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Reliability of a novel technique to assess palmar contracture in young children with unilateral hand injuries

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ABSTRACT

Background: Palmar contracture in young children can have significant developmental consequences. Despite this, objective techniques to measure palmar range of movement and quantify contracture in young children are limited.
Purpose: The purpose of this study was to determine the reliability of hand span and hand length measures in young children and to establish whether there is any association with age, sex and presence of a palmar burn injury in the reliability of these measures. The study also sought to determine the normative difference and establish a cut off value for the between-hand difference to identify loss of movement in 1 hand.
Study design: Cross sectional
Methods: Forty-four children aged 0 to <5 years were recruited. Twenty-two children had a unilateral palmar burn injury and 22 did not have a palmar burn injury. Each child's hand span and hand length were measured 3 times. This was performed twice by the first assessor and once by the second assessor. Intraclass correlation coefficients were calculated to determine the intra-rater and inter-rater reliability. The largest of the 3 values for both hand span and hand length from the first assessor's first assessment were used to determine the normative between-hand difference. Outliers were removed prior to determining the normative difference. Children were considered outliers if their between-hand difference in hand span and/or hand length was in the top 5% of values.
Results: Excellent reliability was established for hand span and hand length measures for the whole group (intra-rater $ICC_{2,1}$ ≥0.95, inter-rater $ICC_{2,1}$ ≥0.94). The mean normative between-hand difference for both measures was 2 mm. The cut-off for the normative difference in hand span was <9 mm and hand length was <6 mm.
Conclusion: This measurement technique has excellent reliability and could be a useful method to quantify palmar range of movement and identify contracture in young children with unilateral hand injuries.

Introduction

Palmar contracture in young children can result from acute injury, such as burn or fracture or chronic conditions including neurological or connective tissue diseases.[1–3] Palmar contracture can impact on a young child's ability to play, acquire fine motor skills and develop self-care competencies.[4] Techniques to manage palmar contracture vary depending on the etiology. Botox, for example, may be used to reduce upper limb spasticity in children with cerebral palsy,[5] while surgical release and use of orthoses may be used in children post hand burn injury to improve range of movement (ROM).[6] Despite different etiologies and management techniques, the necessity to objectively determine the effectiveness of an intervention on palmar contracture remains the same. However,

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in the clinical setting, methods available to measure ROM across the palm and to quantify palmar contracture in young children remain limited. The importance of a measurement tool to evaluate this is particularly relevant in young children as, unlike adults, there are unique challenges associated with growth, making effective monitoring essential over the pediatric years.[7]

There are several methods available to measure hand ROM in the clinical setting. Goniometry is a well established, objective and reliable method of measuring ROM of the wrist and individual digits.[8,9] Tools to assess thumb abduction have also been described. These include calipers to measure the maximum linear distance between the first and second metacarpals and the pollexograph to measure the angle of the first webspace at end of range abduction.[10,11] However, these methods cannot completely assess ROM across the palm and consequently identify loss of palm ROM. Measurement of hand span and hand length could be considered methods to address the limitations of these measures. Hand span and hand length measures have been used in adults to assess generalized hypermobility and hand ROM.[8,12] In adults, Nicholson and Chan[12] used the ratio of hand span to hand length as 1 component of an assessment scale to diagnose upper limb hypermobility. Therefore, it is conceivable that measurement of hand span and hand length may also be useful for diagnosing hypomobility and contracture. To the best of our knowledge these measures have not been used in children.

Palmar burn injuries are common in young children, particularly as their mobility progresses and they actively explore their environment.[4,13] These factors combined with both the thin palmar epidermis and slow withdrawal reflex result in an increased susceptibility to deep palm burns.[4,13,14] These burns may have significant long term consequences, as the development of thick scar tissue with reduced pliability across the flexor surface of the hand can result in palmar contracture.[15] In the clinical setting, assessment of palm ROM post burn injury is often subjective from visual examination by the clinician. A description of the presence of skin tension and line of pull at end of range (EOR) is a method frequently used to monitor scar progress.[16] However, this method is subjective and early changes in ROM may be missed. The ability to objectively measure palm ROM is imperative to quantify loss of ROM as well as to provide insight into the recovery of ROM and the effectiveness of clinical interventions.[8] As palmar burn scar contracture has the ability to impact both hand span and hand length, absolute values of hand span and hand length may be more insightful than their ratio.

Due to the rapid growth of a child's hand in their early years, the ability to compare measures taken from the same hand over time is limited.[17] To overcome this limitation, comparing hand span and hand length measures between the affected and unaffected hands could be considered a way to monitor ROM in the affected hand. It is anticipated that loss of ROM in the affected hand will result in a greater difference in hand span and hand length between the 2 hands. These measures would be particularly useful in young children post palmar burn as hypertrophic scar tissue will not accommodate growth and consequently contracture may develop years after a burn injury.[16]

The primary aims of this study were twofold. First, to determine the intra-rater and inter-rater reliability of hand span and hand length measures in young children and second, to establish whether there is any association with age, sex and presence of a palmar burn injury in the reliability of these measures. The study also aimed to determine the normative difference and to establish a cut-off value for the difference in hand span and hand length between the left and right hands to identify loss of ROM in 1 hand.

Fig. 1(A). Child's hand position on paper for measurement.

Materials and methods

Patient population

Two groups of children aged 0 to <5 years were recruited through the Burns Unit at the Children's Hospital at Westmead (CHW). The first group were consecutively recruited children 3 to 6 months post unilateral, mid-dermal to full thickness palmar burn injury and were receiving scar management through the Burns Unit at CHW (burn group). The second group were conveniently recruited siblings of children presenting to the Burns Unit for treatment and had not sustained a burn injury to the hand (non-burn group). Children were excluded if they were aged ≥5 years old or had a pre-existing medical condition affecting hand function. In addition, children were excluded from the burn group if their hand burn injury also involved the dorsal aspect of their hand and/or wrist. This study was approved by the Sydney Children's Hospital Network Human Research Ethics Committee (2019/ETH09844). Informed consent was obtained from parentsor caregivers of all participants.

Measures and procedure

Each child was seen on 1 occasion and had multiple measures taken by 2 assessors. The child's hand was positioned palm side down on paper by the assessor. Their thumb and fifth digit were concurrently passively positioned at end range extension (thumb) and abduction (fifth digit). The assessor marked the paper with a pen at the tip of the thumb and the tip of the 5th digit to determine hand span and the tip of the 3rd digit and the first wrist crease on the radial aspect of the wrist to determine hand length (Fig. 1A). This was repeated 3 times on each hand. The linear distance in millimeters (mm) was measured with the same ruler for each attempt (Fig. 1B). Of the 3 measures of hand span and hand

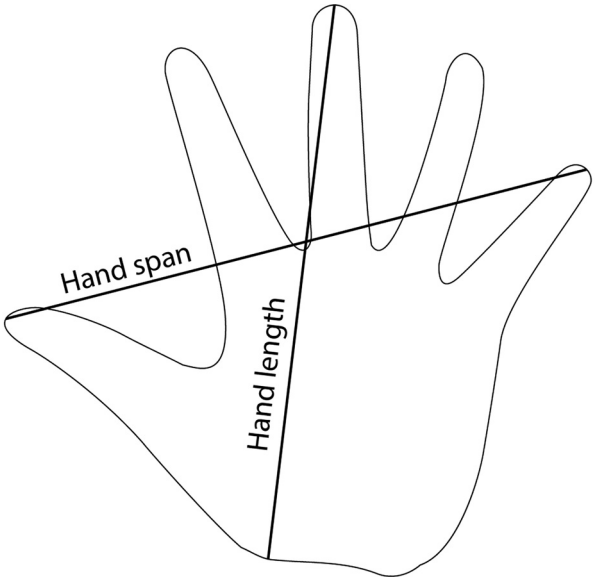

Fig. 1(B). Hand span and hand length measures.

length taken each time, the largest measure on each hand was used for analysis.

The measures were performed twice by the first assessor to evaluate the intra-rater reliability and repeated by the second assessor to evaluate the inter-rater reliability. Three physiotherapists were involved in the measurement process (RT, SW, CT) and randomly alternated the role of first and second assessors. All assessors had >10 years' experience in pediatric physiotherapy.

Statistical analysis

Data analysis was performed using IBM SPSS Statistics for Windows Version 26.0 (Armonk, New York).[18] Descriptive analysis of the children's demographic variables was completed to characterize the study sample. As all children in the burn group had only 1 burned hand, their non-burn hand was used for analysis in the non-burn group. To determine reliability, the intraclass correlation coefficient (ICC) was calculated from the raw scores of hand span and hand length, using a 2 way random-effect model based on single measures and absolute agreement ($ICC_{2,1}$). $ICC_{2,1}$ was used to determine the intra-rater reliability for each physiotherapist as well as the inter-rater reliability between therapists. To determine whether the measures of hand span and hand length were reliable in different groups of children the intra-rater $ICC_{2,1}$ and inter-rater $ICC_{2,1}$ were calculated for both measures in the following subgroups: children with and without burn injuries; boys and girls; and children aged 0 to <24 months, 24 to <36 months and 36 to <60 months. Benchmarks outlined by Cicchetti and Sparrow[19] were used to interpret $ICC_{2,1}$ with a value >0.75 indicating excellent reliability and a value between 0.60 and 0.74 indicating good reliability. For all statistical tests, 95% confidence intervals and *P*-values were calculated, with $P \leq .05$considered statistically significant. A post-hoc power analysis was performed to verify that the study was adequately powered.

The largest of the 3 values for both hand span and hand length from the first assessor trial 1 was used to determine the mean normative difference between the right and left hands. Children with aberrant large values due to poor compliance throughout the measurement process and children demonstrating early signs of contracture on clinical examination, such as banding at EOR palmar extension were considered outliers and their data removed prior to determining the normative difference between the left and right hands. To remove these outliers, a cumulative percent was generated from the frequency of values of the difference in hand span and hand length between both hands from the 3 trials (first assessor trial 1 and 2, and second assessor). In pediatric orthopedics, data points within 2 standard deviations of the mean (95% of all values) are considered within normal variance.[17] Due to the small sample size, the top 5% of values were removed to ensure all outliers were excluded. All children with burn injuries included in the calculation of normative values had full palmar ROM with no EOR banding as determined by 2 experienced burns therapists, who assessed each child using digit goniometry and visual inspection. A cut-off value was established for the normative difference in hand span and hand length between the 2 hands. The mean normative difference and standard deviation (SD) were calculated for all remaining children as well as the sub-groups. The differences between the children with and without burn injuries and boys and girls were analyzed with unpaired t-tests. The difference between the 3 age groups was analyzed with a 1 way analysis of variance (ANOVA). Post-hoc t-tests were performed to compare the difference between sub-groups.

Results

Forty-four children participated in this study with a mean age of 28 months (SD 11.8). The mean age of the 22 children with burn injuries was 24 months (SD 11.2) and the mean age of the 22 children without burn injuries was 32 months (SD 11.1). Of the 44 children who participated, there were 22 hands with burn injuries and 66 hands without burn injuries. Participant characteristics are presented in Table 1.

Intra-rater reliability

Eighty-eight hands from 44 children were used to determine the reliability of the raw values of hand span and hand length. Both measures demonstrated excellent intra-rater reliability for the whole group with $ICC_{2,1} \geq 0.95$, $P < .001$. Intra-rater reliability for each PT was also excellent (Table 2). Across all groups, intra-rater $ICC_{2,1}$ was excellent for hand span and hand length, although hand span consistently demonstrated greater reliability than hand length (Table 3). For both measures, intra-rater reliability was highest in children aged 36 to <60 months (hand span $ICC_{2,1}$ 0.98, hand

Table 1
Characteristics of participants according to whether or not they had a palmar burn injury.

		All children ($n = 44$) n (%)	Children with burn injuries ($n = 22$) n (%)	Children without burn injuries ($n = 22$) n (%)
Sex	Boys	23 (52)	14 (64)	9 (41)
	Girls	21 (48)	8 (36)	13 (59)
Age	0-<24 months	18 (41)	14 (64)	4 (18)
	24-<36 months	14 (32)	5 (23)	9 (41)
	36-<60 months	12 (27)	3 (13)	9 (41)

Table 2
Intra-rater reliability for 3 physiotherapists.

Physiotherapist	Hand span (88 hands) $ICC_{2,1}$ (95% CI)	Hand length (88 hands) $ICC_{2,1}$ (95% CI)
PT 1	0.97 (0.95-0.99)*	0.95 (0.91-0.98) *
PT 2	0.98 (0.97-0.99) *	0.96 (0.91-0.98) *
PT 3	0.99 (0.98-1.0) *	0.95 (0.88-0.98) *

CI = confidence interval; $ICC_{2,1}$ = intraclass correlation coefficient; PT = physiotherapist.
All $ICC_{2,1}$ have been rounded to 2 decimal places.
* $P < .01$ is statistically significant.

Table 3
Intra-rater and inter-rater reliability for measures of hand span and hand length.

		Intra-rater reliability		Inter-rater reliability	
		Hand span $ICC_{2,1}$ (95% CI)	Hand length $ICC_{2,1}$ (95% CI)	Hand span $ICC_{2,1}$ (95% CI)	Hand length $ICC_{2,1}$ (95% CI)
Hands	All (n = 88 hands)	0.98 (0.97-0.99)*	0.95 (0.93-0.97) *	0.96 (0.94-0.97) *	0.94 (0.91-0.96) *
	Burn (n = 22 hands)	0.98 (0.96-0.99) *	0.95 (0.87-0.98) *	0.97 (0.94-0.99) *	0.95 (0.86-0.98) *
	Non-burn (n = 66 hands)	0.98 (0.97-0.99) *	0.95 (0.92-0.97) *	0.95 (0.92-0.97) *	0.94 (0.90-0.96) *
Sex	Boys (n = 46 hands)	0.99 (0.98-0.99) *	0.97 (0.95-0.98) *	0.96 (0.93-0.98) *	0.96 (0.91-0.98) *
	Girls (n = 42 hands)	0.98 (0.95-0.99) *	0.91 (0.84-0.95) *	0.96 (0.93-0.98) *	0.92 (0.85-0.96) *
Age	0-<24 months (n = 36 hands)	0.96 (0.92-0.98) *	0.86 (0.75-0.93) *	0.92 (0.85-0.96) *	0.82 (0.67-0.90) *
	24-<36 months (n = 28 hands)	0.92 (0.84-0.96) *	0.82 (0.65-0.91) *	0.92 (0.82-0.96) *	0.83 (0.66-0.92) *
	36-<60 months (n = 24 hands)	0.98 (0.95-0.99) *	0.91 (0.81-0.96) *	0.85 (0.69-0.93) *	0.90 (0.74-0.96) *

CI = confidence interval; ICC = intraclass correlation coefficient; n = number.
All $ICC_{2,1}$ have been rounded to 2 decimal places.
* $P < .01$ is statistically significant.

length $ICC_{2,1}$ 0.91), followed by children aged 0 to <24 months (hand span $ICC_{2,1}$ 0.96, hand length $ICC_{2,1}$ 0.86) and children aged 24 to <36 months (hand span $ICC_{2,1}$ 0.92, hand length $ICC_{2,1}$ 0.82). There was excellent intra-rater reliability for the 22 hands with a palmar burn (hand span $ICC_{2,1}$ 0.98, hand length $ICC_{2,1}$ 0.95) and the 66 hands without a palmar burn (hand span $ICC_{2,1}$ 0.98, hand length $ICC_{2,1}$ 0.95).

Inter-rater reliability

Inter-rater reliability for hand span and hand length was excellent, with $ICC_{2,1}$ for both measures ≥0.94 ($P < .001$) (Table 3). As shown in Table 3, there was excellent inter-rater reliability for both measures in boys (hand span and hand length $ICC_{2,1}$ 0.96) and girls (hand span $ICC_{2,1}$ 0.96, hand length $ICC_{2,1}$ 0.92) and in children with burn injuries (hand span $ICC_{2,1}$ 0.97, hand length $ICC_{2,1}$ 0.95) and without burn injuries (hand span $ICC_{2,1}$ 0.95, hand length $ICC_{2,1}$ 0.94). For both measures, hands with burn injuries had greater inter-rater reliability than hands without burn injuries. In all groups except age 36 to <60 months, the inter-rater reliability was higher for hand span compared to hand length. A post-hoc power analysis determined that a sample size of 43 children was required to achieve 85% power with the following parameters: minimum acceptable ICC 0.60, $P < .05$.[20]

Normative difference between hands for hand span and hand length

Based on the spread of differences shown in Figure 2, the top 5% of values for hand span were between 9 mm and 16 mm. Therefore, the cut-off for the normative difference in hand span

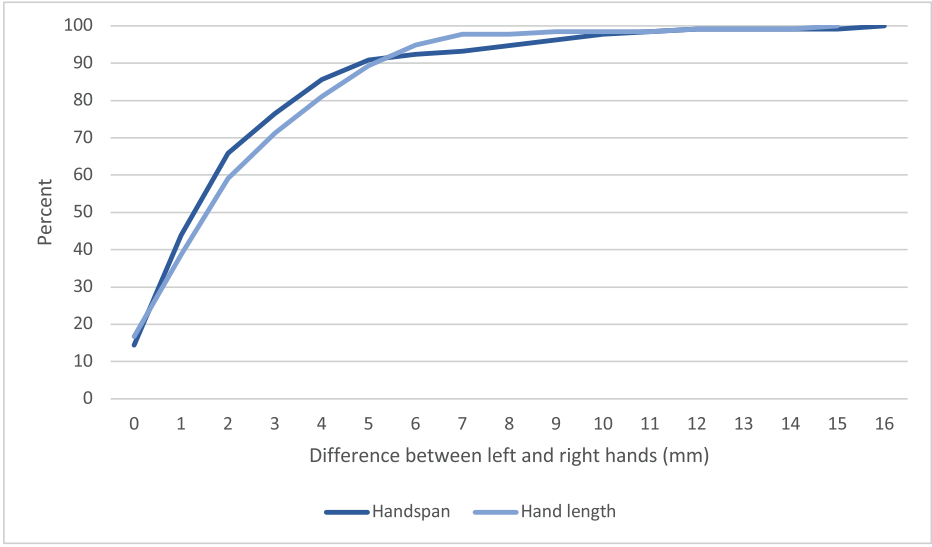

Fig. 2. Cumulative percent for the difference in hand span and hand length between right and left hands.

Table 4
Mean difference in hand span and hand length by participant type, gender and age.

		Hand span (n = 41 children)			Hand length (n = 39 children)		
		Between-hand difference (mm) Mean (SD)	Between group difference (mm) (95% CI)	P-value	Between-hand difference (mm) Mean (SD)	Between group difference (mm) (95% CI)	P-value
Participants	Burn	2 (1.55)	-0.03 (-0.96-0.90)	0.95	2 (1.70)	0.42 (-0.56-1.41)	0.39
	Non-burn	2 (1.40)			2 (1.31)		
Sex	Boys	2 (1.72)	0.07 (-0.84-0.98)	0.88	2 (1.38)	-0.53 (-1.51-0.46)	0.29
	Girls	2 (1.12)			3 (1.65)		
Age	0-<24 months*	2 (1.26)			2 (1.70)		
	24-<36 months	2 (1.42)	0.36 (-0.67-1.38)	0.48	2 (1.49)	-0.17 (-1.44-1.11)	0.79
	36-<60 months	3 (1.66)	-0.63 (-1.76-0.51)	0.27	2 (1.44)	-0.19 (-1.48-1.10)	0.76

CI = confidence interval; n = number; mm, millimeters; SD = standard deviation.
* Between group differences in age reported are in comparison to 0-<24 months. One way ANOVA for between group difference in hand span; F(2,38)=1.488, P = .2 and hand length; F(2,36)=0.059, P = .94.

was determined to be <9 mm. For hand length, the top 5% of values were between 6 mm and 15 mm (Fig. 2). Therefore, the cut-off for hand length was determined to be <6 mm.

The mean normative difference between the left and right hands was the same for hand span and hand length; 2 mm (hand span SD 1.52, hand length SD 1.45). There were no statistically significant differences in these measures with respect to age, gender or presence of a palmar burn injury (Table 4).

Discussion

This is the first study to determine the reliability of hand span and hand length measures in young children. Excellent intra-rater and inter-rater reliability for both measures was established. In young children, the mean normative difference in hand span and hand length between the left and right hands was determined to be 2 mm. Furthermore, cut-off values were established for both measures to identify loss of palmar ROM: (1) a difference in hand span of ≥9 mm, and (2) a difference in hand length of ≥6 mm. Our findings suggest that this measurement technique could be a clinically useful and reliable measure to quantify palmar ROM and determine contracture in young children.

Previous studies have shown linear hand measures to be reliable in adult populations.[8,10] In individuals with and without impaired hands, Murugkar et al.[10] found measurement of the linear distance between the first and second metacarpal was more reliable to assess ROM of the first webspace than goniometry measurement of thumb abduction angle (ICC 0.88 vs ICC 0.26). In adults post burn injury, Edgar et al.[8] established excellent inter-rater reliability for the linear measure of hand span (ICC 0.975). The results of our study concur with this previous work and demonstrate that linear hand measures are very reliable in young children with and without palmar burn injuries.

Identification of the normative acceptable difference in hand span and hand length between the left and right hands can assist the therapist to determine early loss of palmar ROM and therefore initiate non-surgical intervention to improve ROM, such as serial casting. Earlier studies have demonstrated that active scar tissue is responsive to non-surgical intervention, when initiated within 2 months of burn injury.[16,21] This measurement technique can also be utilized to track changes developing over time in the growing child. Our study determined acceptable between-hand difference in hand span to be <9 mm and hand length to be <6 mm. Edgar et al.[8] compared measures taken from the same hand in adults and established measurable change in hand span to be >1 centimeter (cm). This suggests that the acceptable difference for hand span measures taken from the same hand in adults is ≤1 cm. Compared to Edgar et al.[8], our study found that smaller values in children may indicate loss of palmar ROM. As hand span and hand length are smaller in children compared to adults, we would expect detectable change in these measures to also be smaller.

In young children, our method of determining loss of palmar ROM through comparison of hand span and hand length measures taken from the left and right hands is efficient and relatively easy to perform. It demonstrated excellent reliability when performed by the same physiotherapist, as well as different physiotherapists, and therefore could be easily incorporated into clinical practice. The materials required are all readily available in the clinical setting: pen, paper and a ruler. While some compliance from the child is needed to complete the technique, limited active participation is required, as passive ROM is assessed. In most children, cooperation with the measurement process was satisfactory, although there were situations where a child's anxiety or limited understanding of the procedure made it difficult. This was not unique to our measurement technique as challenges with cooperation in the assessment and treatment of young children have been previously reported.[13,22]

This study has some limitations. Firstly, the technique cannot be applied to children where both hands have potential for contracture, for example bilateral hand burn injuries, as we cannot be sure that 1 hand has full ROM to provide a comparator. Also, as comparison between a child's 2 hands is central to this technique, a cut-off value based on raw values of hand span and hand length, which may indicate loss of palmar ROM in each age group, was not determined. Therefore, the question of how to determine loss of ROM in bilateral hand burns remains unanswered. Additionally, a convenience sample of children without palmar burns was used, rather than age matched controls. While there were no significant differences in the reliability of hand span and hand length measures in children with and without palmar burn injury, we cannot be sure that there were not inherent differences in the populations. Finally, a power analysis was completed post-hoc instead of a priori.

This study has provided preliminary evidence of a reliable, clinically applicable measure of hand span and hand length in young children. Future research could focus on increasing the applicability of this technique by examining reliability in older children and children with neurological conditions. In older children, the effect of hand dominance may need to be accounted for, as it is reasonable to expect that hand span and hand length measures may be larger in the dominant hand of an older child. Our study did not account for this as hand preference is typically inconsistent in young children.[23] Another consideration is to trial the technique in children with known contracture, to determine whether it can identify children with and without contracture. Finally, future research incorporating larger sample sizes could seek to

establish normative raw values of hand span and hand length based on age.

Conclusion

Due to the rapid growth of a child's hand in their early years, the ability to quantify palmar ROM through comparison of values taken from both hands can assist health professionals to identify developing contracture, monitor loss of ROM evolving over time as well as evaluate the effectiveness of interventions. While some challenges exist in performing this assessment with young children, this study has demonstrated that this technique has excellent reliability when completed by experienced physiotherapists.

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Quiz: # 856

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1. The authors' primary goal was to establish a reliable clinical measurement technique for determining
   a. palmar skin pliability in a pediatric population
   b. the correlation between function and hand span
   c. digital length vs palmar span
   d. palmar ROM

2. Hand length was defined as the distance between the
   a. confluence of the thenar and hypothenar eminences to the tip of the ring finger
   b. distal pole of the scaphoid to the tip of the 3rd digit
   c. 1st wrist crease (radial aspect) to the tip of the 3rd finger
   d. tip of the thumb to the tip of the little finger

3. The average difference between left and right hand span and length was approximately
   a. 2 mm
   b. 5 mm
   c. 1 cm
   d. 4 cm

4. Reliability was
   a. moderate
   b. excellent
   c. poor
   d. not measured

5. A key clinical application of the measure is to help recognize early contracture development
   a. false
   b. true

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