# Hand Span Influences Optimal Grip Span in Male and Female Teenagers

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**Purpose:** To determine if there is an optimal grip span for determining the maximum handgrip strength in male and female teenagers, and if the optimal grip span was related to hand span. If they are related then the second aim was to derive a mathematic equation relating hand span and optimal grip span.

**Methods:** One hundred healthy teenage boys (15.1 ± 1.1 y) and 106 girls (15.4 ± 1.3 y) were evaluated (age range, 13–18 y). Each hand was randomly tested on 10 occasions using 5 different grip spans, allowing a 1-minute rest between attempts. The hand span was measured from the tip of the thumb to the tip of the small finger with the hand opened as wide as possible.

**Results:** The results showed that an optimal grip span to determine the maximum handgrip strength was identified for both genders, and the optimal grip span and hand span correlated in both genders.

**Conclusions:** The results suggest that there is an optimal grip span to which the dynamometer should be adjusted when measuring handgrip strength in teenagers. The optimal grip span was influenced by hand span in both genders. For males the optimal grip span can be derived from the equation y = x/7.2 + 3.1 cm, and for females from the equation y = x/4 + 1.1 cm. where y is the optimal grip span and x is the hand-span. These equations may improve the reliability and accuracy of the results and may guide clinicians and researchers in selecting the optimal grip span on the hand dynamometer when measuring handgrip strength in teenagers. (J Hand Surg 2006;31A:1367–1372. Copyright © 2006 by the American Society for Surgery of the Hand.)

**Key words:** Dynamometry, handgrip strength, reliability, standardization, young subjects.

The handgrip strength test is a simple and economic test that gives practical information about muscle, nerve, bone, or joint disorders.[1–5] In adults, handgrip strength has been proposed as a possible predictor of mortality and the expectancy of being able to live independently.[6,7]

The measure of handgrip strength is influenced by several factors including age; gender; different angle of shoulder, elbow, forearm, and wrist[8–10]; posture[9,11]; and grip span.[9,11–15]

Another important factor affecting handgrip strength is hand span.[14,15] Several attempts have been made to find the optimal grip span that results in maximum handgrip strength and that increases reliable and reproducible handgrip strength in adult and elderly populations. Härkönen et al[14] showed that handgrip strength varied with handgrip position and was slightly affected by hand span. We have shown that there is an optimal grip span at which the maximum handgrip strength is obtained in adults.[15] Moreover, the optimal grip span has been shown to be influenced by individual hand span in adult women, but not in men. This can be in relation to the smaller hand span and/or less grip strength in women compared with men. Teenagers also present a smaller hand span and less handgrip strength than adults. Handgrip strength is a widely used test in experimental and epidemiologic studies.

The first aim of the present study was to determine if there is an optimal grip span for determining the maximum handgrip strength in male and female teenagers, and if that grip span is related to hand span. If these are related than the second aim was to derive a mathematic equation relating hand span and optimal grip span.

## Materials and Methods

### Subjects

One hundred boys (15.1 ± 1.1 y) and 106 girls (15.4 ± 1.3 y), with an age range of 13 to 18 years, volunteered to participate in the study after receiving information about the aim and clinical implications of the investigation. The study was conducted in 3 schools located in 3 different geographic areas of Spain. All of the teenagers included in the present study were in good health and free of any lesion or impairments in the upper limbs. The subjects were encouraged to do their best when performing the tests. The study was approved by the Review Committee for Research Involving Human Subjects at our University.

## Methods

Measurement of hand span. Hand span was measured in both hands from the tip of the thumb to the tip of the small finger with the hand opened as wide as possible (Fig. 1). The precision of the measure was 0.5 cm, but the results of the hand span measurement were rounded to the nearest whole centimeter.

Measurement of handgrip strength. Handgrip strength was measured using a digital dynamometer (T.K.K. 5101 Grip-D; Takey, Tokyo, Japan), and the scores were recorded in kilograms. The reported precision of the dynamometer was 0.1 kg. When performing the measurement, subjects were instructed to maintain the standard bipedal position during the entire test with the arm in complete extension and not to touch any part of the body with the dynamometer except the hand being measured. Each subject performed (alternately with both hands) the test twice using different grip spans in random order, allowing a 1-minute rest between the measurements.[11] For each measure, the hand to be tested first was chosen randomly. The grip spans used were 4.5, 5.0, 5.5, 6.0, 6.5, and 7.0 cm. If the hand span was less than 20 cm then the highest grip span was rejected; if the hand span was more than 20 cm then the lowest grip span was rejected. For each hand the best result for each grip span was retained. For the hand dynamometer (Jamar; Fit Systems Inc., Calgary, Canada) the grip span equivalence for the different positions are as follows: position 1, 3.5 cm; position 2, 4.8 cm; position 3, 6.0 cm; position 4, 7.3 cm; and position 5, 8.6 cm.

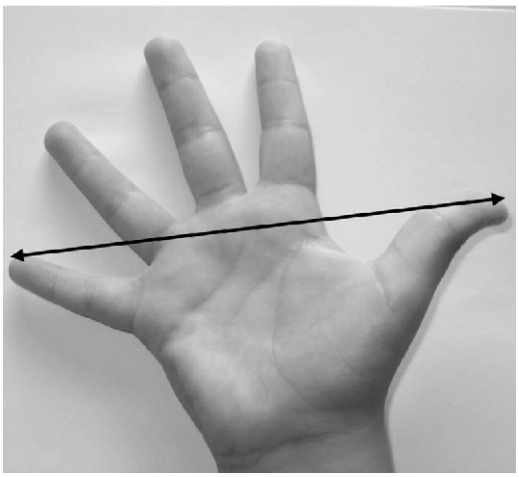

**Figure 1.** Measure of hand span (0.5-cm precision).

Determination of optimal grip span. The optimal grip span is the grip span at which the maximum handgrip strength is obtained. To determine the individual optimal grip span for each hand of each individual we first established the kind of association relating grip span and handgrip strength (ie, the results of handgrip strength obtained at the different grip spans). For that purpose, statistical software (SPSS v.14.0; SPSS Inc., Chicago, IL) was used. The association could be lineal, logarithmic, potential, exponential, or polynomial. In all subjects (except for 6) the association was statistically significant. All functions were considered, and the most relevant one was retained. The mathematic function of the relation was individually determined through the least-square fit and graphically represented (Fig. 2). In 190 of the patients it was quadratic and parabolic (corresponding to a second-degree polynomial equation). Once we defined the equation, the optimal grip span was calculated as $x/f'(x) = 0$, where x equals the optimal grip span (cm) and f(x) equals the handgrip strength (kg). In graphic terms, this corresponded to the maximum of the curves (Fig. 2). For nonpolynomial equations ($n = 16$), the optimal grip span was graphically determined and this corresponded to one of the extreme grip spans used for that particular subject. In those subjects in whom there was no association

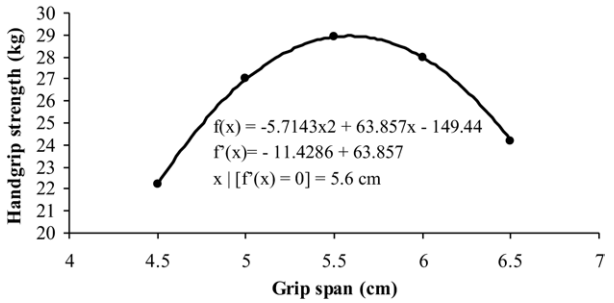


**Figure 2.** Association of handgrip strength and grip span in 1 subject. The maximum of the second-degree polynomial regression equation relating handgrip strength and grip span [f′(x)] was the optimal grip span for each hand of each individual. f(x) = −5.7143x2 + 63.857x − 149.44; f′(x) = −11.4286 + 63.857; x | [f′(x) = 0] = 5.6 cm.

between handgrip strength and grip span (n = 6), the average of the chosen grip spans was retained.

Determination of the optimal grip span for a given hand span. By using statistical software (SPSS package v.14.0), we studied whether optimal grip spans were significantly related to hand spans ($p < .05$). In case of a significant relationship, we used the least-square fit to calculate the mathematic function relating both variables. This equation allows the establishment of the optimal grip span for a given hand span. In case of a nonsignificant relationship, the conclusion is that optimal grip spans are not related to hand spans.

Usefulness and reliability of the optimal grip span. To confirm the usefulness of using the optimal grip span when measuring handgrip strength, an additional group of 21 teenagers (13 males, 8 females) ages 14 to 17 years volunteered to perform the handgrip strength test at 3 grip spans: optimal grip span, 1 cm below the optimal grip span, and 1 cm above the optimal grip span. Each subject performed (alternately with both hands) the test twice using different grip spans in a random order, allowing a 1-minute rest between the measurements.[11] For each measure, the hand to be tested first was chosen randomly. For each hand the best result at each grip span was retained.

To confirm the reliability of measurements of handgrip strength at the optimal grip span, 17 (13 males, 4 females) of the previous 21 teenagers less than 18 years of age performed the test at the optimal grip span 3 hours later. The subjects were advised not to perform strenuous exercise during the 3 hours preceding the second test.

### Statistical Analysis

The normality of the distribution of the measured variables was ascertained by the Shapiro-Wilk test. The hand span, handgrip strength, and the optimal grip span obtained for each hand span was compared by 1-way analysis of variance (ANOVA). Bivariate correlation analysis was performed to examine the relationship between optimal grip span and hand span for each hand and gender. In case of an association, the mathematic function defining the association was calculated through the least-square fit.

For confirming the usefulness of measuring handgrip strength at the optimal grip span, 1 cm below the optimal grip span, and 1 cm above the optimal grip span, a 1-way ANOVA was used. The reliability coefficient of handgrip strength measured at the optimal grip span on 2 different occasions was calculated; values were compared through 1-way ANOVA and correlated through parametric bivariate correlation analysis. The $\alpha$ error was fixed at .05.

## Results

All subjects completed the tests satisfactorily. The mean ± SD measured hand span was 21.0 ± 1.3 cm for males (n = 100) and 18.7 ± 1.1 cm for females (n = 106) ($p < .001$). Males obtained higher values of handgrip strength at each grip span than females ($p < .01$) (data not shown). In both genders, and for both hands, an optimal grip span was obtained. The optimal grip span for each hand span for males and females is presented in Tables 1 and 2, respectively. No significant differences were obtained between both hands for each hand span ($p > .70$). Because the optimal grip span was not different between the right and left hands, the mean value was retained and used for subsequent analysis.

**Table 1. Optimal Grip Span Determined in Females (n = 106) for Each Hand Span**

| Hand Span, cm | Optimal Grip Span for Right Hand, cm | Optimal Grip Span for Left Hand, cm | Optimal Grip Span, cm* |
|---|---|---|---|
| 16 | 5.0 ± 0.7 | 4.9 ± 0.5 | 5.0 |
| 17 | 5.6 ± 0.7 | 5.6 ± 0.6 | 5.6 |
| 18 | 5.5 ± 0.7 | 5.5 ± 0.6 | 5.5 |
| 19 | 5.8 ± 0.6 | 5.8 ± 0.5 | 5.8 |
| 20 | 5.8 ± 0.5 | 6.4 ± 0.6 | 6.1 |

The precision of the hand-span measurement was 0.5 cm and was rounded to the nearest whole centimeter. No significant differences were obtained between both hands for each hand span ($p > .70$).

*Optimal grip span obtained from the mean of the right- and left-hand optimal grip spans.

**Table 2. Optimal Grip Span Determined in Males (n = 100) for Each Hand Span**

| Hand Span, cm | Optimal Grip Span for Right Hand, cm | Optimal Grip Span for Left Hand, cm | Optimal Grip Span, cm* |
|---|---|---|---|
| 18 | 5.3 ± 0.7 | 5.6 ± 0.9 | 5.5 |
| 19 | 5.9 ± 0.5 | 5.7 ± 0.9 | 5.8 |
| 20 | 6.1 ± 0.6 | 6.0 ± 0.6 | 6.1 |
| 21 | 6.0 ± 0.6 | 6.0 ± 0.7 | 6.0 |
| 22 | 6.0 ± 0.6 | 6.2 ± 0.7 | 6.1 |
| 23 | 6.2 ± 0.8 | 6.3 ± 0.6 | 6.3 |

The precision of the hand-span measurement was 0.5 cm and was rounded to the nearest whole centimeter.

No significant differences were obtained between both hands for each hand span ($p > .70$).

*Optimal grip span obtained from the mean of the right- and left-hand optimal grip spans.

**Table 3. Optimal Grip Span for Each Hand Span Calculated From the Equations Provided**

| Hand Span, cm | Optimal Male and Female Grip Span, cm | Optimal Male Grip Span, cm | Optimal Female Grip Span, cm |
|---|---|---|---|
| 16.0 | 5.2 | 5.3 | 5.1 |
| 16.5 | 5.3 | 5.4 | 5.2 |
| 17.0 | 5.4 | 5.5 | 5.4 |
| 17.5 | 5.5 | 5.5 | 5.5 |
| 18.0 | 5.5 | 5.6 | 5.6 |
| 18.5 | 5.6 | 5.7 | 5.7 |
| 19.0 | 5.7 | 5.7 | 5.9 |
| 19.5 | 5.8 | 5.8 | 6.0 |
| 20.0 | 5.9 | 5.9 | 6.1 |
| 20.5 | 5.9 | 5.9 | 6.2 |
| 21.0 | 6.0 | 6.0 | 6.4 |
| 21.5 | 6.1 | 6.1 | 6.5 |
| 22.0 | 6.2 | 6.1 | 6.6 |
| 22.5 | 6.3 | 6.2 | 6.7 |
| 23.0 | 6.3 | 6.3 | 6.9 |

For males and females: $y = 0.16x + 2.66$ ($r = .92$, $p = .001$); males: $y = x/7.2 + 3.1$ ($r = .92$, $p = .01$); females: $y = x/4 + 1.1$ ($r = .93$, $p = .02$), where x is the hand span (maximal width between the thumb and small finger, with 0.5-cm precision), and y is the optimal grip span in cm.

In teenagers, hand span and optimal grip span showed a significant linear association ($y = 0.16x + 2.66$; $r = .92$, $p = .001$) where x is the hand span, and y is the optimal grip span at which the dynamometer should be adjusted before the test. The equation relating grip span as a function of hand span in males is formulated as $y = 0.1386x + 3.101$ ($r = .92$, $p = .01$). A simplification of this algorithm would be the following: $y = x/7.2 + 3.1$ (Fig. 3). The equation relating grip span as a function of hand span in females is formulated as $y = 0.25x + 1.09$ ($r = .93$, $p = .02$). A simplification of this algorithm would be the following: $y = x/4 + 1.1$ (Fig. 3). Table 3 shows the optimal grip span calculated from the equations provided, for each hand span in males and females.

The handgrip strength obtained at the optimal grip span was significantly higher ($p < 0.006$) than the strength obtained when the grip was set 1 cm below or 1 cm above the optimal grip span, in both hands and genders (Fig. 4).

Seventeen adolescents (13 males, 4 females) from the previous 21 repeated the test 3 hours later at the optimal grip span. The results showed a reliability coefficient of 0.98 and 0.96 for the right and left hands, respectively. Moreover, the 1-way ANOVA did not show a statistical difference between the test and retest results ($p = .45$ and .53 for the right and left hands, respectively). A significant correlation between the test and retest results was obtained for right ($r = .96$, $p < .001$) and left ($r = .92$, $p < .001$) hands at the optimal grip span.

## Discussion

This study suggests that there is an optimal grip span to which the standard dynamometer should be ad-

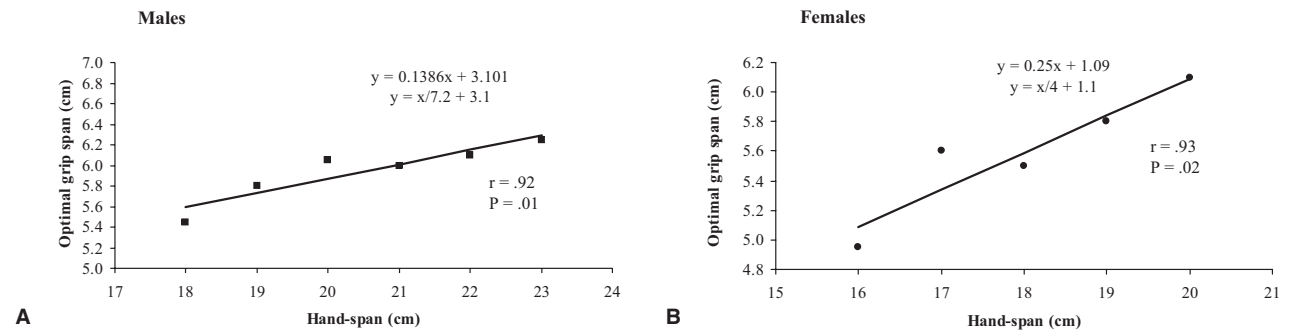


**Figure 3.** Association between hand span and optimal grip span in (A) males (n = 100) and (B) females (n = 106). (A) $y = 0.1386x + 3.101$; $y = x/7.2 + 3.1$; $r = 0.92$; $p = .01$. (B) $y = 0.25x + 1.09$; $y = x/4 + 1.1$; $r = 0.93$; $p = .02$.

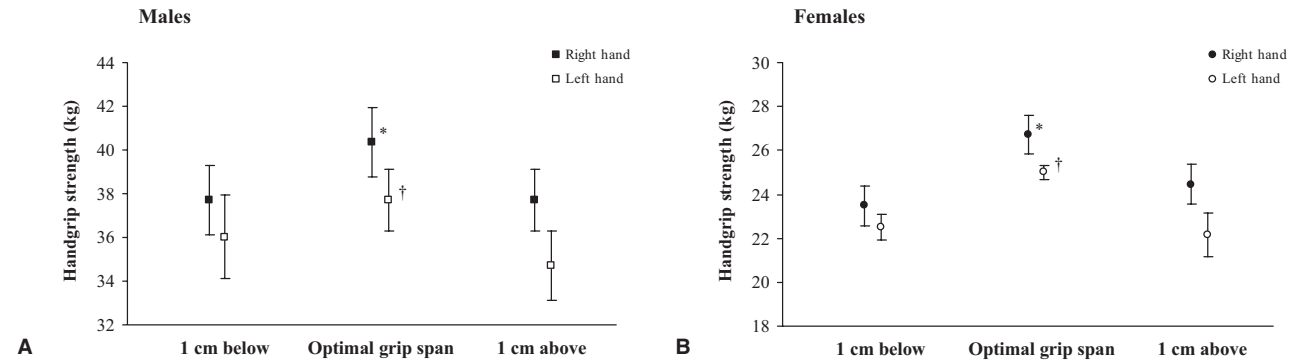


**Figure 4.** Handgrip strength measured for the right and left hands at the optimal grip span, 1 cm below the optimal grip span, and 1 cm above the optimal grip span in (A) males (n = 13) and (B) females (n = 8) (age range, 14–17 y). The values are mean ± standard error of the mean. *p < .005 compared with 1 cm below and 1 cm above the optimal grip span. †p < .006 compared with 1 cm below and 1 cm above the optimal grip span. (A) ■, right hand; □, left hand; (B) ●, right hand; ○, left hand.

justed when measuring handgrip strength in both males and females ages 13 to 18 years. In both genders the optimal grip span is influenced by hand span, which implies the need for adjustment of the grip span of the dynamometer to the hand span. For that purpose gender-specific equations are proposed, and are valid for both hands. Handgrip strength is a widely used test in experimental and epidemiologic studies in young people.

We have previously shown similar results in adult men and women.[12] In women the optimal grip span was influenced by hand span, and an equation to calculate the optimal grip span from the measure of the hand span was proposed (y = x/5 + 1.5). In men there was an optimal grip span for determining the maximum handgrip strength, but that optimal grip span was not hand-span dependent; therefore a fixed optimal grip span was proposed (5.5 cm). Teenagers have smaller hand spans and less handgrip strength compared with adults. Because of these differences one would expect that teenagers may need a different optimal grip span when measuring handgrip strength compared with adults. In the present study, the optimal grip span was influenced by hand span in both male and female teenagers, similar to what we found previously in adult women, but not in adult men. Adult men, usually already part of the workforce (mostly manual workers), might compensate for the hand-span effect with higher muscle mass and muscle strength in their forearm. This could partially explain the lack of association between the hand span and the optimal grip span in adult men.

Other studies also have shown a specific grip span at which the maximum handgrip strength is obtained.[11–13,16,17] Middle grip spans seem to favor greater forces than smaller or larger grips.[16] Oh and Radwin[17] reported that hand span affected maximal and submaximal handgrip strengths. They found that hand span affected grip strength, grip force, and exertion level. In another study,[13] the optimal grip span was suggested to be 5.0 to 6.0 cm for women and 5.5 to 6.5 cm for men. Similar values have been found recently in a larger study[11] in which the subjects performed the handgrip test at 3 different grip spans: one grip span, called the *standard grip span*, was calculated from the half distance between the index fingertip and the metacarpophalangeal joint flexion crease at the base of the thumb (men, 5.8 cm; women, 5.4 cm), the other grip spans were at −10% and +10% of the standard grip span. It was concluded that the grip span that achieves maximum handgrip strength is somewhere between the standard grip span and a 10% increase of that distance. The age and the number of participants in the earlier-mentioned studies make comparisons difficult.

Different measures of handgrip strength are currently used worldwide. There are some international physical fitness test batteries specifically designed for the young population that include a handgrip strength test (eg, EUROFIT test battery[18]). From a public health perspective it is important to standardize the procedure and increase the reliability because otherwise the measurement error may be too large to detect actual changes in strength; however, different kinds of dynamometers and postures might change the results. We do not know whether these findings can be directly transferred to measurements with other dynamometers.

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