Reliability of Hand Strength Measurements Using the Rotterdam Intrinsic Hand Myometer in Children

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Purpose Grip strength and pinch strength measurements are often used to assess hand function. However, both measure a number of muscle groups in combination, and grip strength in particular is dominated by extrinsic hand muscles. The Rotterdam Intrinsic Hand Myometer (RIHM) was recently introduced to measure the force that individual fingers and thumb can exert in different directions. The aim of this study was to establish the reliability of these measurements with use of the RIHM in children.

Methods Sixty-three healthy children between 4 and 12 years of age participated in this study. The RIHM was used to measure thumb palmar abduction, thumb opposition, thumb flexion at the metacarpal-phalangeal (MP) joint, index finger abduction, and little finger abduction. A retest was performed with an average test-retest interval of 26 days.

Results For the thumb, palmar abduction strength had intraclass correlation coefficients (ICCs) of .98 for both hands. For both thumb opposition and flexion at the MP joint, ICCs were .97 for the dominant hands and .98 for the nondominant hands. Index finger abduction had ICCs of .94 and .95 and little finger abduction had ICCs of .90 and .92 for the dominant and nondominant hands, respectively. The smallest detectable differences for dominant and nondominant hands respectively were thumb palmar abduction, 15% and 15%; thumb opposition, 12% and 9%; thumb flexion (at the MP joint), 12% and 9%; abduction of the index finger, 17% and 17%; and little finger abduction, 26% and 26%.

Conclusions We found that the RIHM was reliable for use in children. Intraclass correlation coefficients and smallest detectable differences were comparable with those obtained with use of the RIHM in adults and with values found for pinch and grip strength in children. Because the RIHM measures more specific aspects of hand function than grip and pinch, adding the RIHM to measurement protocols may contribute to a more complete overview of a child's hand function. *(J Hand Surg 2008;33A:1796–1801. Copyright © 2008 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Children, hand function, intrinsic hand muscles, rehabilitation, reliability, strength.

TOGETHER WITH THE brain, the hand is the most important organ for accomplishing tasks of adaptation, exploration, prehension, perception, and manipulation unique to humans.[1] If hand function is reduced because of trauma or malformations of the hand, a person has to incorporate a whole new coordination pattern for handling objects in life. Instruments regularly used in therapy such as the Jamar dynamometer measure predominately extrinsic muscle strength. Grip strength dynamometers are found to be very reli-

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FIGURE 1: RIHM measuring palmar abduction of the thumb.

able in children and adults.[2–9] Strength measurements of the individual fingers of the hand are generally not incorporated in clinical or rehabilitation programs. Because thumb functions like opposition and abduction in combination with the fingers are important functions, measuring these functions more directly than with grip or pinch dynamometers could be very relevant in therapy and rehabilitation.

The Rotterdam Intrinsic Hand Myometer (RIHM) was designed at the Erasmus Medical Center Rotterdam (Rotterdam, The Netherlands) to measure the strength of the individual fingers and thumb in different directions (Fig. 1). This allows measuring more detailed aspects of hand function than with grip strength and pinch strength dynamometers and, in some specific situations, allows measurement of isolated intrinsic hand muscle strength. For example, when measuring index finger abduction, the resulting force is solely created by the first interosseous muscle. However, other movements are enforced by a combination of multiple muscles. For example, in the case of thumb flexion at the metacarpal-phalangeal (MP) joint level, not only intrinsic hand muscles but also the extrinsic muscle flexor pollicis longus contribute to the movement.

The RIHM has already proved to be reliable in adults, but reliability is unknown for children.[10,11] And because children with congenital hand malformations are often treated soon after birth or very early in life, it is important to follow their development after intervention. Therefore, the aim of our study was to test the reliability of the RIHM for use in children.

MATERIALS AND METHODS

Population

With approval of the institutional review board and after informed consent of the parents, children of a primary school were approached to participate in this study. All children with upper-extremity problems (eg, trauma, malformations, neurologic damage) were excluded from the study. A total of 63 children participated in this study, with ages ranging from 4 to 12 years.

Materials

The RIHM (Fig. 1) is a dynamometer that measures strength by means of muscle resistance in a break test–, which is performed while pulling with the RIHM under an angle that is easily controllable.[12] The examiner and subject are seated opposite to each other at a table, and the subject is shown and instructed how to keep his or her finger or thumb in place. Slowly, while the subject is instructed to hold the position of the finger or thumb, force is increased, and after about 1 second the examiner pulls to "break" the position. This way, different muscles in the hand can be measured.

Measurements

For this study, we measured abduction of the index and little fingers. In addition, for the thumb, we measured thumb palmar abduction (primarily an action of the abductor pollicis brevis muscle), thumb opposition (primarily the opponens pollicis muscle), and thumb flexion in the MP joint (primarily caused by the intrinsic flexor pollicis brevis muscle). The measurements were repeated 3 times, and the mean of the 3 tests was registered. For reliability, a retest was performed with an average test-retest interval of 26 days (SD 11.5).

Statistical methods

Test-retest reliability of measurements was analyzed using intraclass correlation coefficient (ICC), smallest detectable difference (SDD), and normalized SDD. Reliability was visualized using Bland-Altman plots.[13]

Intraclass correlation coefficient is the ratio of variance of interest (between-subject variance) over variance of interest and error variance (between-subject plus within-subject variance).

The SDD is the amount of change between tests that is needed to detect a real difference in a subject's performance and is sometimes also referred to as the *smallest real difference*[14] or the *minimal clinically important difference*.[15] For a 95% confidence level, the SDD is calculated as $1.96 \times \checkmark 2 \times$ SEM, where the standard error of measurement (SEM) is the square root of the error variance. When 2 measurements differ by more than the SDD, it can be concluded that the change represents a real (non-error) change in strength.[16]

Normalized SDD is the above-mentioned SDD expressed as a percentage of the mean maximum voluntary contraction (MVC). With normalization, the SDDs are directly comparable among instruments because they are expressed as a percentage of the mean out-

TABLE 1. Number of Participants Divided Among Age Groups and Gender

Age (y)	Boys	Girls	Total
4–6	8	8	16
7–9	11	11	22
10–12	13	12	25
Total	32	31	63

come. In addition, the normalized SDD had the advantage of being easily interpretable from a clinical point of view. For example, a normalized SDD of 25% indicates that the follow-up should differ with at least 25% in order to detect a real (non-error) change in grip strength.

RESULTS

For all muscle strength tests, we found high ICCs ranging from .90 to .98 for the total group (4–12 years of age). More specifically, the index finger had ICCs of .94 and .95 and the little finger had ICCs of .90 and .92 for the dominant and nondominant hands, respectively. For the thumb, all measurements ranged between .97 and .98 for dominant and nondominant hands. The different age subgroups showed ICCs of .93 and higher for thumb measurements. The index finger scored ICCs of .80 and higher, whereas the little finger had the lowest ICC of .61. All ICC values are shown in Table 1.

In the Bland-Altman plots, all data are evenly distributed around the zero line (Fig. 2). The differences between test and retest were approximately the same for each age group and muscle strength test. The measurement error was higher in the younger and weaker group compared with that of the stronger and older children when this error was expressed as a percentage of the MVC.

The influence of age on mean MVC, SDD, and normalized SDD for all measurements is shown in Table 2. Even though the SDD increased overall with age, the normalized SDD is reduced. This effect is caused by the higher MVC of older and therefore stronger children. The normalized SDDs for palmar abduction was 15% for both the dominant and nondominant hands. The normalized SDDs for metacarpal-phalangeal joint flexion were 12% for the dominant hands and 9% for the nondominant hands. Opposition scored approximately the same with SDDs of 12% for dominant hands and 9% for nondominant hands. Normalized SDDs of the abduction of the index finger were 17% for both dominant and nondominant hands. Finally, the reliability of the abduction strength of the little finger was slightly less with SDDs of 27% for dominant hands and 26% for nondominant hands.

DISCUSSION

The aim of our study was to test the reliability of the RIHM in children (4–12 years of age). Reliability values of children found in this study were comparable with values of the RIHM in adults.[10,11] For children, the ICCs were .98 for abduction of the thumb and .97 for opposition of the thumb. For the reliability of the abduction of the index and little fingers, we noted ICC values of at least .94 for the index finger and .90 for the little finger.

Because ICCs are not only determined by measurement error but also by between-subject variation, ICC values in the literature are difficult to compare.[17] The same influence of between-subject variation on ICC values may also explain why all 3 age groups, with lower between-subject variation than those for the total group, had lower ICCs than the ICC of the total group.

A good comparison of reliability can be made using the (normalized) SDD. The normalized SDDs were between 9% and 31%, with the thumb measurements showing the lowest normalized SDDs of 9% to 15%. The measurements on the index finger were slightly less reliable (17%), and the little finger was the least reliable (26%). The SDDs are comparable with those found in adults, with adults showing normalized SDD values of 18% to 27%.[10,11] Comparing the reliability in children of the RIHM to a Jamar-like dynamometer, the RIHM seems slightly more reliable with normalized SDDs of 9% to 26% compared with 19% to 27% for a Jamar-like dynamometer.[9]

There are some limitations to our study. First, because this study was performed only in children without impairment of the upper limb, no conclusion can be drawn on the reliability in children with impairments. Furthermore, in some cases the interval between the test and the retest was relatively long (range, 7–46 days; average, 26 days). However, no overall increase in strength was found in the retest measurement, a finding illustrated by the even distribution of the data around the zero-difference line for all age groups (Fig. 2). This suggests that the interval between measurements was not long enough to allow a systematic improvement in strength in the retest measurements.

Some problems need to be considered when measuring children. Because of their lower attention span, a break test may be more difficult to perform because it involves the subject holding a static position that the examiner tries to "break" (change) through force exer-

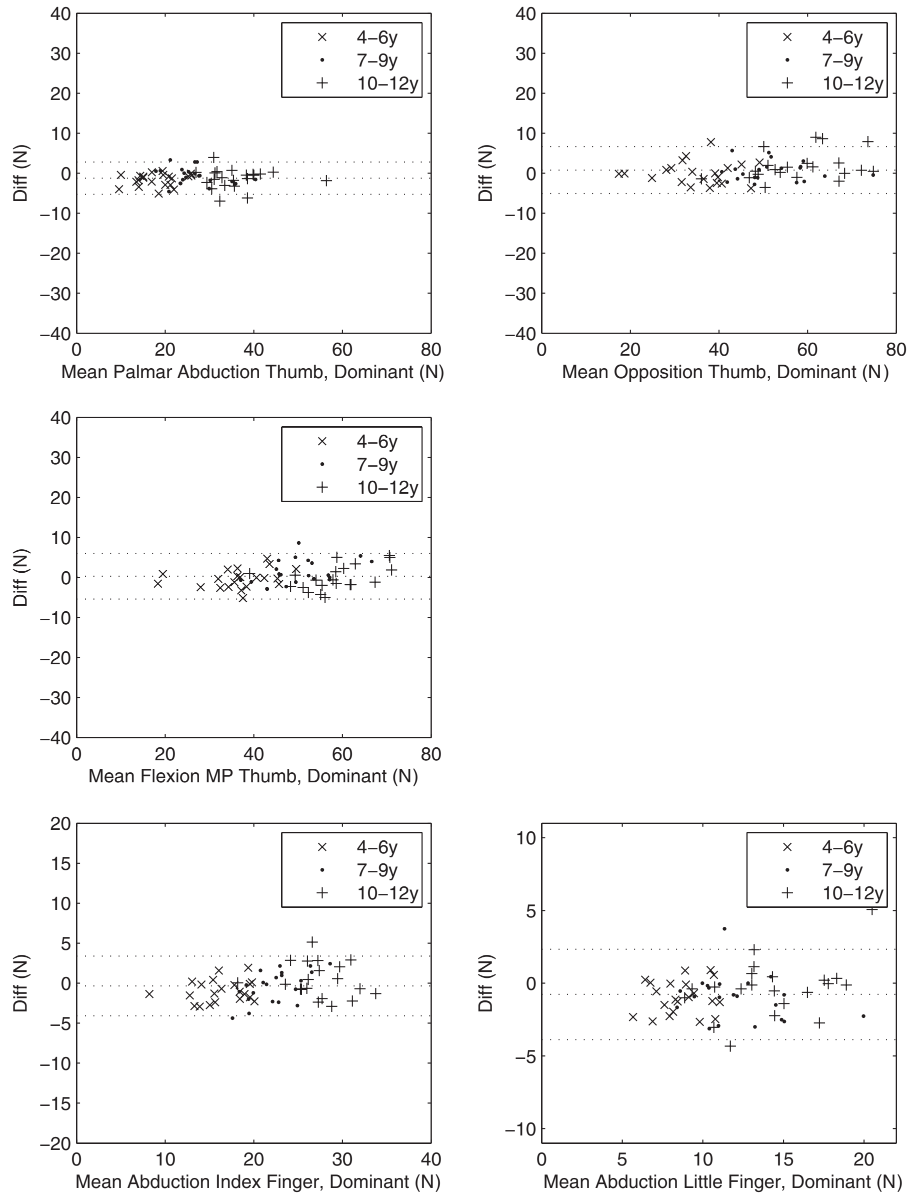

FIGURE 2: Bland-Altman plots of the mean MVC of the dominant hand using a Jamar-like dynamometer versus the difference between the MVCs in test and retest. In order from top: thumb abduction, thumb opposition, thumb MP joint flexion, and abduction of the index finger and of the little finger.

tion. The instruction to hold a finger in place may be less interesting then trying to move an object. However, it should also be noted that the break test has the advantages that it is easy to provide instruction to the children ("maintain your position") and that the examiner can easily determine whether the children create the force in the appropriate directions.

In most clinical practices, hand motor function is evaluated by measuring grip strength. Grip strength is a combination of both extrinsic and intrinsic hand muscles. No specific conclusions can be drawn on the function of intrinsic hand muscles when using grip strength devices like the Jamar handheld dynamometer. However, intrinsic muscle function can play an important role in different congenital hand malformations, such as hypoplasia or dysplasia of the fingers or thumb.

One specific example of a patient group in which the RIHM may add useful information to the assessment of hand function is in patients with congenital hand malformations. For children with congenital hand malformations who are treated very early in their lives, it is very important to receive the right therapy. Measurement of both intrinsic and extrinsic hand muscles is important in these children as part of the intervention to obtain a more normal hand function. Because strength measurements of individual fingers and thumb were

TABLE 2. Mean MVC, SD, ICC, SDD, and Normalized SDD for All Measurements in 63 Children

Measurement	Mean MVC	SD	ICC	SDD	%SDD (%)
Thumb palmar abduction, DOM (4–6 y)	16.8	4.72	.94	3.2	19
Thumb palmar abduction, non-DOM (4–6 y)	15.4	4.51	.95	2.9	19
Thumb palmar abduction, DOM (7–9 y)	24.7	4.84	.93	3.6	15
Thumb palmar abduction, non-DOM (7–9 y)	23.1	5.44	.95	3.3	14
Thumb palmar abduction, DOM (10–12 y)	35.0	6.79	.93	4.9	14
Thumb palmar abduction, non-DOM (10–12 y)	33.2	7.48	.96	4.4	13
Thumb palmar abduction, DOM (all)	26.8	9.25	.98	4.0	15
Thumb palmar abduction, non-DOM (all)	25.2	9.41	.98	3.7	15
Thumb opposition, DOM (4–6 y)	33.8	8.52	.95	5.5	16
Thumb opposition, non-DOM (4–6 y)	34.7	8.19	.97	3.9	11
Thumb opposition, DOM (7–9 y)	48.9	9.98	.97	4.8	10
Thumb opposition, non-DOM (7–9 y)	49.9	10.52	.97	4.9	10
Thumb opposition, DOM (10–12 y)	57.3	9.78	.94	6.7	12
Thumb opposition, non-DOM (10–12 y)	58.1	10.19	.97	5.0	9
Thumb opposition, DOM (all)	48.4	13.27	.97	5.9	12
Thumb opposition, non-DOM (all)	49.3	13.46	.98	4.7	9
Thumb MP flexion, DOM (4–6 y)	35.3	8.19	.97	4.1	12
Thumb MP flexion, non-DOM (4–6 y)	34.7	8.00	.98	3.2	9
Thumb MP flexion, DOM (7–9 y)	47.6	8.37	.93	6.2	13
Thumb MP flexion, non-DOM (7–9 y)	46.9	9.18	.98	4.1	9
Thumb MP flexion, DOM (10–12 y)	57.2	7.89	.93	5.7	10
Thumb MP flexion, non-DOM (10–12 y)	56.0	8.94	.96	5.0	9
Thumb MP flexion, DOM (all)	48.3	11.85	.97	5.7	12
Thumb MP flexion, non-DOM (all)	47.4	12.15	.98	4.3	9
Index finger abduction, DOM (4–6 y)	15.8	3.30	.92	2.6	16
Index finger abduction, non-DOM (4–6 y)	15.0	3.50	.88	3.4	23
Index finger abduction, DOM (7–9 y)	21.2	3.28	.88	3.1	15
Index finger abduction, non-DOM (7–9 y)	19.8	2.95	.80	3.7	19
Index finger abduction, DOM (10–12 y)	26.5	3.97	.84	4.5	17
Index finger abduction, non-DOM (10–12 y)	25.9	4.78	.93	3.6	14
Index finger abduction, DOM (all)	22.0	5.54	.94	3.7	17
Index finger abduction, non-DOM (all)	21.0	5.86	.95	3.5	17
Little finger abduction, DOM (4–6 y)	8.6	1.81	.80	2.2	25
Little finger abduction, non-DOM (4–6 y)	7.9	1.43	.61	2.5	31
Little finger abduction, DOM (7–9 y)	10.7	2.26	.77	3.0	28
Little finger abduction, non-DOM (7–9 y)	9.5	1.78	.72	2.6	27
Little finger abduction, DOM (10–12 y)	14.6	3.26	.84	3.6	25
Little finger abduction, non-DOM (10–12 y)	14.0	3.52	.89	3.3	23
Little finger abduction, DOM (all)	11.7	3.59	.90	3.1	27
Little finger abduction, non-DOM (all)	10.9	3.65	.92	2.8	26

%SDD, normalized SDD; DOM, dominant hand; non-DOM, nondominant hand.

found to be reliable, we recommend including such measurements when evaluating interventions. Measuring strength of the individual fingers and the thumb can provide a more complete picture of hand function when diagnosing and evaluating hand problems. Therefore, testing with the RIHM will add great value to better understand the role of muscle strength of the individual fingers and thumb in relation to hand function and other grip tests.

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