SCIENTIFIC ARTICLE

Hand Span Influences Optimal Grip Span in Boys and Girls Aged 6 to 12 Years

Vanesa España-Romero, BS, Enrique G. Artero, BS, Alba M. Santaliestra-Pasias, BS, Angel Gutierrez, MD, PhD, Manuel J. Castillo, MD, PhD, Jonatan R. Ruiz, PhD

Purpose The first aim was to determine whether there is an optimal grip span for determining the maximum hand grip strength in boys and girls aged 6 to 12 years and whether the optimal grip span was related to hand span. If so, the second aim was to derive a mathematical equation relating hand span and optimal grip span.

Methods A total of 123 boys (9 y ± 2) and 70 girls (8 y ± 2) were evaluated. 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 little finger with the hand opened widely.

Results An optimal grip span to determine maximum hand grip strength was identified for both genders. Hand span and optimal grip span showed a significant linear association in the studied children. The equation relating grip span as a function of hand span in boys is formulated as $y = x/4 + 0.44$ and in girls as $y = 0.3x - 0.52$, where x is the hand span (maximal width between first and fifth fingers) and y is the optimal grip span.

Conclusions The results suggest that there is an optimal grip span to which the dynamometer should be adjusted when measuring hand grip strength in children. The optimal grip span was influenced by hand span in both genders. *(J Hand Surg 2008;33A:378–384. Copyright © 2008 by the American Society for Surgery of the Hand.)*

Key words Children, dynamometry, hand grip strength, reliability, standardization.

Hand grip strength is a widely used test in experimental and epidemiologic studies in children.[1–3] The measure of hand grip strength is influenced by several factors, including age; gender; different angle of shoulder, elbow, forearm, and wrist; and posture.[4–9] Other important factors affecting hand grip strength are grip span[8,10,11] and hand span.[12–15] Härkönen et al[11] showed that hand grip strength varied with hand grip position and was slightly affected by hand span. We have shown that there is an optimal grip span at which the maximum hand grip strength is obtained in both teenagers[12] and in adults.[13] Therefore, one would expect that children may need a different optimal grip span when measuring hand grip strength compared with older populations. Studies examining which position on the grip dynamometer will result in maximum hand grip strength in children are lacking.

The first aim of the current study was to determine if there is an optimal grip span for determining the maximum hand grip strength in boys and girls aged 6 to 12 years and if that grip span is related to hand span. If so, the second aim was to derive a mathematical equation relating hand span and optimal grip span.

From the Department of Physiology, School of Medicine, University of Granada, Granada, Spain; the Unit for Preventive Nutrition, Department of Biosciences and Nutrition at NOVUM, Karolinska Institute, Huddinge, Sweden; and the E. U. Ciencias de la Salud, University of Zaragoza, Zaragoza, Spain.

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Corresponding author: Vanesa España-Romero, BS, Department of Physiology, School of Medicine, University of Granada, 18071 Granada, Spain; e-mail: vanesaespana05@yahoo.es.

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MATERIALS AND METHODS

Subjects

A total of 123 boys (9 y ± 2), and 70 girls (8 y ± 2) participated in the study. A comprehensive verbal description of the nature and purpose of the study was given to both the children and their teachers. One parent or legal guardian provided written informed consent, and all children gave verbal assent. All the children included in the current study were in good health and free of any lesion or

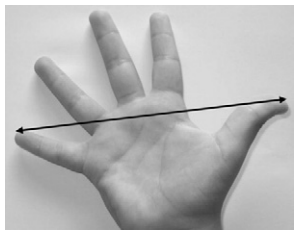

FIGURE 1: Measurement of hand span (0.5-cm precision).

impairments in the upper limbs. The children were encouraged to do their best when performing the tests. The study protocol was performed in accordance with the ethical standards established in the 1961 Declaration of Helsinki (as revised in Hong Kong in 1989 and in Edinburgh, Scotland, in 2000) and was approved by the Review Committee for Research Involving Human Subjects at the University of Granada.

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 accuracy of the measure was 0.5 cm. The results of hand span were therefore rounded to the nearest whole centimeter.

Measurement of grip span: Grip span was measured from the external base of the grip to the mark placed in the central strip of the dynamometer (see arrow in Fig. 2).

Measurement of hand grip strength: Hand grip strength was measured using a digital hand dynamometer (T.K.K. 5401 Grip-D; Takey, Tokyo, Japan), and the scores were recorded in kilograms. The reported precision of the dynamometer was 0.1 kg.

FIGURE 2: Device for measurement of grip span (0.1-cm precision).

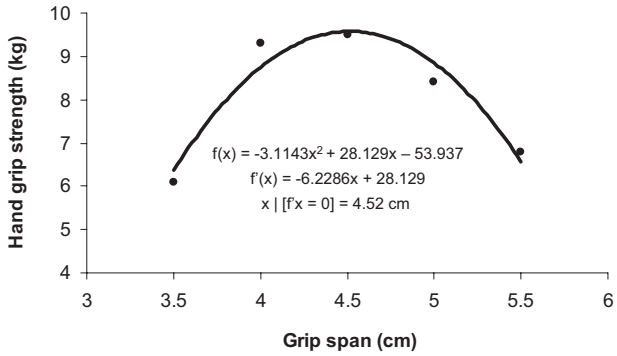

FIGURE 3: Association relating hand grip strength and grip span in 1 of the cases (boy, 7 years old, right hand). The maximum of the second-degree polynomial regression equation relating hand grip strength and grip span, $f'(x)$, was the optimal grip span for each hand of each individual.

A detailed description of the test can be found elsewhere.[12,13] In brief, the children were standing during the entire test with the arm at the side with the shoulder slightly abducted (~10°), the elbow extended, and the forearm and wrist in neutral position. Each child performed the test twice (alternately with both hands) using different grip spans in random order and allowing a 1-minute rest between measures. For each measure, the hand to be tested first was chosen randomly. The grip spans used were 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, and 6.5 cm. If the hand span was bigger than 17 cm, then the lowest grip span was rejected; if the hand span was smaller than 17 cm, then the highest grip span was rejected. Furthermore, if the hand span was smaller than 15 cm, then the grip spans used ranged between 3.5 and 5.5 cm. For each hand, the best result for each grip span was retained.

The grip span equivalence for the different positions in the Jamar hand dynamometer (Fit System Inc., Calgary, Canada) are position 1, 3.5 cm; position 2, 4.8 cm; position 3, 6.0; position 4, 7.3 cm; and position 5, 8.6 cm.

Determination of the optimal grip span: The optimal grip span is the grip span at which the maximum hand grip strength is obtained. To determine the individual optimal grip span for each hand of each child, we first established the kind of association relating grip span and hand grip strength (ie, the results of hand grip strength obtained at the different grip spans). For that purpose, the statistical software SPSS ver. 15 (SPSS Inc., Chicago, IL) was used. The associations could be linear, logarithmic, potential, exponential, or polynomial. All functions were considered, and the most relevant one was retained. The mathematic function of the relation was individually determined through the least-squares fit and graphically represented (Fig. 3). In 166 of the children, it was quadratic and parabolic, which corresponds with a second-degree polynomial equation. Once the equation was defined, the optimal grip span was calculated as $x \mid f'(x) = 0$, where x equals the optimal grip

TABLE 1: Optimal Grip Span Determined in Boys (n = 123) 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)	p Value‡
15	4.2 ± 0.6	4.3 ± 0.5	4.2	.958
16	4.1 ± 0.6	4.3 ± 0.6	4.2	.284
17	5.0 ± 0.4	4.9 ± 0.5	5	.906
18	5.1 ± 0.6	5.1 ± 0.4	5.1	.885
19	5.2 ± 0.5	5.3 ± 0.4	5.2	.973
20	5.3 ± 0.4	5.3 ± 0.4	5.3	.657

*The precision of the hand span measure was 0.5 cm, and the value was rounded to the nearest whole centimeter.
†Optimal grip span obtained from the mean of right- and left-hand optimal grip span.
‡Comparison between optimal grip span obtained with right hand versus optimal grip span obtained with left hand for each hand span.

span (cm) and $f(x)$ equals the hand grip strength (kg). In graphic terms, this corresponded with the maximum of the curves (Fig. 3). For nonpolynomial equations (n = 12), the optimal grip span was graphically determined, and this corresponded with one of the extreme grip spans used for that particular subject. For those children in whom there was no statistically significant association between hand grip strength and grip span (n = 15; 6 boys and 9 girls aged 6 and 7 y), the average of the chosen grip spans was retained.

Determination of the optimal grip span for a given hand size: By using the statistical software SPSS ver. 15, we studied whether optimal grip spans were significantly related to hand spans. In case of a significant relationship, the least-squares fit was used to calculate the mathematical function relating both variables. These equations allow the establishment of the optimal grip span for a given hand span. In case of a non-significant 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 the optimal grip span when measuring hand grip strength in children aged 6 to 12 years, an additional group of 28 children (18 boys, 10 girls) of the same ages volunteered to perform the hand grip 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 child performed the test following the same protocol as explained above. For each hand, the best result at each grip span was retained. To confirm the reliability of measurements of hand grip strength at the optimal grip span, 22 (17 boys, 5 girls) of the previous 28 children performed the test at the optimal grip span 2 hours later.

Statistical Analysis

The hand span, hand grip strength, and the optimal grip span obtained for each hand span and gender 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 mathematical function defining the association was calculated through the least-squares fit. For confirming the usefulness of measuring hand grip 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 for repeated measures was used. The reliability coefficient of hand grip strength measured at the optimal grip span on 2 different occasions was calculated; values were compared through 1-way ANOVA for repeated measures and correlated through parametric bivariate correlation analysis. The α error was fixed at .05.

RESULTS

The children completed all the tests satisfactorily. The measured hand span (mean ± SD) was 17.8 ± 1.5 cm for boys (n = 123) and 17.2 ± 1.4 cm for girls (n = 70) (p = .004). Boys obtained higher values of hand grip strength at each grip span than did girls (all $p \leq .004$) (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 boys and girls is presented in Tables 1 and 2, respectively. The optimal grip span was not significantly different between right and left hands ($p > .06$); therefore, the mean value was retained and used for subsequent analysis.

The hand span and optimal grip span showed a significant linear association in the studied children ($y = 0.2674x + 0.0883$ cm; $r = 0.98$, $p < .001$), where x is the hand span (maximal width between first and fifth fingers), 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 boys is formulated as $y = 0.2506x + 0.44$ cm ($r = 0.97$, $p = .002$). A simplification of this algorithm would be the following: $y = x/4 + 0.44$ cm (Fig. 4). The equation relating grip span as a function of hand span in girls is formulated as $y = 0.3x -$

TABLE 2: Optimal Grip Span Determined in Girls (n = 70) 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)	p Value‡
15	4.1 ± 0.5	4.2 ± 0.4	4.2	.549
16	4.3 ± 0.6	4.1 ± 0.4	4.2	.413
17	4.4 ± 0.4	4.3 ± 0.3	5	.759
18	5.3 ± 0.5	5.2 ± 0.5	5.1	.657
19	5.3 ± 0.5	5.1 ± 0.5	5.2	.492

*The precision of the hand span measure was 0.5 cm, and the value was rounded to the nearest whole centimeter.
†Optimal grip span obtained from the mean of right- and left-hand optimal grip span.
‡Comparison between optimal grip span obtained with right hand versus optimal grip span obtained with left hand for each hand span.

0.52 cm (r = 0.96, p = .008) (Fig. 4). The optimal grip span for each hand span in boys and girls calculated from the equations provided is presented in Table 3.

The hand grip strength obtained at the optimal grip span was significantly higher 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 ($p < .02$; Fig. 5).

Twenty-two children (17 boys and 5 girls) from the previous 28 repeated the test 2 hours later at optimal grip span. The results showed a reliability coefficient of 0.972 and 0.985 for right and left hands, respectively. Moreover, the 1-way ANOVA for repeated measures did not show statistical difference between test and retest ($p = .991$ and .402 for right and left hands, respectively). A significant correlation between test and retest was obtained for right ($r = 0.923$, $p < .001$) and left ($r = 0.971$, $p < .001$) hands at the optimal grip span.

DISCUSSION

This study shows that there is an optimal grip span at which the standard dynamometer should be adjusted when measuring hand grip strength in children. In both genders, the optimal grip span is influenced by hand span, which implies the need of adjusting the grip span of the dynamometer to the hand span. For that purpose, gender-specific equations are proposed. This study shows how to mathematically adjust the grip span of the dynamometer to the hand span when measuring hand grip strength in both boys and girls as young as 6 to 12 years.

These findings are in agreement with our previous reports in teenagers[12] and in adults.[13] The optimal grip was influenced by hand span in male and female teenagers as well as in adult women. The equation to calculate the optimal grip span from the measure of the hand span in male and female teenagers was $y = x/7.2 + 3.1$ cm ($r = 0.92$, $p = .01$) and $y = x/4 + 1.1$ cm ($r = 0.93$, $p = .02$), respectively.[12] In adult women, the equation was $y = x/5 + 1.5$ cm ($r = 0.97$, $p = .004$), whereas in adult men, there was an optimal grip span for determining the maximum hand grip strength, but that optimal grip span was not hand span–dependent. Therefore, a fixed optimal grip span was proposed (5.5 cm).[13] Children have smaller hand spans and lower hand grip strength compared with teenagers and adults. The same applies to teenagers in comparison with adults. Because of these differences, one would expect that each age group may need a different optimal grip span when measuring hand grip strength. For the same reasons, gender-specific equations have also been proposed.

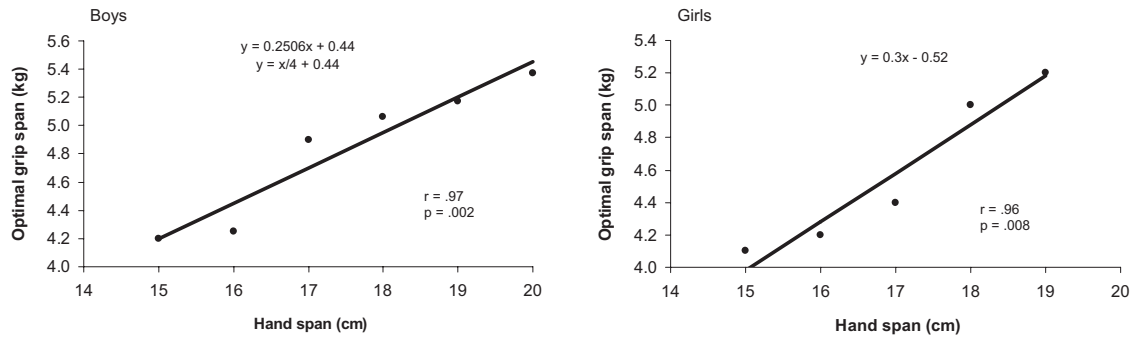

FIGURE 4: Association between hand span and optimal grip span in boys (n = 123) and girls (n = 70).

TABLE 3: Optimal Grip Span for Each Hand Span Calculated From the Equations Provided*

Hand Size (cm)	Optimal Grip Span for Boys (cm)	Optimal Grip Span for Girls (cm)	Optimal Grip Span for Boys and Girls (cm)
15.0	4.2	4.0	4.1
15.5	4.3	4.1	4.2
16.0	4.4	4.3	4.4
16.5	4.6	4.4	4.5
17.0	4.7	4.6	4.6
17.5	4.8	4.7	4.8
18.0	5.0	4.9	4.9
18.5	5.1	5.0	5.0
19.0	5.2	5.2	5.2
19.5	5.3	5.3	5.3
20.0	5.5	5.5	5.4

*For boys and girls, $y = 0.2674x + 0.0883$ cm ($r = 0.98$, $p < .001$); for boys, $y = x/4 + 0.44$ cm ($r = 0.97$, $p = .002$); for girls, $y = 0.3x - 0.52$ cm ($r = 0.96$, $p = .008$); where x is the hand span (maximal width between thumb and little finger, with 0.5-cm precision), and y is the optimal grip span in centimeters.

There is a general agreement suggesting that both grip and hand spans affect maximum hand grip strength.[8,10–19] Oh and Radwin[18] reported that hand span affected maximal and submaximal hand grip strength. They found that hand span affects grip strength, grip force, and exertion level. Firrell and Crain[19] studied which setting of the dynamometer produced maximal grip strength and correlated that setting with characteristics of the individual. They reported that the majority of the hands (89%) had a maximal strength at setting II (of V) of a hand dynamometer, whereas no clear significant correlation between hand size and maximal setting was found. More recently, Ratamess et al[17] examined the strength performance of 6 common resistance-training exercises using free-weight bars of 3 different thicknesses. They found significant differences in the strength performance between bars and concluded that the observed differences might be due to greater reliance on maximal grip strength and larger hand size.

Hand grip strength is currently used worldwide because it is a relatively cheap test that gives practical information on muscle, nerve, bone, or joint disorders.[20–25] In adults, hand grip strength has been proposed as a possible predictor of mortality and the expectancy of being able to live independently.[26,27] Moreover, hand grip strength is associated with bone mineral density,[28–30] impaired cognition,[31] nutritional status,[32,33] and cardiovascular disease risk factors.[34,35] Therefore, from a public health perspective,

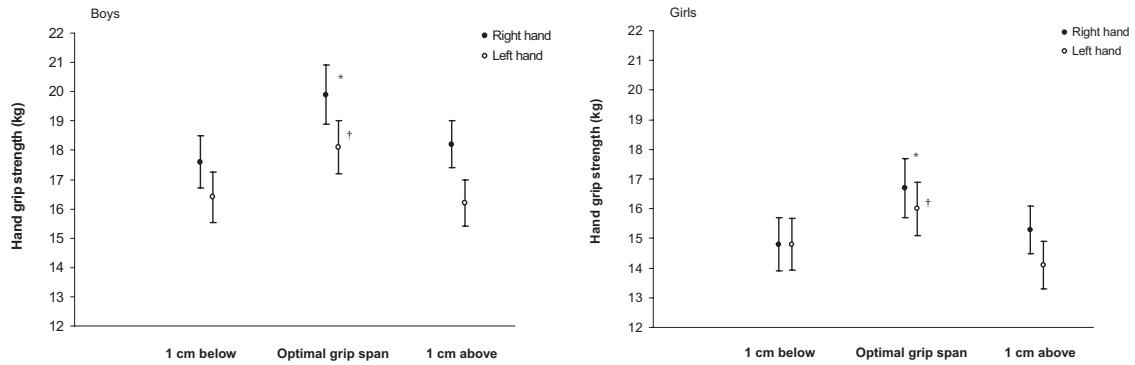

FIGURE 5: Hand grip strength measured in right and left hands at optimal grip span, 1 cm below, and 1 cm above in boys (n = 18) and girls (n = 10) (age range, 6 to 12 y). Values are mean ± standard error of the mean. *$p \leq .01$ compared with 1 cm below and 1 cm above. †$p < .02$ compared with 1 cm below and 1 cm above.

it is important to standardize the procedure and increase the reliability, as otherwise the measurement error may be too large to detect actual changes in strength. It must be borne in mind that 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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