

Optimal Grip Span for Measuring Maximum Handgrip Strength in Preschool Children

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How to cite this paper: Abe, T., Sanui, R., Sasaki, A., Ishibashi, A., Daikai, N., Shindo, Y., Abe, A. and Loenneke, J.P. (2022) Optimal Grip Span for Measuring Maximum Handgrip Strength in Preschool Children. *International Journal of Clinical Medicine*, 13, 479-488.

<https://doi.org/10.4236/ijcm.2022.1311035>

Received: September 25, 2022

Accepted: October 30, 2022

Published: November 2, 2022

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Abstract

Background: Since the minimum grip span of a standard Smedley hand dynamometer is 4 cm, the handgrip strength (HGS) value at a less than 4 cm grip span has not been reported. **Objective:** The present study examined the impact of grip span on handgrip strength (HGS) in young children using a dynamometer ranging from 2 to 4.5 cm of grip span. **Methods:** A total of 93 (39 girls and 54 boys) children were recruited from a local kindergarten with the cooperation of their parents. Each participant performed one test trial and then five maximal trials using different grip spans (2.0, 3.0, 3.5, 4.0, and 4.5 cm) in random order and allowing a 1-minute rest between measures. **Results:** There was a statistically significant difference in HGS depending on which grip span was used, $\chi^2(4) = 211.5$ ($p < 0.001$). Mean ranks were 1.03, 2.79, 3.72, 3.94, and 3.53 for 2 cm, 3 cm, 3.5 cm, 4 cm, and 4.5 cm, respectively. Follow-up tests found statistically significant differences between each grip span comparison except for the 3.5 cm vs. 4.0 cm comparison ($p = 0.166$) and the 3.5 cm vs. 4.5 cm comparison ($p = 0.611$). Our finding showed that the highest HGS appeared at a grip span of 4.0 cm. In addition, the difference between HGS at a grip span of 4.0 cm and 3.5 cm or a grip span of 4.0 cm and 4.5 cm was statistically different but relatively small. **Conclusion:** Our results recommended that the target grip span for measuring maximal HGS in young children is about 4 cm (4 ± 0.5 cm).

Keywords

Childhood, Grip Span, Grip Strength, Hand Morphology, Reliability

1. Introduction

Muscle strength is a critical determinant of physical function. Skeletal muscle and the nervous system are two factors associated with muscle strength and both of these variables increase dramatically during development [1] [2] [3]. In studies of children, physical function (e.g., standing long jump and countermovement jump) is used as a surrogate when muscle strength cannot be measured directly [4]. When muscle strength is measured during development, it is typically assessed via handgrip strength (HGS) [5] [6] [7]. This is because HGS is a potential predictor of current and future health [8] [9] [10] and is associated with cardio metabolic and bone health outcomes in children [11] [12]. In addition, it is expected that measurements using a handgrip dynamometer will be actively used in research on early childhood in the future. Therefore, accurate measurement of a child's HGS is essential, but equipment for children is limited [13].

A standard model for measuring HGS is the Smedley hand dynamometer. The grip span is set before testing to adjust an individual's hand size with this device. However, the device was developed for adults. Thus, it has a limited range of grip span (≥ 4 cm) and may not be suitable for the hand size of young children. In addition, the device for adults has a HGS measurement range of 5 kg or more and cannot measure the HGS of some children. Using a Smedley hand dynamometer, several studies investigated the relationship between grip span (grip handle position) and HGS. When HGS is measured with grip spans of various lengths, the peak value of HGS appears at a specific grip span (*i.e.*, optimal grip span) compared with other measured grip spans. For example, Ruiz *et al.* [14] investigated the relationship between grip span and HGS of 30 men (mean age, 39 years old; range, 20 - 80 years) and 40 women (mean age, 41 years old; range, 20 - 80 years) and reported that there is an optimal grip span for both men and women. The same research group observed similar results for children (age range, 3 - 5 years) [15] and adolescents (age range, 13 - 18 years) [16]. The authors of those studies use hand size (*i.e.*, maximal hand width) to propose a standard grip span for measuring maximum HGS [14] [15] [16]. As mentioned above, however, the minimum grip span of a standard HGS dynamometer is 4 cm, so the optimal grip span remains unclear in studies of young children. In other words, in young children, the peak value may appear at the minimum grip span of 4 cm [15], and the HGS value at a less than 4 cm grip span has not been reported. We hypothesized that the peak HGS could appear with a grip span of 4 cm or less, given that young children's hand size is about half that of adults. Thus, the purpose of this study was to examine the impact of grip span on HGS in young children using a specially designed hand dynamometer (range of grip span, 2.0 - 4.5 cm).

2. Methods

2.1. Participants

A total of 93 (39 girls and 54 boys) Japanese children between the ages of 4.2 and

6.5 years were recruited from a local kindergarten with the cooperation of their parents (**Table 1**). Children with their parents were fully informed about the purpose of the study and its safety and written informed consent was obtained from the parents for each child. Participants did not include non-right-handers (left-handed or mixed-handed). This study received approval from the University's Institutional Review Board (HSS #29-17 & SG #2021-2-2).

2.2. Anthropometric Variables

Body mass and standing height were measured to the nearest 0.1 kg and 0.1 cm, respectively, by using a digital height and weight scale (DST-210S, Muratec KDS Corp, Kyoto, Japan). The forearm circumference of the right arm was measured at 30% proximal to the forearm length using a tape measure. We measured four different hand sizes using a ruler. Full hand length was measured as the linear distance between the distal wrist crease and the tip of the middle finger. Palm length was measured as the distance between the distal wrist crease and the midpoint of proximal flexion crease of the middle finger [17]. The index finger length was also measured as the distance between the tip of the index finger and the metacarpophalangeal joint flexion crease at the base of the thumb [18]. Maximum hand width was measured from the tip of the thumb to the tip of the little finger with the hand opened as wide as possible, and the distance between the two was measured to the nearest 0.1 cm [15].

2.3. Grip Span Measurements

Grip span was measured using a vernier caliper as the distance between the external bases of the grip to the central strip of the dynamometer.

2.4. Handgrip Strength Measurements

Maximum voluntary HGS was measured with the right hand using a Smedley handgrip dynamometer (TKK Grip-A, Niigata, Japan; ranges 0 - 30 kg strength and 2 - 5 cm grip span) [19]. All participants were instructed to maintain an upright standing position to keep their arms at their side. The participants held the dynamometer in the right hand with the elbow extended downward without squeezing. Each participant performed one test trial and then five maximal trials using different grip spans in random order and allowing a 1-minute rest between measures. The grip spans used were 2.0, 3.0, 3.5, 4.0, and 4.5 cm (**Table 2**). All the participants appeared motivated during the strength tests.

2.5. Reliability of Handgrip Strength Measurements

Test-retest reliability of HGS measurements using the intraclass correlation coefficient (ICC3,1), standard error of measurement, and the minimal difference (*i.e.* absolute reliability) was determined for data from an additional group of 13 young children (8 boys and 5 girls) tested twice, one week apart prior to the study. The same grip span for each participant was used at the test and retest measurements (setting grip span ranged 3.5 - 4.0 cm).

Table 1. Anthropometric variables of the participants.

	Girls	Boys	Overall
n	39	54	93
Age (years)	5.4 (0.8)	5.3 (0.8)	5.3 (0.8)
Height (m)	1.07 (0.07)	1.09 (0.07)	1.08 (0.07)
Body mass (kg)	18.0 (2.6)	18.8 (3.0)	18.4 (2.8)
Forearm length (cm)	14.4 (1.3)	15.0 (1.3)	14.7 (1.3)
Forearm girth (cm)	16.9 (1.0)	17.2 (1.1)	17.0 (1.1)
Hand length (cm)	12.0 (0.8)	12.4 (0.8)	12.2 (0.8)
Palm length (cm)	6.8 (0.5)	7.0 (0.5)	6.9 (0.5)
Hand width (cm)	13.9 (1.0)	14.1 (0.9)	14.0 (0.9)
Index finger length (cm)	7.3 (0.6)	7.5 (0.6)	7.4 (0.6)

Table 2. Handgrip strength with different grip spans.

	Grip span (cm)				
	2.0	3.0	3.5	4.0	4.5
Handgrip strength (kg)					
Girls (n = 39)	3.4 (1.3)	7.6 (2.1)	8.6 (2.4)	8.8 (2.7)	8.5 (2.9)
Boys (n = 54)	4.6 (1.4)	8.9 (2.1)	9.7 (2.2)	9.9 (2.6)	9.5 (2.7)
Overall (n = 93)	4.1 (1.5)	8.3 (2.2)	9.2 (2.3)	9.4 (2.7)	9.1 (2.8)

2.6. Statistical Analysis

Test-retest reliability was determined by calculating the difference between the values from the initial test to that of the retest. The standard deviation (SD) of that difference was divided by the square root of 2 in order to calculate the standard error of the measurement. The minimal difference (*i.e.* absolute reliability) was calculated by multiplying the SD of the difference by 1.96. Limits of agreement (95% level) were set by adding and subtracting the minimal difference value from the mean difference.

Differences in HGS were determined using the nonparametric Friedman test in order to obtain mean ranks. If there was a statistically significant result, pairwise comparisons were made using the Wilcoxin signed ranks test. Statistical significance was set at $p \leq 0.05$. The limits of agreement were calculated as noted before by taking the mean difference (e.g. 4 cm - 2 cm) in strength values. This allowed for a visual comparison between the strength differences in grip spans.

3. Results

3.1. Test-Retest Reliability

Paired t-tests revealed no significant differences between test [10.3 (SD 1.4) kg] and retest [10.1 (SD 1.1) kg], and mean difference was 0.18 (SD 0.82) kg. The correlation coefficient between the two tests was 0.815. The standard error of

measurement and minimal difference were, respectively, 0.58 kg and 1.60 kg. The 95% limits of agreement were 1.4, 1.7 kg.

3.2. Handgrip Strength with Different Grip Spans

There was a statistically significant difference in handgrip strength depending on which grip span was used, $\chi^2(4) = 211.5$, $p < 0.001$ (Figure 1). Mean ranks were 1.03, 2.79, 3.72, 3.94, and 3.53 for 2 cm, 3 cm, 3.5 cm, 4 cm, and 4.5 cm, respectively. Follow-up tests (Table 3) found statistically significant differences between each grip span comparison except for the 3.5 cm. vs. 4.0 cm comparison ($p = 0.166$) and the 3.5 cm vs. 4.5 cm comparison ($p = 0.611$).

The direct comparison between grip spans with the 95% limits of agreement is found in Figure 2. The dotted red-lines are the limits of agreement from the test-retest plotted to see how each difference compares with the error of the measurement itself. It is clear that using the smallest grip span produces lower estimates than the other four settings. All other comparisons produced varying level of estimates, with 4.5 cm and 4 cm being most similar.

Table 3. The results of the Wilcoxin Signed Rank Test. The median value for strength is represented in kg for each grip span ranging from 2 cm to 4.5 cm. Each grip span is compared with each other to determine how the ranks compare. – ranks denote how many participants had higher values on the second variable compared to the first variable (*i.e.* first variable vs. second variable), + ranks denote how many participants had higher values on the first variable compared to the second variable. Ties denote that how many participants did not differ. Z is the test statistic and an * means it was statistically significant at $p \leq 0.05$.

Grip Span	2 cm	3 cm	3.5 cm	4 cm	4.5 cm
Median (kg)	4.0	8.8	9.6	9.9	9.3
vs. 3 – ranks	92				
+ ranks	1				
Ties	0				
Z	-8.367*				
vs. 3.5 – ranks	93	68			
+ ranks	0	20			
Ties	0	5			
Z	-8.375*	-5.828*			
vs. 4 – ranks	93	68	50		
+ ranks	0	20	38		
Ties	0	5	5		
Z	-8.375*	-5.647*	-1.386		
vs. 4.5 – ranks	91	63	44	33	
+ ranks	1	29	48	54	
Ties	1	1	1	6	
Z	-8.322*	-3.874*	-0.508	-2.728*	

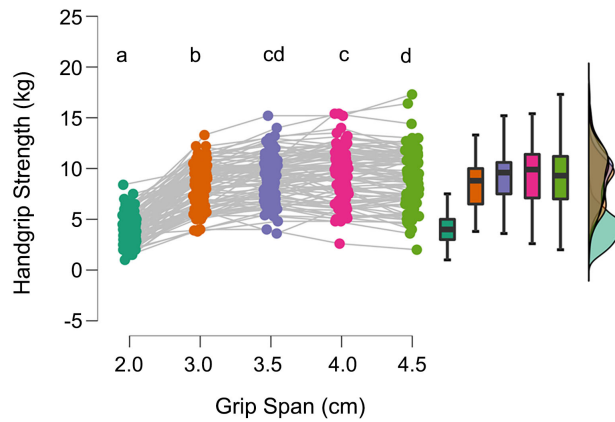


Figure 1. A comparison of handgrip strength (in kg) across the different grip spans ranging from 2 cm to 4.5 cm. The box pot represents the interquartile range of the difference and the cloud on the far right shows the distribution of the data. The letters above each grip span are there to denote which comparisons differ. Comparisons that share letters are not statistically different from each other (e.g. 3.5 vs. 4.5 share “d”) and are not statistically different. Figure was made using JASP 0.16.3.

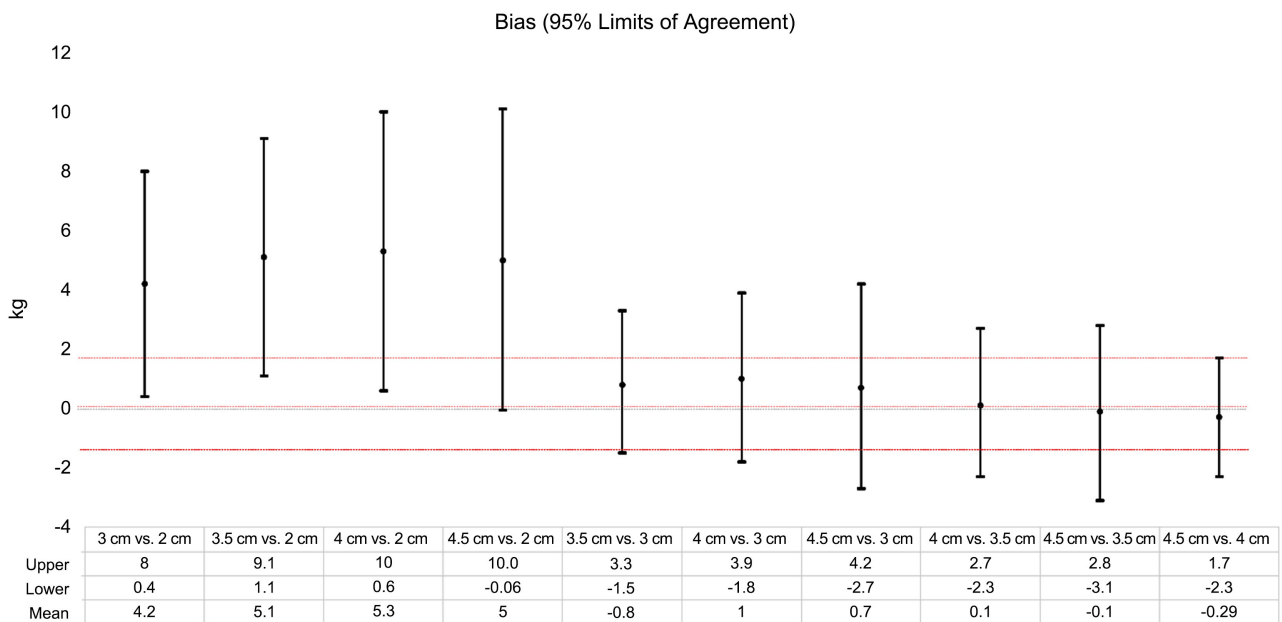


Figure 2. The mean difference (in cm) between each grip span and the 95% limits of agreement of each comparison. The wider the bounds, the less agreement. The dotted red lines represent the limits of agreement to just taking the same measurement twice with the same device (*i.e.* there is some variability to just testing). The bottom includes the values used to create the figure. Upper represents the upper bound of the limits of agreement, Lower represents the lower bound of the limits of agreement, and mean represents the mean difference.

4. Discussion

The present study examined the impact of grip span on HGS in young children using a dynamometer ranging from 2 - 4.5 cm of grip span. The highest HGS

appeared at a grip span of 4.0 cm, and the difference between HGS at a grip span of 4.0 cm and 3.5 cm or a grip span of 4.0 cm and 4.5 cm was significantly different but relatively small, as described later.

As mentioned above, Sanchez-Delgado and colleagues [15] examined the association between grip span and HGS in children aged 3, 4, and 5. The authors used hand size (*i.e.*, maximal hand width) to propose a standard grip span for measuring maximum HGS. However, the grip span ranged from 4 cm to 6 cm, with a maximum HGS observed at 4 cm and a minimum HGS observed at 6 cm in all three age groups. Thus, the HGS value at smaller grip spans (<4 cm) was not investigated, although the hand size of participants was small compared with adults. In the present study, the highest HGS value appeared at 4 cm in the range of grip spans from 2 cm to 4.5 cm. The results from the present and previous studies suggest that the optimal grip span for young children (between ages of 4.6 and 6.5 years) would be approximately 4 cm.

Our findings showed that the difference in HGS between the grip span of 4.0 and 4.5 cm was 0.3 kg in boys and 0.4 kg in girls. Similar results were reported from a previous study [15] that the difference between the two grip spans (4.0 vs. 4.5 cm) was from 0.3 - 0.4 kg in boys between the ages of 3.5 - 5.6 years and 0.2 - 0.5 kg in girls of the same age range. In the present study, a similar phenomenon appeared in the difference in HGS between 3.5 and 4.0 cm grip span, and the difference was 0.2 kg in girls and 0.2 kg in boys (**Table 2**). Therefore, a difference of 1 kg or less was observed in HGS under conditions where the optimum grip span and the grip span of 0.5 cm are different. Importantly, the limits of agreement between 4 cm and 3.5 cm and 4 cm and 4.5 cm are relatively small compared to the test-retest reliability (**Figure 2**). When separated by sex, the limits of agreement were visually similar (data not shown). In addition, previous studies have confirmed similar results in adults [18] [20]. Those studies reported that the peak value of HGS was observed at the optimal grip span and that there were similar HGS values at 0.5 cm narrow or greater in width from the optimal grip span.

On the other hand, several studies have investigated the optimal grip span for measuring maximum HGS in children aged 6 to 13 years [21], adolescents [16], and adolescents with down syndrome [22]. Those studies compared the HGS at the optimal grip span with the HGS at 1 cm shorter or longer than the optimal grip span. When it was 1 cm shorter than the optimal grip span, the HGS was significantly lower, and the difference between the two was about 2 - 3 kg [16] [21] [22]. Considering that children and adults have different optimal grip spans [16] [21], hand size influences the difference. We found mean differences between our optimal grip span of 4 cm and the smaller grip spans. The difference between 4 cm and 2 cm grip spans was pronounced and was post-hoc found to be related to the size of the hand ($r = 0.425$, $p = 0.003$). In other words, as the size of the hand increased, the greater the difference was between the 4 cm and 2 cm grip spans.

5. Conclusion

The current study examined the impact of grip span on HGS in young children using a dynamometer ranging from 2 - 4.5 cm of grip span. The highest HGS appeared at a grip span of 4.0 cm. In addition, the difference between HGS at grip span 4.0 cm and 3.5 cm or grip span 4.0 cm and 4.5 cm was significant but relatively small. Our results recommended that the target grip span for measuring maximal HGS in young children is about 4 cm (4 ± 0.5 cm).

Acknowledgements

The authors are grateful to all the children who took part in this study, their caregivers, and all the supporting staff of this study. This work was supported, in part, by grant support from the Japan Society for the Promotion of Science Grants-in-Aid for Scientific Research (JSPS KAKENHI Grant Number 22510373).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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