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Scientific/Clinical Article

# Reference values of intrinsic muscle strength of the hand of adolescents and young adults

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ABSTRACT

*Study Design:* A cross-sectional clinical measurement study.
*Introduction:* Measuring intrinsic hand muscle strength helps evaluate hand function or therapeutic outcomes. However, there are no established normative values in adolescents and young adults between 13 and 20 years of age.
*Purpose of the Study:* To measure hand intrinsic muscle strength and identify associated factors that may influence such in adolescents and young adults through use of the Rotterdam intrinsic hand myometer.
*Methods:* A total of 131 participants (male: 63; female: 68) between 13 and 20 years of age completed the strength measurements of abductor pollicis brevis, first dorsal interosseus (FDI), deep head of FDI and lumbrical of second digit, flexor pollicis brevis (FPB), and abductor digiti minimi. Two trials of the measurements of each muscle were averaged for analyses. Self-reported demographic data were used to examine the influences of age, sex, and body mass index (BMI) on intrinsic hand muscle strength.
*Results:* Normative values of intrinsic hand muscle strength were presented by age groups (13, 14, 15-16, 17-18, 19-20 year olds) for each sex category (male, female). A main effect of sex, but not age, on all the muscles on both the dominant (FPB: $P = .02$, others: $P < .001$) and non-dominant (FDI: $P = .005$, FPB: $P = .01$, others: $P < .001$) sides was found. A significant effect of BMI was found on dominant ($P = .009$) and non-dominant abductor pollicis brevis ($P = .002$). In addition, FDI ($P = .005$) and FPB ($P = .002$) were stronger on the dominant side than the non-dominant side.
*Discussion:* Intrinsic hand muscle strength may be influenced by different factors including sex, BMI, and hand dominance. A larger sample is needed to rigorously investigate the influence of age on intrinsic strength in male and female adolescents and young adults.
*Conclusion:* The results provide reference values and suggest factors to be considered when evaluating hand function and therapeutic outcomes in both clinical and research settings. Further study is recommended.
*Level of Evidence:* VI.



## Introduction

Hand strength is a common outcome measure in hand and developmental therapy.[1] Grip and pinch dynamometry reflect the combination of both the extrinsic and intrinsic muscle activity,[2] whereas intrinsic myometry can provide more direct information regarding intrinsic muscle function.[3] The strength of intrinsic muscles of digits and thumb contribute to important functional hand activities, especially for those requiring dexterous hand movements, such as handwriting.[4,5] Moreover, measuring isolated hand intrinsic muscle strength can evaluate or monitor the progression or resolution of certain hand pathologies, hand therapy intervention effects, and research outcomes with greater specificity. For example, the first dorsal interosseous (FDI) and abductor digiti minimi are innervated by ulnar nerve, and thus the strength

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of these muscles may be clinical indicators to understand hand function and recovery in patients with ulnar nerve injuries.[3] However, isolated intrinsic muscle strength of the hand is not commonly assessed in clinic. This might be due to manual muscle testing (MMT)'s lack of responsiveness to change,[6] reduced awareness of the availability of clinically appropriate intrinsic myometers, and incomplete normative data for such instrumentation.

The Rotterdam intrinsic hand myometer (RIHM) has been found to be a valid and reliable tool used to measure strength of individual intrinsic hand muscles in children and adults aged 4-12 and 16-70 years.[3,7-10] RIHM reference values are also available in younger children between 4 and 12 years; yet, there are no reports of similar normative values in adolescents and young adults between 13 and 20 years.[11] This gap limits our understanding regarding the development of isolated intrinsic muscle strength, which further restricts the application of the RIHM among adolescents and young adults with hand dysfunction.

Measuring isolated intrinsic muscle strength of the hand has potential to be widely used in youth with genetic, developmental, neurologic, or orthopedic conditions. Decreased hand intrinsic strength may be experienced in youth with Charcot-Marie-Tooth disease, brachioplexopathies, juvenile rheumatoid arthritis, and hand overuse[12-18] and may be associated with limitations in self-care skills (eg, opening a snack box) and academic performance (eg, handwriting).[4] Many with hand dysfunction require surgeries such as tendon transfers or lengthening and nerve repair,[19,20] hand therapy after acute injuries and operation, or developmental rehabilitation for hand use in those born with disabilities. The use of a responsive psychometrically sound tool with normative reference values can assist in evaluating the success of these therapy and surgical interventions.

However, to better monitor the success of interventions that target intrinsic hand function in children and youth, normative testing should be expanded to include adolescents and young adults. The primary purpose of this study was to establish normative strength values, using the RIHM, in selected intrinsic hand muscles in individuals between 13 and 20 years. A secondary purpose was to evaluate if factors known to influence gross grasp strength (ie, age, sex, handedness, and body mass index [BMI]) also influence intrinsic hand muscle strength in this age range.

## Methods

### *Participants*

Adolescents or young adults between 13 and 20 years were recruited in this study via stratified convenience sampling at an US state fair, a statewide gathering with exhibitions and recreational and university research activities. Exclusion criteria included self-reported hand dysfunction, any neurologic diseases that influenced their movement control and hand muscle strength, deformities or amputations of tested digits, pain that prohibited or was made worse by testing procedures, and the inability to follow standardized procedures.

### *General procedures*

This study was approved by a Midwestern US institutional review board. Informed consent and assent were obtained from legal guardians and participants between 13 and 17 years; consent was obtained from participants between 18 and 20 years. Five testers, including 2 physical therapists, 1 occupational therapist, and 2 graduate physical therapy students, received a minimum of 2 hours of training in performing 5 intrinsic muscle strength measurements using the RIHM by a trained occupational therapy academician and certified hand therapist. Each tester was required to demonstrate competency on each measure (eg, consistency in positioning the device and participant for testing).[7] Muscle strength measurement data were collected across 3 days on different participants at the state fair. Participants entered demographic information (ie, age, sex, race, ethnicity, and BMI) into a secured tablet device through use of the research electronic data capture electronic data capture tools before strength measurements,[21] and the same system was used to record RIHM data.

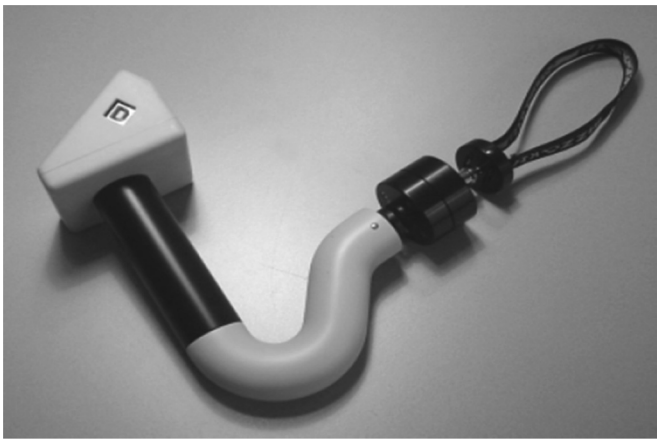

**Fig. 1.** The Rotterdam intrinsic hand dynamometer.

### *Measurements*

Three calibrated RIHM instruments, capable of accurately measuring up to 300 N (Fig. 1),[22] were used to quantify the maximum voluntary strength of selected hand movements produced primarily by intrinsic musculatures. These movements included the thumb carpometacarpal palmar abduction (abductor pollicis brevis [APB]), index finger metacarpophalangeal (MP) abduction (superficial head of FDI), index finger MP flexion (deep head of FDI and lumbrical of second digit), thumb MP flexion (flexor pollicis brevis [FPB]), and small finger MP abduction (abductor digiti minimi). The aforementioned muscles are likely not the only muscles contracting during these assessments; however, as we presumed to be measuring the prime movers,[11] we will henceforth be referring to the muscles and not the movements tested. In a manner consistent with MMT, the maximal voluntary contractile strength of the intrinsic muscles was quantified through the break test according to the standardized procedures described by Schreuders et al[9,23] (Fig. 2). The testing sequence of the 5 muscle tests was randomized to control for an order effect; however, testing always began with the right hand. For our protocol, 2 trials of each intrinsic measure were performed by considering the feasible time that we asked from each volunteered participant and the existed protocols and acceptable reliability of muscle strength assessment from 2-trial averaged results.[24-29] If a protocol deviation was observed during testing, such as slippage of the device sling, a third trial was recorded. The third trial measurement replaced the result of the failed attempt and was used for further analysis. A nonslip piece of Dycem Reel (Dycem, Bristol) was added under the sling by testers to reduce skin slippage if needed. Thirty-second rest breaks were offered between each testing trial to control for the influence of fatigue. The testing results were read and entered to the research electronic data capture system by the tester.