is a slight decrease in strength for the heaviest group.

## DISCUSSION

The Ab-Adductometer is a calibrated device designed to quantitatively measure the power of palmar adduction and abduction of the thumb reflecting the function of median and ulnarly innervated neuromuscular units separately, thus providing specific information of their integrity. Commonly used devices measuring pinch and grip do not provide this level of specificity. In our study, care was taken to evaluate subjects with no history of any hand pain, surgery, or disability.

Boatright et al.[11] measured thumb abduction strength (TAS) comparing it to pinch and grip strength. They demonstrated that TAS decreased after age 60 years and that men were stronger than women in all age groups. From ages 20–59 years, there was no significant decrease in strength. They found that TAS is significantly related to body weight in women and in men more than 60 years and also found correlations between TAS and grip and pinch strength. This confirmed work done earlier by An et al.[12] Trumble et al.[13] used a similar device to

TABLE 5. Abductor Reference Readings (Unit lb) for Right-handed–Dominant Females 45° Setting

| Weight Range | Number | Hand | Mean (SD) | Range | 95% Limits | Age Range (lb) |
|---|---|---|---|---|---|---|
| 90–119 | 33 | R | 1.91 (0.82) | 0.7–5.1 | 0.3–3.5 | 10–39 |
| | | L | 1.92 (0.72) | 0.8–3.5 | 0.5–3.3 | |
| 120–129 | 41 | R | 2.40 (0.59) | 1.2–3.7 | 1,2–3.6 | 11–46 |
| | | L | 2.10 (0.71) | 0.5–4.5 | 0.7–3.5 | |
| 130–139 | 44 | R | 2.33 (0.84) | 0.5–4.2 | 0.7–4.0 | 11–65 |
| | | L | 2.08 (0.82) | 0.6–4.0 | 0.5–3.7 | |
| 140–149 | 36 | R | 2.49 (0.78) | 1.2–5.2 | 1.0–4.0 | 15–69 |
| | | L | 2.12 (0.72) | 1.0–3.9 | 0.7–3.5 | |
| 150–159 | 46 | R | 2.34 (0.77) | 1.0–4.2 | 0.8–3.8 | 19–67 |
| | | L | 2.04 (0.74) | 0.8–3.6 | 0.6–3.5 | |
| 160–179 | 44 | R | 2.62 (0.84) | 0.4–4.6 | 1.0–4.3 | 15–68 |
| | | L | 2.26 (0.76) | 0.7–4.4 | 0.8–3.8 | |
| 180–240 | 31 | R | 2.53 (0.80) | 1.0–4.1 | 1.0–4.1 | 20–66 |
| | | L | 2.18 (0.97) | 0.5–4.3 | 0.3–4.1 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

measure the return of TAS after nerve grafting. Boatright did indicate that patients with carpometacarpal (CMC) arthritis of the thumb will show spurious values for thumb abduction.

In another study,[14] Boatright studied subjects who had undergone a low median nerve block similar to Kozin. He found that TAS diminished 70% in men and 74% in women. He concluded that the flexor pollicis brevis and abductor pollicis longus are contributors to thumb abduction. One limiting factor of their device as described is that there is no control of the starting position of thumb abduction. Our study, however, demonstrated that the thumb's starting position may have a bearing on the level of recorded abduction and adduction measurements.

Liu et al.[15] in 2000 evaluated a hand held device designed to test the strength of thumb abduction. In performing the test, the subject would resist a manual force placed against the radial aspect of the thumb interphalangeal (IPJ) by the tester and would resist that force until no longer possible. They found that until age 59 years, there were no discernable differences due to age or hand dominance. No assessment was made correlating thumb abduction to weight. Men were stronger than women. They described the test as a "break test" vs. "make test." A "break test"

TABLE 6. Adductor Reference Readings (Unit lb) for Right-handed–Dominant Females 45° Setting

| Weight Range | Number | Hand | Mean (SD) | Range | 95% Limits | Age Range (lb) |
|---|---|---|---|---|---|---|
| 90–119 | 33 | R | 11.93 (2.56) | 7.3–16.7 | 6.9–17.0 | 10–39 |
| | | L | 11.17 (2.93) | 3.5–16.8 | 5.4–16.9 | |
| 120–129 | 41 | R | 13.27 (2.59) | 8.4–19.1 | 8.2–18.4 | 11–46 |
| | | L | 12.45 (2.72) | 6.3–17.2 | 7.1–17.8 | |
| 130–139 | 44 | R | 14.33 (3.20) | 6.2–21.7 | 8.1–20.6 | 11–65 |
| | | L | 13.29 (3.21) | 4.3–18.7 | 7.0–19.6 | |
| 140–149 | 36 | R | 15.24 (3.09) | 9.0–21.5 | 9.2–21.3 | 15–69 |
| | | L | 14.59 (3.32) | 1.5–20.1 | 8.1–21.1 | |
| 150–159 | 46 | R | 15.40 (2.57) | 10.1–21.3 | 10.4–20.4 | 19–67 |
| | | L | 14.46 (3.21) | 6.0–.21.7 | 8.2–20.8 | |
| 160–179 | 44 | R | 15.47 (2.92) | 8.1–21.2 | 9.8–21.2 | 15–68 |
| | | L | 14.62 (3.76) | 6.7–21.3 | 7.2–22.0 | |
| 180–240 | 31 | R | 15.29 (3.99) | 4.8–21.9 | 7.5–23.10 | 20–66 |
| | | L | 14.93 (4.22) | 4.5–21.8 | 6.7–23.2 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

TABLE 7. Abductor Reference Readings (Unit lb) for Right-handed–Dominant Males 45° Setting

| *Weight Range* | *Number* | *Hand* | *Mean (SD)* | *Range* | *95% Limits* | *Age Range (lb)* |
|---|---|---|---|---|---|---|
| 95–139 | 31 | R | 2.67 (0.93) | 1.2–5.1 | 0.9–4.5 | 10–64 |
| | | L | 2.39 (1.01) | 1.1–5.1 | 0.4–4.4 | |
| 140–150 | 28 | R | 3.62 (1.02) | 1.6–6.6 | 1.6–5.6 | 14–69 |
| | | L | 2.90 (1.06) | 1.0–6.5 | 0.8–5.0 | |
| 151–160 | 39 | R | 4.33 (1.47) | 1.8–6.5 | 1.4–7.2 | 15–67 |
| | | L | 3.77 (1.32) | 1.6–6.5 | 1.2–6.4 | |
| 161–170 | 31 | R | 3.93 (1.43) | 2.2–6.8 | 1.1–6.7 | 16–68 |
| | | L | 3.60 (1.34) | 1.8–6.1 | 1.0–6.2 | |
| 171–180 | 37 | R | 4.18 (1.51) | 1.5–7.5 | 1.2–7.1 | 16–67 |
| | | L | 3.68 (1.34) | 1.3–7.4 | 1.0–6.3 | |
| 181–190 | 45 | R | 4.69 (1.42) | 1.7–7.2 | 1.9–7.5 | 16–69 |
| | | L | 4.09 (1.58) | 1.1–6.8 | 1.0–7.2 | |
| 191–200 | 27 | R | 5.21 (1.27) | 2.5–7.2 | 2.7–7.7 | 25–68 |
| | | L | 4.84 (1.08) | 2.1–6.7 | 2.7–7.0 | |
| 201–215 | 22 | R | 5.27 (1.32) | 3.3–7.9 | 2.7–7.9 | 22–66 |
| | | L | 4.54 (1.31) | 2.4–7.5 | 2.0–7.1 | |
| 216–290 | 15 | R | 5.09 (1.25) | 2.7–7.6 | 2.6–7.5 | 31–61 |
| | | L | 4.72 (1.36) | 2.2–6.9 | 2.0–7.4 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

was defined as one where the subject resists the examiner until the joint gives way, whereas the "make test" as one where the dynamometer is held stationary. Although Bohannon[16] found that these in general may be equally reliable, in this test, there is no control over the starting angular position of the thumb, and as we have seen, that can have a significant bearing on the data. Additionally, the fact that the test is done with the forearm in full supination, may bias the result in that the pronator quadratus can be used to augment thumb abduction simply by contracting isometrically, even if the patient is monitored. Their device does not measure thumb adduction and thus no comparisons between adduction and abduction can be made. Cooney et al.[17] demonstrated by electromyography (EMG) analysis

TABLE 8. Adductor Reference Readings (Unit lb) for Right-handed–Dominant Males 45° Setting

| *Weight Range* | *Number* | *Hand* | *Mean (SD)* | *Range* | *95% Limits* | *Age Range (lb)* |
|---|---|---|---|---|---|---|
| 95–139 | 31 | R | 13.12 (2.86) | 6.2–21.2 | 7.5–18.7 | 10–64 |
| | | L | 12.82 (2.80) | 5.1–18.3 | 7.3–18.3 | |
| 140–150 | 28 | R | 15.87 (3.31) | 6.1–22.3 | 9.4–22.4 | 14–69 |
| | | L | 15.35 (3.78) | 4.4–22.0 | 7.9–22.8 | |
| 151–160 | 39 | R | 17.49 (2.84) | 13.1–22.8 | 11.9–23.1 | 15–67 |
| | | L | 17.15 (2.85) | 11.0–21.5 | 11.6–22.7 | |
| 161–170 | 31 | R | 17.92 (3.28) | 12.5–23.8 | 11.5–24.4 | 16–68 |
| | | L | 17.14 (3.13) | 12.4–22.6 | 11.0–23.3 | |
| 171–180 | 37 | R | 17.54 (4.04) | 4.7–22.9 | 9.6–25.5 | 16–67 |
| | | L | 17.17 (3.64) | 5.4–22.2 | 10.0–24.3 | |
| 181–190 | 45 | R | 18.27 (3.17) | 6.9–23.4 | 12.1–24.5 | 16–69 |
| | | L | 18.40 (3.47) | 4.5–23.5 | 11.6–25.2 | |
| 191–200 | 27 | R | 18.61 (2.82) | 11.6–23.4 | 13.1–24.1 | 25–68 |
| | | L | 17.64 (2.76) | 11.2–23.2 | 12.2–23.1 | |
| 201–215 | 22 | R | 19.26 (1.89) | 14.5–22.5 | 15.6–23.0 | 22–66 |
| | | L | 18.48 (2.26) | 14.6–22.7 | 14.1–22.9 | |
| 216–290 | 15 | R | 16.83 (4.44) | 10.4–23.0 | 8.1–25.5 | 31–61 |
| | | L | 16.59 (3.38) | 10.8–22.3 | 10.0–23.2 | |

The first column represents predetermined groups. Number is the number of subjects in the group. Hand is whether the right or left hand data are presented. Mean is the arithmetic mean. SD is the standard deviation, a statistical measure of "spread." Range is the actual observed smallest and largest value within the particular group. The 95% limits are the classic statistical limits assuming an underlying bell-shaped–normal-gaussian distribution of the scores. These are the limits one would expect for 95% of the data is they followed a bell-shaped curve. Hence, the values are approximations to the Areal world@ of data. However, the observed ranges could of course be used as levels of expectation in practice. The last column represents the observed range of values within the first column's predetermined groups.

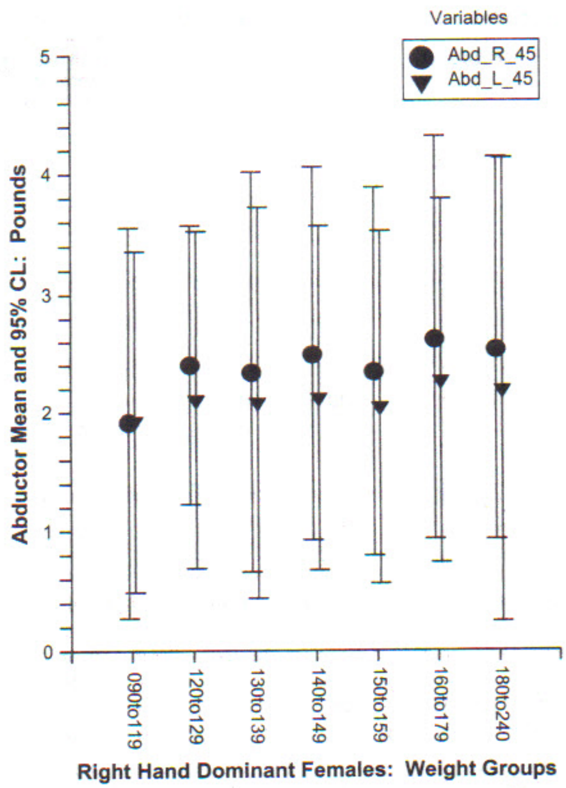


*FIGURE 13. Right- and left-hand abductor readings for right-hand–dominant females. Means and 95% confidence limits by weight groups.*

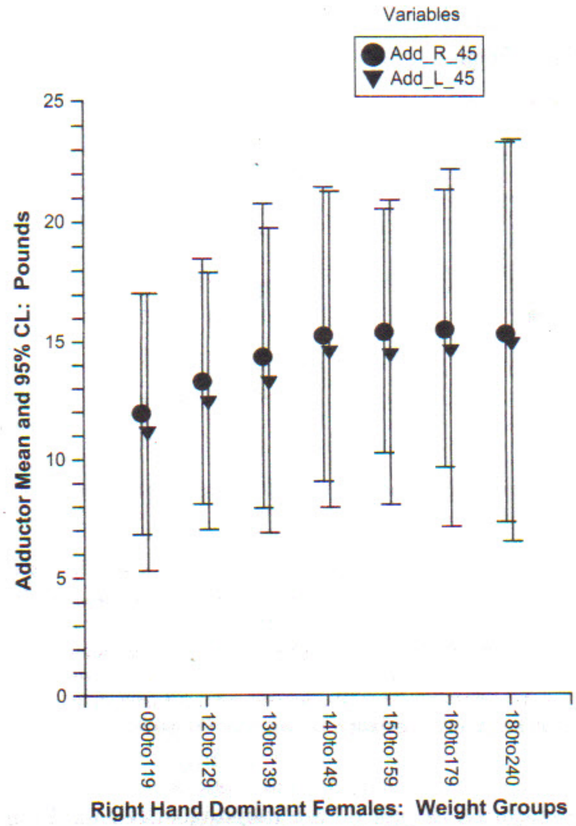


*FIGURE 14. Right- and left-hand adductor readings for right-hand–dominant females. Means and 95% confidence limits by weight groups.*

placing the thumb so that it exerts isometric force, that the APB is the main muscle involved in abduction but that the opponens pollicis, abductor pollicis longus, and flexor pollicis brevis may also contribute.

Kaufman et al.[18] constructed a device that measured the isometric force vector generated at the interphalangeal joint of the thumb in eight directions. This was correlated with multichannel electromyography to determine which muscles fire during each direction. The data were collected before and after median nerve block. The device included an adjustable metal ring, which fits about the interphalangeal joint of the thumb. The wrist was stabilized by a stable heavy base (Figure 17). (Both elements are incorporated into the current device design.) They found that the flexor pollicis brevis was most active in flexion but less so in abduction. The opponens pollicis is most active in abduction and less in extension. The APB was primarily an abductor with only slight flexion and extension moment. The adductor pollicis was active in adduction and flexion. The abductor pollicis longus was active in abduction and extension. The EPL was primarily an extensor with some adduction/abduction function. The FPL was most active in flexion and adduction functions. After median nerve block, the ability to produce force in the abduction direction was "essentially nonexistent" but flexion, adduction, or extension was not "seriously affected." The myoelectric activity of the APB, opponnens (OPP), and superficial head of the FPB was eliminated after the median block. The adductor pollicis lost its flexor vector after median block and became more of an adductor. The FPL function was unchanged. The EPL still functioned as adductor but with a power of about 15% of that of the ADP. Thus, the median nerve governs opposition and abduction and the ulnar nerve innervates adduction and flexion. The Ab-Adductometer measures motion in a pure abduction and adduction direction essentially eliminating other force vectors.

Similarly, Ichie et al.[19] studied the EMG characteristic of thenar muscles with and without external stimulation. The thumb was brought through a full range of motion at the CMC joints in every direction in 45° increments with the metacarpophalangeal (MCP) and interphalangeal (IP) joints in about 30° flexion. In pure palmar abduction, the APB and OPP were dominant with lesser contributions from EPL, APL, EPB, and PL. In adduction, the ADP was dominant with lesser contributions from EPL and EPB. This would indicate that these motions are quite specific for median (abduction) and ulnar nerve (adduction) function.

O'Driscoll et al.[20] showed that the optimal values for grip strength could be achieved if the wrist was held in 35° extension. He called this a "self selected" position in those subjects who automatically

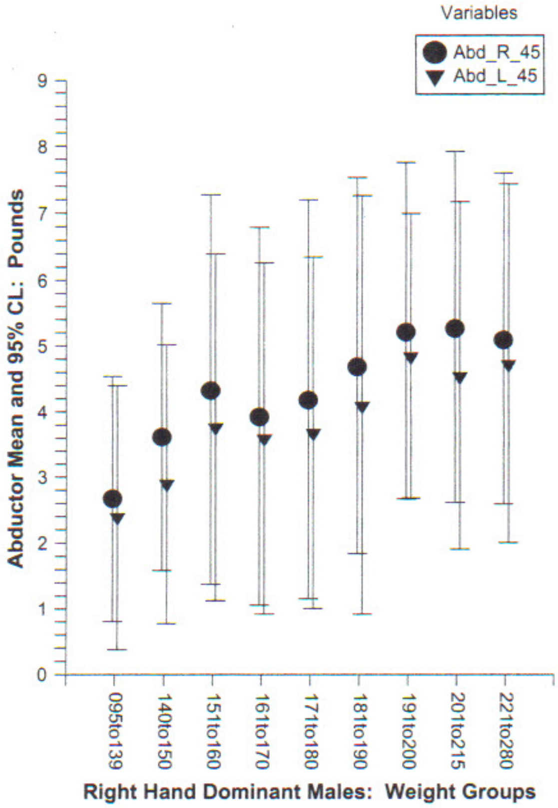


*FIGURE 15. Right- and left-hand abductor readings for right-hand–dominant males. Means and 95% confidence limits by weight groups.*

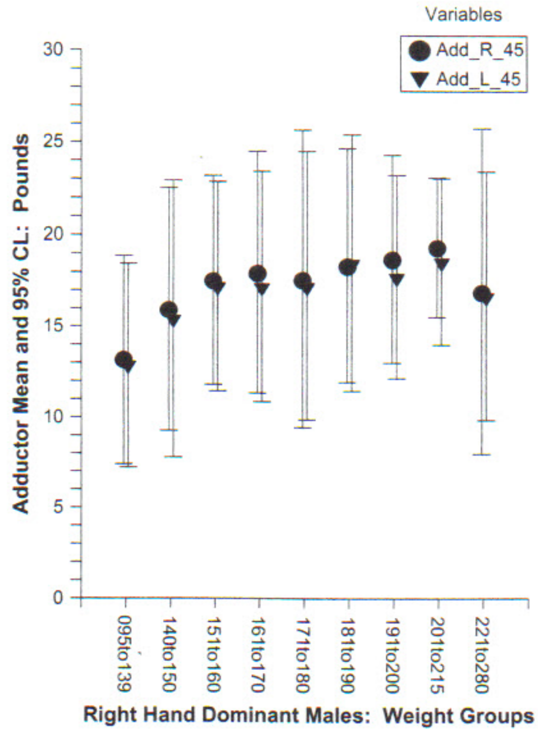


*FIGURE 16. Right- and left-hand adductor readings for right-hand–dominant males. Means and 95% confidence limits by weight groups.*

assumed that pose while executing grip strength. We found that our subjects adopted the same wrist position while positioned in the Ab-Adductometer.

As is true with any new device or concept unless one develops normative data, its usefulness is limited. This study introduces the Ab-Adductometer and presents normative data, which are stratified according to age and weight. There is a predictive value to these normal values as presented in that by taking into account age, gender, and weight, "normal" value for abduction and adduction can be predicted. Thus, these can be compared to hands with a median or ulnar nerve deficit.

The use of a single parameter alone is far less useful in predicting what a normal value should be, as the correlation coefficients are low for age and grip strength as well as for abduction and adduction. This calls into some question the long-held reliance on "normal" values for grip strength based on age consideration alone that has been reported in the literature.

Further studies plan to include multichanneled electromyography of the thenar musculature that may reveal which muscles fire and which stay silent during adduction and abduction. Selective nerve blocks of the median and ulnar nerve at the wrist will illustrate the high sensitivity and specificity of the device. Finally, a cohort of patients with proven delays in their distal motor latency (DML) of the median nerve through the carpal tunnel or the ulnar nerve in the cubital or ulnar tunnel who have presented with clinical complaints of carpal, cubital, or ulnar syndrome will be assessed and compared to the presented norms. It is assumed at this point that this device with further study may be a useful adjunct in the study of median and ulnar nerve injury either acute or chronic. Using electro-diagnostic criteria, we clinically grade the severity of carpal and cubital tunnel syndrome[21] before apparent thenar

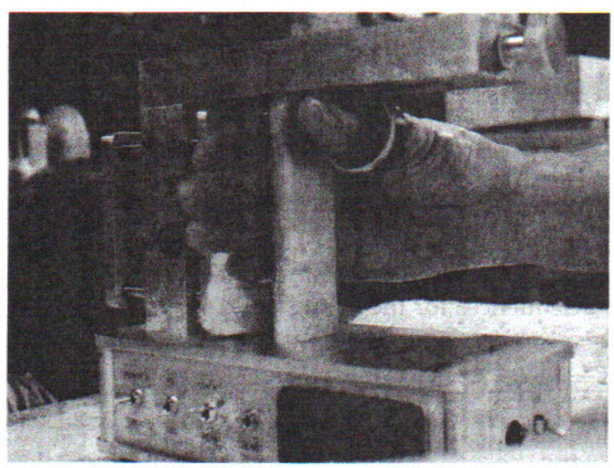

*FIGURE 17. The device as seen end on with the base, arm, and ring assembly visible. Toggle switches to determine pounds vs. kilograms, "zero" switch, peak value vs. real-time numbers, and readout shut off switches are also visible.*

atrophy has occurred. In a clinical setting, data from this device can serve as an adjunct in deciding indications for median or ulnar nerve decompression about the wrist by documenting the level of muscle weakness about the thumb. This is of course, in addition to a history, physical and electro-diagnostic criteria. Preliminary data from patients with delay in DML suggest an inverse correlation between the magnitude of DML delay and TAS. In general, it can be said that the more significant the delay in the motor and sensory latencies are pre-op the worse the prognosis is post-op.[22,23] Werner and Albers[24] wrote that motor and sensory latencies were strongly and linearly correlated with the presence of axonal loss in the median nerve and denervation in the thenar muscles. It would be instructive to evaluate post-op patients to determine return of thumb abduction function. Although it is known that patients with severe thenar atrophy rarely get return of APB function, there may be a pre-op threshold of thumb abduction weakness beyond which full return may not be expected.

Senda et al.[25] determined that after endoscopic carpal tunnel surgery only 32% of patients recovered normal DMLs although 89% achieved clinical improvement. It would be instructive to determine postoperative abduction strength and correlating it to the DML. One might be able to set forth objective criteria for surgical indication using loss of motor function as a criterion. New studies are underway to correlate TAS with DML in patients with carpal tunnel syndrome preoperatively and to test these patients' return of TAS at three and six months postoperatively.

Newer prototypes have been developed to integrate the Ab-Adductometer directly into a digital, graphical interface that has improved data collection and storage. This current study thus represents the first in a series of explorations into this new way of looking at motor function in the hand.

## CONCLUSION

The Ab-Adductometer device is an early prototype, which has shown to be reliable in measuring pure thumb abduction and adduction strength, which may have interesting research and clinical consequences for the future.

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