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# The added value of measuring thumb and finger strength when comparing strength measurements in hypoplastic thumb patients

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ABSTRACT

*Background:* When interventions to the hand are aimed at improving function of specific fingers or the thumb, the RIHM (Rotterdam Intrinsic Hand Myometer) is a validated tool and offers more detailed information to assess strength of the involved joints besides grip and pinch measurements.
*Methods:* In this study, strength was measured in 65 thumbs in 40 patients diagnosed with thumb hypoplasia. These 65 thumbs were classified according to Blauth. Longitudinal radial deficiencies were also classified. The strength measurements comprised of grip, tip, tripod and key pinch. Furthermore palmar abduction and opposition of the thumb as well as abduction of the index and little finger were measured with the RIHM.
*Findings:* For all longitudinal radial deficiency patients, grip and pinch strength as well as palmar abduction and thumb opposition were significantly lower than reference values ($P < 0.001$). However, strength in the index finger abduction and the little finger abduction was maintained or decreased to a lesser extent according to the degree of longitudinal radial deficiency. All strength values decreased with increasing Blauth-type. Blauth-type II hands (n = 15) with flexor digitorum superficialis 4 opposition transfer including stabilization of the metacarpophalangeal joint showed a trend toward a higher opposition strength without reaching statistical significance ($P = 0.094$),however compared to non-operated Blauth-type II hands (n = 6) they showed a lower grip strength ($P = 0.019$).
*Interpretation:* The RIHM is comparable in accuracy to other strength dynamometers. Using the RIHM, we were able to illustrate strength patterns on finger-specific level, showing added value when evaluating outcome in patients with hand related problems.



## 1. Introduction

Thumb hypoplasia is a spectrum of congenital abnormalities of the thumb varying from small defects to complete absence of the thumb (Riley and Burgess, 2009). Thumb hypoplasia can be classified according to Blauth in five different types and can be accompanied by Longitudinal radial deficiency (LRD) (see Table 1) (Bayne and Klug, 1987; Blauth, 1967) Interventions in hypoplastic thumb patients can vary from improving range of motion by widening the 1st web-space or improve joint stability and increase strength with tendon transfers to complete pollicization of the index finger. One of the tools to assess these interventions are hand strength measurements. To assess different muscle functions in the hand, different types of strength measurements are needed. For example, grip strength measurement in patients with thumb hypoplasia may not be able to assess the success of interventions specifically aimed at thumb function, such as tendon transfers for improving opposition or a pollicization.

Strength measurements of the hand are generally performed using grip and pinch dynamometers. While grip and pinch strength measurements are reliable in children and adults (Bellace et al., 2000; Bohannon and Schaubert, 2005; Clerke et al., 2005; Mathiowetz et al., 1984; Molenaar et al., 2008b; Schreuders et al., 2003; Smidt et al., 2002; van den Beld et al., 2006) and evaluate relevant functions of the hand, they cannot evaluate relevant functions of the hand, they cannot evaluate strength of the thumb and fingers in isolation. Therefore, they may not be sensitive enough to assess hand function in patients with a hypoplastic thumb. For example, patients with a hypoplastic thumb type IV or V or patients with an immobile stiff thumb may be able to exert a high grip force while their thumb strength is negligible. To overcome this lack of sensitivity, there is a need to assess outcome of interventions on a finger-specific level.

The Rotterdam Intrinsic Hand Myometer (RIHM) has the ability to measure individual finger and thumb strength, such as thumb opposition, palmar abduction of the thumb and abduction of the index and little finger. The RIHM was found to be reliable in both healthy children and adults. Furthermore, reference values for children and adults are

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**Table 1**
Blauth type distribution and Bayne and Klug Classification for of the patient group.

| Blauth type classification | Modified classification by Manske and McCarroll | Number hands |
|---|---|---|
| Type I | Minor hypoplasia of the whole thumb compared to contra lateral | 1 |
| Type II | Adduction contracture of the first web space, MCP joint instability<br>Thenar muscle hypoplasia | 24 |
| Type IIIa | Same abnormalities as in Type II<br>Extrinsic muscle hypoplasia<br>Hypoplastic first carpometacarpal | 7 |
| Type IIIb | Same abnormalities as in Type IIIa<br>Aplasia of the first carpometacarpal joint | 8 |
| Type IV | Floating thumb | 15 |
| Type V | Absent thumb | 10 |
| **Bayne and Klug classification** | **For longitudinalradial deficiency** | **Number hands** |
| Type I | Deficient distal radial epiphysis | 12 |
| Type II | Deficient distal and proximal radial epiphyses | 4 |
| Type III | Present proximally (partial aplasia) | 3 |
| Type IV | Completely absent (total aplasia — most common) | 12 |

available (Molenaar et al., 2008a; Schreuders et al., 2004, 2006). The added value of the RIHM to the grip and pinch dynamometer has been reported in patient groups with peripheral nerve injury (Schreuders et al., 2004), Charcot Marie Tooth (Selles et al., 2006), and carpal tunnel syndrome (Geere et al., 2007). However, the RIHM instrument has never been applied in patients with congenital hand deformities. Because individual fingers are often affected in congenital hand malformations, use of the RIHM, in addition to regular grip and pinch measurements, might possibly result in more specific diagnostic information.

The aim of this study was to evaluate the spectrum of different strength measurements, such as pinch dynamometers, grip dynamometers and the RIHM, in patients with a hypoplastic thumb either or not with LRD and specifically determine the added value of individual thumb and finger strength measurements.

## 2. Methods

### 2.1. Subjects

After approval of the Institutional Review Board and after informed consent of the patients and parents, a total of 40 patients diagnosed with thumb hypoplasia were included in this study. The patient's age ranged between 4 and 31 years. Of these 40 patients, 65 affected hands were assessed using grip, pinch and RIHM measurements. Using the Blauth classification, modified by Manske and McCaroll(James et al., 1996), we included 1 hand with type I, 24 hands with type II, 7 hands with type IIIa, 8 hands with type IIIb, 15 hands with type IV and 10 hands with type V. Presence of longitudinal radial deficiency (LRD) was described using the classification according to Bayne and Klug(Bayne and Klug, 1987). 34 hands did not have LRD. Of the 31 hands with LRD, 12 hands were associated with type I, 4 hands with type II, 3 hands with type III and 12 hands with type IV LRD. Types III & IV represent more severe LRD and are treated in the same manner. Therefore we joined the 4 categories for LRD in two separate groups with either a mild (types I & II) or a severe (types III &IV) LRD.

Of the total of 65 hands, 53 hands had been operated, of which 18 Blauth II, 6 Blauth IIIa, 8 Blauth IIIb, 15 Blauth IV and 6 Blauth V. And to further illustrate the diversity in this operated group of 53 hands, 41 hands had mild LRD and 12 hands had severe LRD. Operations performed were 21 Flexor Digitorum Superficialis of the fourth finger (FDS4) tendon transfers for opposition and metacarpophalangeal (MCP) joint instability; 16 abductor digiti quinti transfers for opposition and 28 pollicizations. Pollicization is a plastic surgery technique in which a thumb is created from the existing index finger.

### 2.2. Strength measurements

All measurements were performed in a randomized order by the same researcher (HMM). A mean of three maximum voluntary contractions was recorded for each hand. When one of the measurements showed a difference of more than 10% with the other measurements, that measurement was disregarded and a fourth measurement was added. The mean of 3 remaining maximum voluntary contractions (MVCs) was recorded for each hand. All children were seated in an appropriately adjusted chair during the measurements.

For grip strength we used a Lode dynamometer (Lode BV, Groningen, The Netherlands) (Fig. 1), which is an electronic dynamometer comparable to the Jamar dynamometer. It operates similarly and is calibrated to measure the same outcome as the Jamar dynamometer but is more accurate than the hydraulic Jamar, especially in the lower strength ranges. In a previous study, we quantified the measurement error of this instrument in children and found the Lode dynamometer to be accurate for measuring hand and finger strength in healthy children from 4-12 years old. We also found that measurement errors of the Lode dynamometer decreased with age and was negligible in adults and children 12 years and older and that children of 12 years old had similar reliability as adults (Bohannon and Schaubert, 2005; Clerke et al., 2005; Mathiowetz, 2002; Mathiowetz et al., 1984; Schreuders et al., 2003). The Lode dynamometer was used as recommended by the American Society of Hand Therapists: for the hand dynamometer measurements, the subject sat with the shoulder adducted and the arm at the side of the body, the elbow flexed in a 90-degree angle, and the wrist in a neutral position (ASHT, 1992). We used the Lode dynamometer with the handlebar in position 2 for all hands to maximize the comparability between subjects (Firrell and Crain, 1996).

Pinch strength was measured using the same electronic console as used for grip strength. This console was linked to a pinch gauge to measure tip pinch (the thumb is pinched against the pulp of the index finger while the other fingers are flexed), tripod pinch (thumb pulp to index and middle finger pulp with remaining fingers flexed and key pinch (thumb pulp to lateral aspect of proximal interphalangeal joint of the index finger, other fingers flexed) (Fig. 1) (Warwick, 2009). Before the start of each measurement, the subject was told to “squeeze as hard as you can!”.

The Rotterdam Intrinsic Hand Myometer (RIHM; Fig. 1) was used to measure the strength of the thumb, index finger and little finger. The RIHM is a dynamometer that measures strength by means of muscle resistance in a break-test. This break-test is performed while pulling with the RIHM at an easily controllable angle (Ketchum et al., 1978). The examiner and subject are seated opposite to each other at a table and the subject is shown and instructed how to try to maintain their finger or thumb in the same position. Slowly, while the subject is instructed to hold position, force is increased and after a few seconds the examiner pulls to “break” the position. We have previously demonstrated that the RIHM can reliably measure the breaking strength of the palmar abduction, thumb opposition, and index finger and little finger abduction in the hand in children (Molenaar et al., 2008a). In a recent study on the reliability of the RIHM, we found that the intraclass correlation coefficients (ICCs) of the RIHM for a group of children (4–12 years old) were >0.97 for the thumb measurements, >0.94 for the index finger, and >0.90 for the little finger when analyzed for the whole group. No relation was found between age and reliability (Molenaar et al., 2008a). For adults the reliability of the RIHM in peripheral nerve injured patients was >0.94 for all measurements (Schreuders et al., 2004, 2006).

In this study, we used the RIHM to measure thumb palmar abduction (primarily the Abductor Pollicis Brevis muscle) and thumb opposition (primarily the Opponens Pollicis muscle). In addition we measured abduction of the index finger (initiated by the first Dorsal Interosseous muscle) and little finger (initiated by Abductor Digiti Quinti muscle) (Schreuders et al., 2004). For each measurement the RIHM was held at the correct perpendicular angle for the appropriate measurement.