SCIENTIFIC ARTICLE

Palmar Abduction Measurements: Reliability and Introduction of Normative Data in Healthy Children

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Purpose Previously, we studied normative and reliability data of palmar thumb abduction measurements (conventional goniometry, the Pollexograph thumb, the Pollexograph metacarpal, the Inter Metacarpal Distance, the American Society of Hand Therapists method, and the American Medical Association method) in healthy adults. Because many interventions aiming to improve palmar abduction are performed at an early age, the goal of this study was to assess normative and reliability data of these measurement methods in children.

Methods We performed measurements with the Pollexograph thumb, the Pollexograph metacarpal and Inter Metacarpal Distance in 100 healthy children to acquire normative data. A retest was performed in 63 children to assess intraobserver reliability.

Results Mean active and passive palmar abduction measured with the Pollexograph thumb was 62° (range, 40° to 76°). The range of motion of the Pollexograph metacarpal was smaller (mean 49°, range, 32° to 64°). The mean Inter Metacarpal Distance was 50 mm (range, 36–70 mm). Intraclass correlation coefficients of the Pollexograph thumb, Pollexograph metacarpal, and Inter Metacarpal Distance indicated excellent reliability (intraclass correlation coefficients between 0.85 and 0.92).

Conclusions Normative Pollexograph thumb and Pollexograph metacarpal data showed that means measured in children are comparable to values found in healthy adults. Reliability data indicated that the Pollexograph thumb, the Pollexograph metacarpal, and Inter Metacarpal Distance are also reliable measurement methods in children. *(J Hand Surg 2009;xx:. © 2009 Published by Elsevier Inc. on behalf of the American Society for Surgery of the Hand.)*

Key words Normative data, palmar abduction, reliability.

THERE IS NO clear consensus on measurement methods for palmar thumb abduction, and the same is true for definitions for palmar abduction.[1–8] An often used definition for palmar abduction is "the angle between metacarpal 1 and 2 with the thumb maximally abducted."[3,9,10] This angle is conventionally measured with a goniometer and has been described by Hartigan et al.,[9] Brand,[3] and Tubiana et al.,[10] among others. Another frequently used definition is "the motion in which the thumb metacarpal moves away from the index metacarpal, perpendicular to the plane of the palm."[8]

Some existing measurement methods have disadvantages that cause difficulties in daily clinical use, such as the low reliability of conventional goniometry[5] or the measurement complexity of 3-dimensional video camera systems.[11–14] Therefore, in a previous study,[15] we designed the Pollexograph (Fig. 1A) with the aim of creating a reliable and simple tool to perform palmar thumb abduction measurements in daily clinical care.

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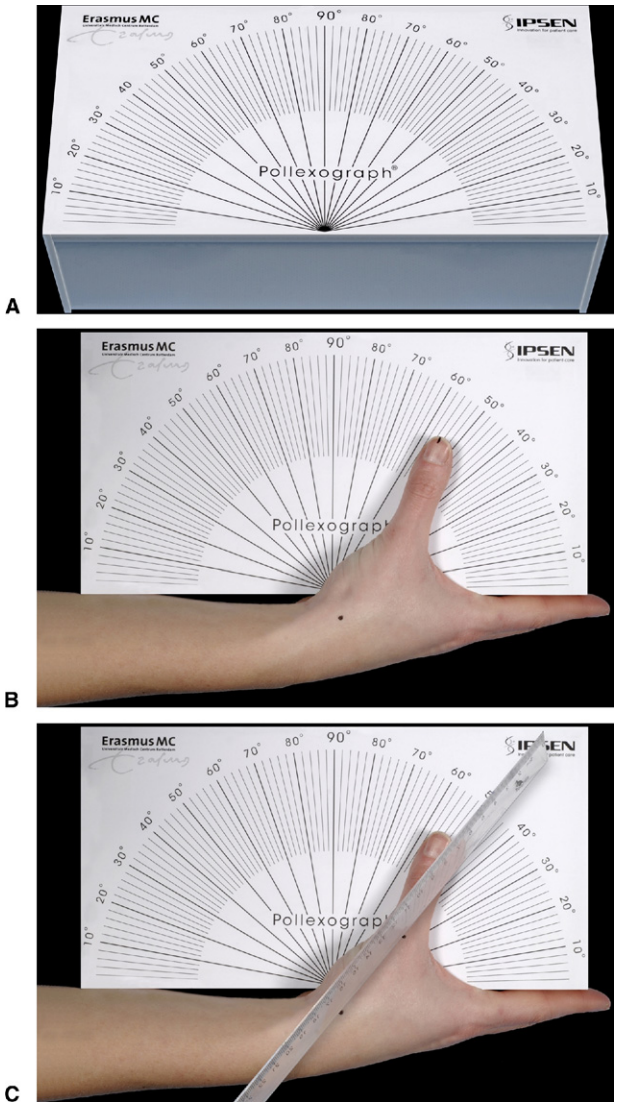

FIGURE 1: A The Pollexograph with a protractor on top. The Pollexograph has a length of 26.5 cm, height of 7 cm, width of 13.5 cm, and radial protractor length of 11.5 cm. The protractor is divided in steps of 2°. **B** Position of hand and forearm on the Pollexograph during a Pollexograph-thumb measurement. Two landmarks are visible: the carpometacarpal joint marking and the nail marking that facilitates angle readings. **C** A Pollexograph-metacarpal measurement. The ruler is placed over the first metacarpal. Possible laxity in the metacarpophalangeal and interphalangeal joint is left out of the measured angle.

After developing the Pollexograph, we studied its reliability in 25 healthy adults.[16] Active and passive measurements were performed with a conventional goniometer, the Pollexograph thumb, the Pollexograph metacarpal, the Inter Metacarpal Distance (IMD),[5] the American Society of Hand Therapists method,[2] and the method described in *Guides to the Evaluation of Permanent Impairment* of the American Medical Association.[1] The high intraclass correlation coefficients (ICCs) and smaller smallest detectable differences (SDDs) and standard error of measurements (SEMs) of the Pollexograph thumb, the Pollexograph metacarpal, and the IMD indicated that the latter 3 were the most reliable methods for measuring palmar abduction. The goal of this study was to assess reliability and collect normative data of the Pollexograph thumb, the Pollexograph metacarpal, and the IMD in children, because many interventions aimed at improving palmar abduction are performed at an early age. Therefore, intraobserver reliability was assessed in 63 children and normative data were acquired in 100 healthy children.

MATERIALS AND METHODS

Children

We measured the right hand of 100 children between the age of 4 to 12 years, attending a primary school in Rotterdam, The Netherlands. The group consisted of 49 boys and 51 girls with no prior injury to the upper extremity or systemic conditions affecting the muscle or nervous system. A total of 95 children were right-handed and the remaining 5 children were left-handed. The Medical Ethics Committee approved this study and all parents gave written consent for their child to participate in this study.

Measurements

We performed active and passive palmar abduction measurements with 2 angular measurement methods (the Pollexograph thumb and the Pollexograph metacarpal) and 1 distance measurement method (IMD). Conventional goniometry, the American Society of Hand Therapists method, and the American Medical Association method were not assessed, because we found low reliability for these methods in adults.

One of the authors (M.K.) performed measurements, and after a mean of 26 days (range, 7–46 days), a retest was performed in 63 children. These 63 children were equally distributed based on age and gender. To prevent the tester from being influenced by the values of prior tests, retest values were written down on a new form.

For the Pollexograph-thumb measurements, 3 landmarks were identified on the hand: the central most proximal part of the first metacarpal, indicating the carpometacarpal joint (CMC joint); the thenar crease; and the central, distal part of the thumbnail. During measurements, the child was seated at a table with the elbow in 90° of flexion. The hand was placed on the Pollexograph with the thenar crease on the edge of the box and the CMC joint marking aligned with the 90° line of the protractor (Fig. 1B). The lower arm was

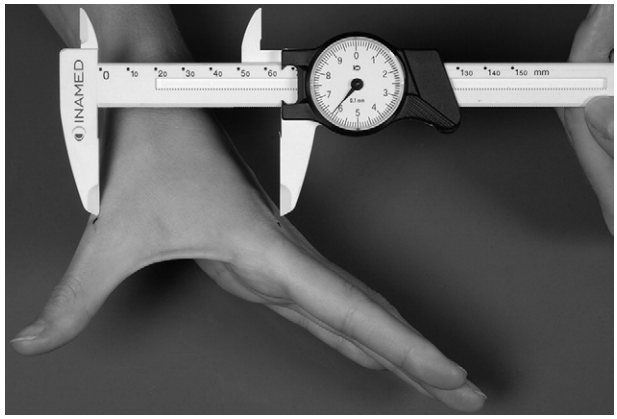

FIGURE 2: An active IMD measurement performed with a caliper.

TABLE 1. Intrarater Reliability per Measurement Method, Expressed With Use of SEMs, SDDs, and ICCs

Method	SEM	SDD	ICC
Pollexograph thumb (degrees)			
Active	2.0	5.5	0.91
Passive	1.8	5.1	0.89
Pollexograph metacarpal (degrees)			
Active	2.3	6.4	0.87
Passive	2.4	6.7	0.85
IMD (mm)			
Active	1.9	5.3	0.92
Passive	1.8	5.0	0.92

positioned parallel to the box with the fingers pointed slightly ulnar. When the hand was placed accurately, the thumb could move without interfering with the box surface. During measurements, the examiner fixed the other fingers against the box. Maximal palmar abduction of the thumb was read from the nail marking position above the protractor.

With the Pollexograph thumb, the angle between the first metacarpal and the palm of the hand is measured, plus the angle caused by possible laxity in the metacarpophalangeal and interphalangeal joints. We therefore evaluated an alternative: the Pollexograph-metacarpal application, in which a ruler is placed over the first metacarpal to measure the angle between the palm of the hand and the first metacarpal. These Pollexograph-metacarpal measurements were performed largely similar to those described for the Pollexograph-thumb measurements. The first 2 skin markings (CMC joint and thenar crease) remained the same; the third marking was placed on the mid-distal head of the first metacarpal marking. During measurements, a ruler was placed over the CMC marking, the first metacarpal marking, and the protractor (Fig. 1C). When the thumb was maximally abducted, the value was read from the ruler position above the protractor, in line with the skin markings.

The distance measurement method we performed was the IMD, introduced by Murugkar et al.[5] For these measurements, the mid-dorsal points of the first and second metacarpal heads were marked and the 2 caliper points were placed on the markings while the thumb was in maximal palmar abduction (Fig. 2). The distance was read in millimeters from the scale.

Statistical methods

Using statistical software (SPSS 14.0; Chicago, IL), we calculated descriptive statistics: means, standard deviations, and ranges of the whole group. Differences in mean values of the different methods indicate systematic differences between measurement techniques.

Intrarater reliability was assessed using ICCs.[17–19] In addition, absolute reliability indices such as SEM and SDD were calculated. The SEM was calculated with the estimated variance components; the SEM is the square root of the error variance.[20,21] From the SEM, the SDD ($1.96 \times \sqrt{2} \times \text{SEM}$) was determined. Specifically for clinicians, the SDD is valuable because with this index an examiner can distinguish between a measurement error and a real (treatment) change. Only a difference that exceeds the SDD is a real (nonerror) change.[22] For example, an SDD of 5° indicates that a follow-up measurement should differ by at least 5° from a baseline measurement to be sure that there is a real (nonerror) change in abduction angle in an individual subject.

We assessed the correlation between age and angle or distance using the Pearson's correlation coefficient. A p value of $\leq .05$ was considered significant. With use of linear regression analysis, we calculated a formula for the relation between IMD and age. With this formula, it is possible to estimate what the average IMD should be for children of a certain age (between the ages of 4 and 12).

RESULTS

Reliability

Table 1 shows the intrarater reliability for each method expressed with the use of SEMs, SDDs, and ICCs measured in 63 children. ICCs for the Pollexograph-thumb and Pollexograph-metacarpal measurements indicated excellent agreement for active and passive measurements (ICCs, 0.85–0.91). The IMD measurement ICCs (0.92) also showed excellent agreement.

TABLE 2. Mean Values, SD, and Ranges for All Active and Passive Pollexograph-Thumb and Pollexograph-Metacarpal Measurements

Method (degrees)	Mean	SD	Range
Pollexograph thumb			
Active	60.7	7.3	40–74
Passive	63.6	5.8	50–76
Pollexograph metacarpal			
Active	48.8	6.5	32–62
Passive	49.9	6.2	34–64

TABLE 3. Mean Values, SD, and Ranges for All Active and Passive IMD Measurements Expressed for the Whole Group and Per Age Group

Age, y (n)	Mean (mm)	SD	Range
Active	49.8	6.5	36–69
4 (8)	39.8	3.6	36–45
5 (8)	43.6	2.6	41–48
6 (13)	44.7	1.8	41–47
7 (11)	50.4	4.7	44–58
8 (13)	50.5	4.1	44–58
9 (14)	51.6	4.7	44–60
10 (13)	52.6	5.1	43–61
11 (14)	56.4	5.6	47–69
12 (6)	57.0	3.8	50–61
Passive	51.5	6.4	39–70
4 (8)	42.6	2.9	39–46
5 (8)	44.8	2.4	42–48
6 (13)	45.9	2.7	41–50
7 (11)	51.4	4.4	45–58
8 (13)	52.9	4.8	45–59
9 (14)	52.8	4.8	44–60
10 (13)	54.8	4.9	46–63
11 (14)	58.3	5.6	48–70
12 (6)	57.0	4.7	48–61

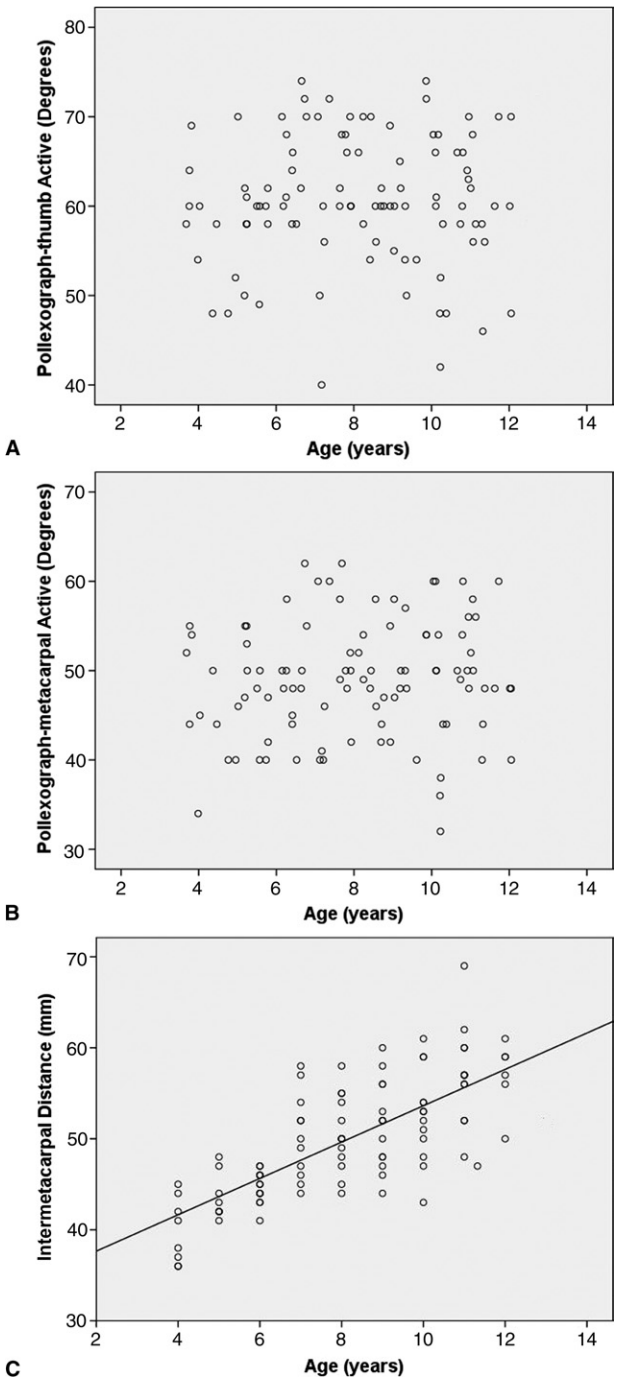

FIGURE 3: A Scatterplot displaying the correlation between age and the Pollexograph-thumb active measurements in 100 children. **B** Scatterplot displaying the correlation between age and the Pollexograph-metacarpal active measurements in 100 children. **C** Scatterplot displaying the correlation between age and the IMD active measurements in 100 children. The corresponding regression line for the active IMD is $y = 33.66 + 1.99x$, where x = age in years and y = IMD distance in millimeters.

Normative data

Table 2 shows normative data: means, standard deviations, and ranges of angular measurement methods for palmar thumb abduction. Mean active and passive angles measured with the Pollexograph thumb were approximately 62° (range, 40° to 76°). Angles found with the Pollexograph metacarpal were smaller: about 49° (range, 32° to 64°). Table 3 lists the means, standard

deviations, and ranges of the distance measurement method. Mean active and passive IMD distances ranged from 36 to 70 mm, with an average of 50 mm.

Figure 3A shows that the palmar abduction angle of the Pollexograph thumb ranged from 40° to 76° and that the angle did not correlate with age ($r = 0.046$, $p = .65$). Figure 3B shows similar results for the Pollexograph metacarpal. This palmar abduction angle ranged from 32° to 64° and also did not correlate with age ($r = 0.064$, $p = .53$). In contrast to Pollexograph angles, IMD distances (Fig. 3C) correlated significantly to age ($r = 0.73$, $p = .001$). Therefore, Table 3 lists normative IMD data separately for each age group, showing an increase of the mean IMD with increasing age.

DISCUSSION

The first goal of this study was to assess whether the Pollexograph thumb, Pollexograph metacarpal, and IMD are reliable measurement methods of palmar abduction in children, because many surgical interventions aimed at improving palmar abduction are performed at an early age. We found that the Pollexograph thumb, Pollexograph metacarpal, and IMD had excellent intrarater reliability to measure palmar abduction in 63 children aged 4 to 12 years. Second, we obtained normative data for palmar abduction of the thumb in 100 children.

With Pollexograph-metacarpal measurements, we found mean palmar abduction to be 49°, ranging from 32° to 62° for active measurements. For passive measurements, we found a mean value of 50° (range, 34° to 64°). Normative data in this study were most comparable to the results of Tubiana et al.,[10] who found normal values ranging from 40° to 80°, whereas Brand[3] reported the normal range of the web angle as being 40° to 50°. Harvey et al.[4] found mean passive palmar abduction to be 56° (range, 53° to 60°) in their healthy adult group. However, these results were reported in healthy adults; to our knowledge, normative palmar abduction angles in children have not been reported. Mean palmar abduction angles measured for the children in this study were similar to the mean values we recently reported for adults, using the same measurement techniques.[16] Because children's hands are not yet fully grown, IMD means were not comparable with means found in adults. We would therefore favor the Pollexograph-thumb and Pollexograph-metacarpal methods for measuring palmar abduction in children.

REFERENCES

1. American Medical Association. Guides to the evaluation of permanent impairment. 4th ed. Chicago: American Medical Association, 1993:28–29.
2. American Society of Hand Therapists. Clinical assessment and recommendations. 2nd ed. Chicago: American Society of Hand Therapists, 1992:64–65.
3. Brand PW. Deformity in leprosy. In: Cochrane RG, ed. Leprosy in theory and practice. 2nd ed. Bristol, UK; John Wright & Sons, Ltd., 1964:485–496.
4. Harvey L, de Jong I, Goehl G, Armstrong B, Allaous J. A torque-controlled device to measure passive abduction of the thumb carpometacarpal joint. J Hand Ther 2006;19:403–408.
5. Murugkar PM, Brandsma JW, Anderson AM, Gurung K, Pun Y. Reliability of thumb web measurements. J Hand Ther 2004;17:58–63.
6. Schwanholt C, Stern PJ. Brief or new: measuring cone for thumb abduction/extension. Am J Occup Ther 1984;38:263–264.
7. Shrinivasan H. Reconstructive surgery in treatment of deformities of hand. In: Dharmendra, ed. Leprosy. Bombay: Kothari Medical, 1978:567–617.
8. International Federation of Societies for Surgery of the Hand. Terminology for hand surgery. Edinburgh: Harcourt Health Sciences, 2001:53–54.
9. Hartigan BJ, Stern PJ, Kiefhaber TR. Thumb carpometacarpal osteoarthritis: arthrodesis compared with ligament reconstruction and tendon interposition. J Bone Joint Surg 2001;83A:1470–1478.
10. Tubiana R, Thomine JM, Mackin E. Examination of the hand and wrist. London: Martin Dunitz, 1998:195–196.
11. Chiu HY, Lin SC, Su FC, Wang ST, Hsu HY. The use of the motion analysis system for evaluation of loss of movement in the finger. J Hand Surg 2000;25B:195–199.
12. Su FC, Kuo LC, Chiu HY, Chen-Sea MJ. Video-computer quantitative evaluation of thumb function using workspace of the thumb. J Biomech 2003;36:937–942.
13. Kuo LC, Su FC, Chiu HY, Yu CY. A quantitative method to measure maximal workspace of the trapeziometacarpal joint: normal model development. J Orthop Res 2004;22:600–606.
14. Degeorges R, Parasie J, Mitton D, Imbert N, Goubier JN, Lavaste F. Three-dimensional rotations of human three-joint fingers: an optoelectronic measurement. Preliminary results. Surg Radiol Anat 2005;27:43–50.
15. de Kraker M, Selles RW, Schreuders TA, Hovius SE, Stam HJ. The Pollexograph®: a new device for palmar abduction measurements of the thumb. J Hand Ther 2009;22:271–277.
16. de Kraker M, Selles RW, Schreuders TA, Stam HJ, Hovius SE. Palmar abduction: reliability of 6 measurement methods in healthy adults. J Hand Surg 2009;34A:523–530.
17. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;8476:307–310.
18. Fleiss JL. The design and analysis of clinical experiments. Newark, NJ: John Wiley and Sons, 1986:1–14.
19. Fleiss JL, Levin B, Paik M. Statistical methods for rates and proportions. Newark, NJ: John Wiley and Sons, 2003:218.
20. Roebroeck ME, Harlaar J, Lankhorst GJ. The application of generalizability theory to reliability assessment: an illustration using isometric force measurements. Phys Ther 1993;73:386–395.
21. Shavelson RJ, Webb NM, Rowley GL. Generalizability theory. Am Psychol 1989;44:922–932.
22. Roebroeck ME, Harlaar J, Lankhorst GJ. Reliability assessment of isometric knee extension measurements with a computer-assisted hand-held dynamometer. Arch Phys Med Rehabil 1998;79:442–448.