2023 World Symposium on Congenital Malformations of the Hand and Upper Limb

Radial Longitudinal Deficiency and The Thumb Grasp and Pinch Assessment

May 17th, 2023

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Shriners Children's Twin Cities

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2023 World Symposium on Congenital Malformations of the Hand and Upper Limb

Wendy A. Tomhave OTR

This speaker has no financial relationships with commercial interest.

My Background

Shriners Children’s 31 years

Pediatric Orthopedics

Specialty Clinics

Clinical Research Interests

- Congenital Hand
- Upper Extremity Cerebral Palsy
- Upper Limb Prosthetics
- Assessment of the Hand

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Shriners Children's: Specialty Hand Clinics

Steven Moran, MD

Mayo Clinic, Rochester

Plastic and Reconstructive Surgery

Shriners Children's, Twin Cities

Pediatric Hand Surgery

Ann Van Heest, MD

University of Minnesota Department of Orthopedic Surgery

Gillette Children's Specialty Healthcare

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Pediatric Hand Surgery

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Radial Longitudinal Deficiency

- Affects the radial aspect of the arm
- Incidence 1 in 30,000 live births
- Mild thumb hypoplasia to complete absence of the radius

Colen DL, Lin IC, Levin LS, Chang B. Radial Longitudinal Deficiency: Recent Developments, Controversies, and an Evidence-Based Guide to Treatment. J Hand Surg Am. 2017 Jul;42(7):546-563. doi: 10.1016/j.jhsa.2017.04.012. PMID: 28669420

Forman M, Canizares MF, Bohn D, James MA, Samora J, Steinman S, Wall LB, Bauer AS; CoULD Study Group. Association of Radial Longitudinal Deficiency and Thumb Hypoplasia: An Update Using the CoULD Registry. J Bone Joint Surg Am. 2020 Oct 21;102(20):1815-1822. doi: 10.2106/JBJS.20.00281. PMID: 33086350.

Causes: Radial Longitudinal Deficiency

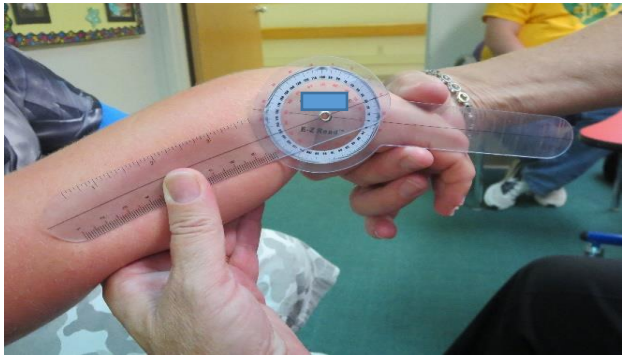
- Majority of the cases are sporadic
- Disrupted limb bud development

- 1/3 of patients have a known syndrome (CoULD registry)
  - VACTERAL (14%)
  - Holt-Oram (17%)
  - Other syndromes (8%)
  - TAR (5%)
  - Fanconi's anemia (2%)
- Occurs bilaterally in 50% of the cases
- Exposure to teratogens (thalidomide and radiation) can yield radial deficiencies

Forman M, Canizares MF, Bohn D, James MA, Samora J, Steinman S, Wall LB, Bauer AS; CoULD Study Group. Association of Radial Longitudinal Deficiency and Thumb Hypoplasia: An Update Using the CoULD Registry. J Bone Joint Surg Am. 2020 Oct 21;102(20):1815-1822. doi: 10.2106/JBJS.20.00281. PMID: 33086350.

Goldfarb, GA: ASSH Review Course on Congenital Hand Differences

Our team studied past literature and developed a thumb assessment protocol in 2006



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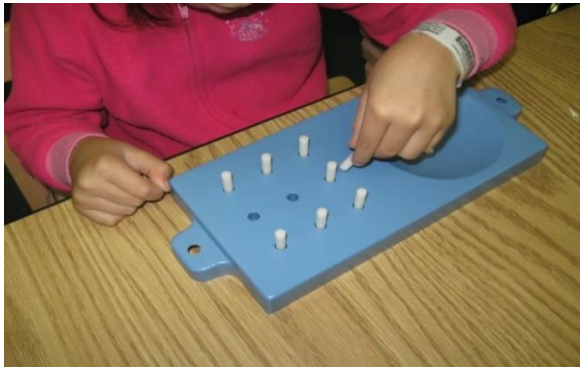
Hand Dexterity

- Repetitive grasping of pegs or blocks
- Score based on speed of performance
- Allow any grasp pattern including no thumb use

9 Hole Peg Test



Functional Dexterity Test

Box and Blocks Test

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Object Handling Assessments

Manske 1992

Grasp/release

- 7 large objects, 7 smaller objects

- Thumb use given a percentage score

  - normal thumb

  - modified fashion

  - no use

Goldfarb 2007

- Grasp/release

  - pop can, block, turn a key, bead

- Thumb use yes/no

Manske PR, Rotman MB, Dailey LA. Long-term functional results after pollicization for the congenitally deficient thumb. J Hand Surg Am. 1992 Nov;17(6):1064-72. doi: 10.1016/s0363-5023(09)91063-2. PMID: 1430939.

Goldfarb CA, Wustrack R, Pratt JA, Mender A, Manske PR. Thumb function and appearance in thrombocytopenia: absent radius syndrome. J Hand Surg Am. 2007 Feb;32(2):157-61. doi: 10.1016/j.jhsa.2006.10.019. PMID: 17275588.

Descriptions of abnormal grasp patterns varied:

- Tricks moves
- Side to side pinch
- Modified manner
- Deviant grasp patterns

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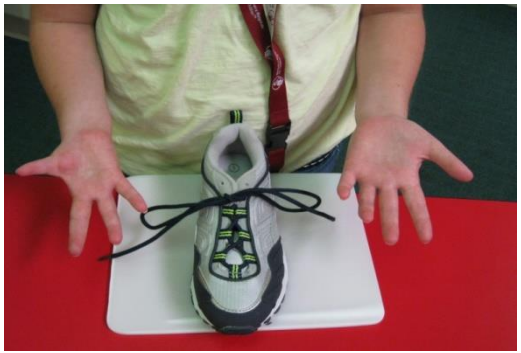
We developed our own thumb use assessment

Thumb Grasp and Pinch Assessment (T-GAP)

Tip pinch	Resistance
Lateral /Key pinch	Manipulation
Small grasp	ADL
Medium grasp	School
Large grasp	



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Scoring hierarchy based on principles of hand development

- Reflexive grasp with no thumb use
- Develop from the palm to the fingertips
- Ulnar to radial side of hand
- Learn to use key pinch, tip and tripod
- Stabilize and manipulate objects at the fingertips

T-GAP Scoring Hierarchy

Grasp and Pinch Style Scoring

0 No Grasp, Passive Stabilization
1 Palmar Grasp, Finger Flexion; No Thumb Use
2 Ulnar Scissor Grasp; No Thumb Use
3 Radial Scissor Grasp; No thumb Use

4 Cylindrical Grasp; Thumb to Fingers
5 Lateral Key Pinch; Thumb to Index
6 Tip Pinch; Thumb to Finger Tip
7 Tripod Pinch; Thumb to Distal Index/Long

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Hand Assessment Protocol 2006

- All patients with congenitally deficient thumbs were referred to OT
- Became our standard of care for establishing baseline skills and progress
- Helped with decision making
- Families had a better understanding of their child's thumb function

Nine years of thumb function assessments were reviewed in 2014

Kathleen Kollitz, MD
Fellowship at Mayo Clinic

Discovered the T-GAP as a new variable to measure hand dexterity

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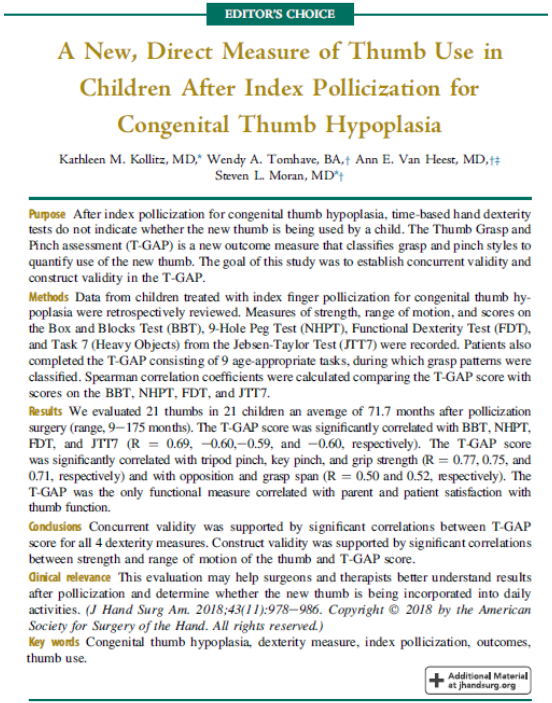
Construct and Concurrent Validity: Results

T-GAP scores were significantly correlated:

Dexterity Measure	P-Value
Box and blocks test	.0048
Functional dexterity test	. 014
Nine hole peg test	. 0051

Strength and Range of Motion	P-Value
Tripod pinch strength	.0001
Key pinch strength	.017
Grip strength	.0083
Kapandji opposition	.0051
Active distal grasp span	.0005



EDITOR'S CHOICE

A New, Direct Measure of Thumb Use in Children After Index Pollicization for Congenital Thumb Hypoplasia

Kathleen M. Kollitz, MD,* Wendy A. Tomhave, BA,† Ann E. Van Heest, MD,†‡ Steven L. Moran, MD*†

Purpose After index pollicization for congenital thumb hypoplasia, time-based hand dexterity tests do not indicate whether the new thumb is being used by a child. The Thumb Grasp and Pinch assessment (T-GAP) is a new outcome measure that classifies grasp and pinch styles to quantify use of the new thumb. The goal of this study was to establish concurrent validity and construct validity in the T-GAP.

Methods Data from children treated with index finger pollicization for congenital thumb hypoplasia were retrospectively reviewed. Measures of strength, range of motion, and scores on the Box and Blocks Test (BBT), 9-Hole Peg Test (NHPT), Functional Dexterity Test (FDT), and Task 7 (Heavy Objects) from the Jebsen-Taylor Test (JTT7) were recorded. Patients also completed the T-GAP consisting of 9 age-appropriate tasks, during which grasp patterns were classified. Spearman correlation coefficients were calculated comparing the T-GAP score with scores on the BBT, NHPT, FDT, and JTT7.

Results We evaluated 21 thumbs in 21 children an average of 71.7 months after pollicization surgery (range, 9−175 months). The T-GAP score was significantly correlated with BBT, NHPT, FDT, and JTT7 ($R = 0.69$, -0.60,-0.59, and -0.60, respectively). The T-GAP score was significantly correlated with tripod pinch, key pinch, and grip strength ($R = 0.77$, 0.75, and 0.71, respectively) and with opposition and grasp span ($R = 0.50$ and 0.52, respectively). The T-GAP was the only functional measure correlated with parent and patient satisfaction with thumb function.

Conclusions Concurrent validity was supported by significant correlations between T-GAP score for all 4 dexterity measures. Construct validity was supported by significant correlations between strength and range of motion of the thumb and T-GAP score.

Clinical relevance This evaluation may help surgeons and therapists better understand results after pollicization and determine whether the new thumb is being incorporated into daily activities.

Key words Congenital thumb hypoplasia, dexterity measure, index pollicization, outcomes, thumb use.

Additional Material at jhandsurg.org

The varied grasp styles employed by these children were not entirely captured by standard outcome measures which are based on speed and allow any pinch pattern to be used including those that exclude the thumb.

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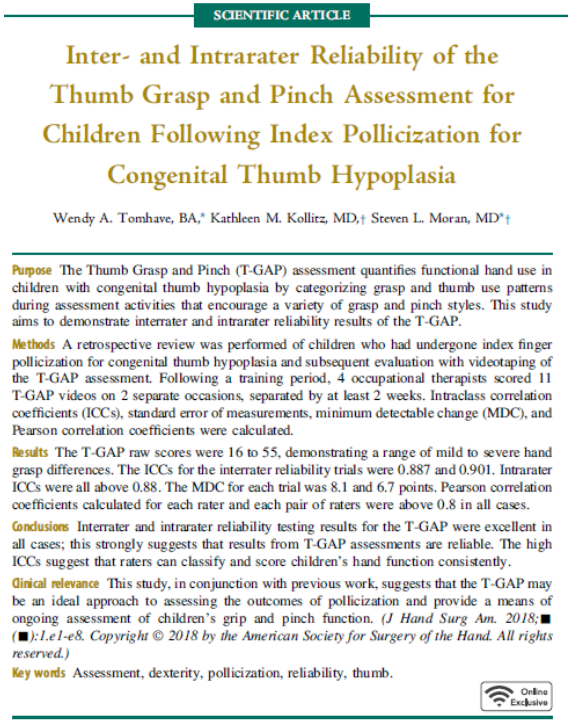
T-GAP Inter and Intra Rater Reliability

- The ICC's for inter rater trials were 0.887 and 0.901
- The ICC's for intra-rater trials were all above 0.88



SCIENTIFIC ARTICLE

Inter- and Intrarater Reliability of the Thumb Grasp and Pinch Assessment for Children Following Index Pollicization for Congenital Thumb Hypoplasia

Wendy A. Tomhave, BA,* Kathleen M. Kollitz, MD,† Steven L. Moran, MD*†

Purpose The Thumb Grasp and Pinch (T-GAP) assessment quantifies functional hand use in children with congenital thumb hypoplasia by categorizing grasp and thumb use patterns during assessment activities that encourage a variety of grasp and pinch styles. This study aims to demonstrate interrater and intrarater reliability results of the T-GAP.

Methods A retrospective review was performed of children who had undergone index finger pollicization for congenital thumb hypoplasia and subsequent evaluation with videotaping of the T-GAP assessment. Following a training period, 4 occupational therapists scored 11 T-GAP videos on 2 separate occasions, separated by at least 2 weeks. Intraclass correlation coefficients (ICCs), standard error of measurements, minimum detectable change (MDC), and Pearson correlation coefficients were calculated.

Results The T-GAP raw scores were 16 to 55, demonstrating a range of mild to severe hand grasp differences. The ICCs for the interrater reliability trials were 0.887 and 0.901. Intrarater ICCs were all above 0.88. The MDC for each trial was 8.1 and 6.7 points. Pearson correlation coefficients calculated for each rater and each pair of raters were above 0.8 in all cases.

Conclusions Interrater and intrarater reliability testing results for the T-GAP were excellent in all cases; this strongly suggests that results from T-GAP assessments are reliable. The high ICCs suggest that raters can classify and score children's hand function consistently.

Clinical relevance This study, in conjunction with previous work, suggests that the T-GAP may be an ideal approach to assessing the outcomes of pollicization and provide a means of ongoing assessment of children's grip and pinch function. *(J Hand Surg Am. 2018;■(■):1.e1-e8. Copyright © 2018 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Assessment, dexterity, pollicization, reliability, thumb.

Online Exclusive

- Inter rater and intra rater reliability results were excellent in which raters could classify and score children's hands consistently

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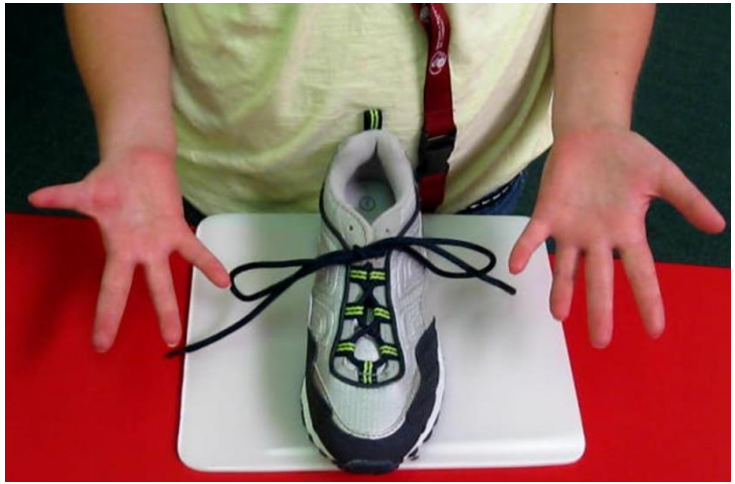
Understanding atypical grasp and thumb use patterns could facilitate the choice of strategies in the:

-therapeutic process

-success of various treatments



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T-GAP Scoring and Interpretation

- 5-10 minutes to administer
- 9 activities are video recorded
- Scored during a subsequent viewing

Identifies 3 components of hand dexterity

- Final T-GAP score (measured using a hierarchical scale)
- Thumb use score
- Number of grasp styles

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Nine developmentally appropriate tasks for 3 age groups

	T-GAP Activity Ages 18 months – 4 years	T-GAP Activity Ages 5 – 7 years	T-GAP Activity Ages 8 – 18 years
Tip Pinch	Pick up 3 Cheerios one at a time and release into a film container *Score how the Cheerio is held*	Pick up 3 pennies one at a time and release into a piggy bank *Score how the penny is held*	Thread 5 plastic beads onto a zip tie *Score how the bead is held*
Lateral Key Pinch	Open a zippered pencil case and remove 2 markers *Score how the zipper tab is held*	Turn a vinyl coated key to open a Padlock *Score how the key is held*	Turn a vinyl coated key to open a Padlock *Score how the key is held*
Small Grasp	Pull cap off a large diameter marker *Score how the marker is held*	Pull cap off a small diameter marker *Score how the marker is held*	Remove cap from ballpoint pen *Score how the pen is held*
Medium Grasp	Separate 5 Duplo style blocks that are stacked together *Score how the duplos are stabilized*	Turn end of kaleidoscope 3 times *Score how the kaleidoscope is held*	Make a telescope with a 6" x 9" sheet of paper and place rubber band over *Score how the paper tube is held*
Large Grasp	Open a 4 oz. container of bubbles *Score how the container is stabilized*	Twist cap from a 1# peanut butter jar *Score how the jar is held*	Twist cap off from a 1# peanut butter jar *Score how the jar is held*
Manipulation	Form moldable clay into a bowl *Score how the moldable clay is held*	Form moldable clay into a bowl *Score how the moldable clay is held*	Rotate a pencil 3 times in a handheld pencil sharpener *Score how the pencil is held*
Resistance	Open a drawstring bag *Score how the bag is held when opened*	Pull back foam pull on slingshot *Score how the foam pull is held*	Pull back foam pull on slingshot *Score how the foam pull is held*
School	Open a box of 8 crayons and remove one *Score how the crayon is held*	Color inside a circle with a crayon *Score how the crayon is held*	Write name with a no. 2 pencil *Score how pencil is held*
ADL	Put sock on over toes *Score how the sock is held open*	Tie shoelaces into a knot *Score how the laces are held*	Tie shoelaces into a bow *Score how the laces are held*

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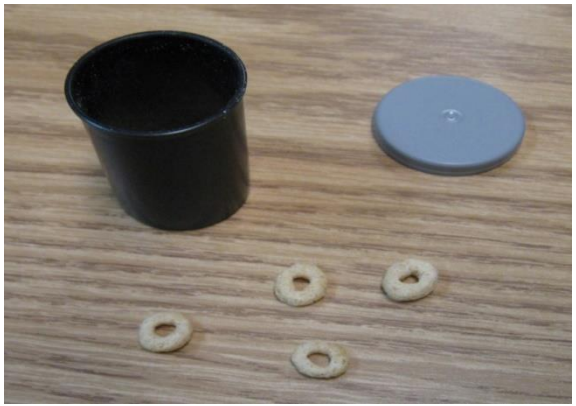
T-GAP Thumb Grasp and Pinch Assessment

- Developmentally appropriate activities for young children
- Standardized 18 months – 18 years
- Object size and shape of each activity was selected to encourage specific grasp styles

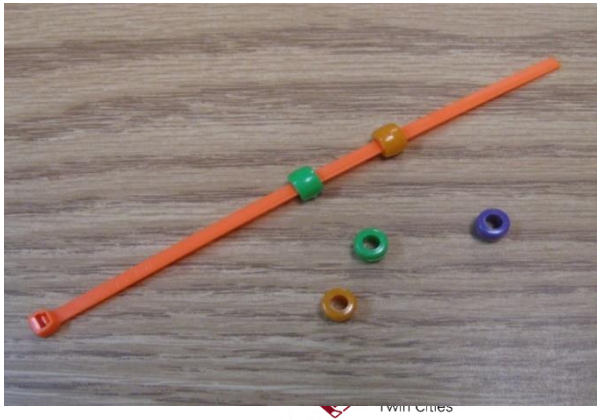
Tip Pinch

18 months – Age 4



Ages 5 – 7

Ages 8 - 18



Sturdy medium size piggy bank and 3 pennies

Place the bank and three pennies in front of the child. Ask the child to pick up and put each penny into the piggy bank

Score: How the penny is held

Padlock (2 3/8" tall) with vinyl-coated key

Demonstrate how to insert the key and turn it to open the padlock then demonstrate how to relock the padlock. Ask the child to unlock and lock the padlock two times.

Score: How the key is held

Small circumference marker (3/8" wide)

Place a marker in front of the child. Ask the child to pull off the cap then put the cap on tightly then pull the cap off again.

Score: How the marker is held

Kaleidoscope (9 " long and 2 ½" wide)

Demonstrate how to use the kaleidoscope by holding it horizontally and looking through it while rotating the end. Ask the child to look through the kaleidoscope and turn the end three times.

Score: How the kaleidoscope is held

1 pound peanut butter jar (3" wide and 5" tall)

Place the peanut butter jar in front of the child and ask the child to take the cover off and put the cover back on.

Score: How the jar is held

T-GAP Administration and Test Kit Items Ages 5 – 7 Years

Full-size container of moldable clay

Demonstrate how to form moldable clay into a bowl then form into a ball and place on the table. Ask the child to make a bowl. You can help start the shape if needed.

Score: How the clay is held

Slingshot with foam pull

Demonstrate how to hold the slingshot, grasp the round end of the pull and pull back with moderate force then release. Ask the child to do this sequence twice

Score: How the foam pull is held

6" x 9" white drawing pad and a crayon

Place a peanut butter jar on the paper and draw a circle around it with the crayon. Ask the child to color in the circle with the crayon.

Score: How the crayon is held

Child-size lace-up shoe with long, flat laces

Place the shoe in front of the child and ask the child to tie a knot with the laces. You can show how to make a knot if needed.

Score: How the laces are held

The Thumb Grasp and Pinch Assessment
T-GAP Score form
5 years – 7 years

T-GAP Activity	LEFT (Score 0-7)	RIGHT (Score 0-7)
Pick up 3 pennies one at a time and release into a piggy bank **(tip pinch)** *Score how penny is held*		
Turn a key to open a padlock **(lateral key pinch)** *Score how key is held*		
Pull cap off a small diameter marker **(small grasp)** *Score how marker is held*		
Turn end of kaleidoscope 3 times **(medium grasp)** *Score how kaleidoscope is held*		
Remove cap from a peanut butter jar **(large grasp)** *Score how jar is held*		
Form Play-Doh into a bowl **(manipulation)** *Score how Play-Doh is held*		
Pull back foam pull on slingshot **(resistance)** *Score how foam pull is held*		
Color inside a circle with a crayon **(school)** *Score how crayon is held*		
Tie shoelaces into a knot **(ADL)** *Score how laces are held*		

Grasp and Pinch Style Scoring

0 No Grasp, Passive Stabilization
1 Palmar Grasp, Finger Flexion; No Thumb Use
2 Ulnar Scissor Grasp; No Thumb Use
3 Radial Scissor Grasp; No thumb Use

4 Cylindrical Grasp; Thumb to Fingers
5 Lateral Key Pinch; Thumb to Index
6 Tip Pinch; Thumb to Finger Tip
7 Tripod Pinch; Thumb to Distal Index/Long

T-GAP Total Score

Left Hand _____/63
Right Hand _____/63

Number of Grasp Styles: Points 1-7

Left Hand _____
Right Hand _____

Thumb Usage: Points 4-7

Left Hand _____/9
Right Hand _____/9

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Grasp Pattern Hierarchy: No Use of Thumb

T-GAP Scoring: 0 - 3 Points

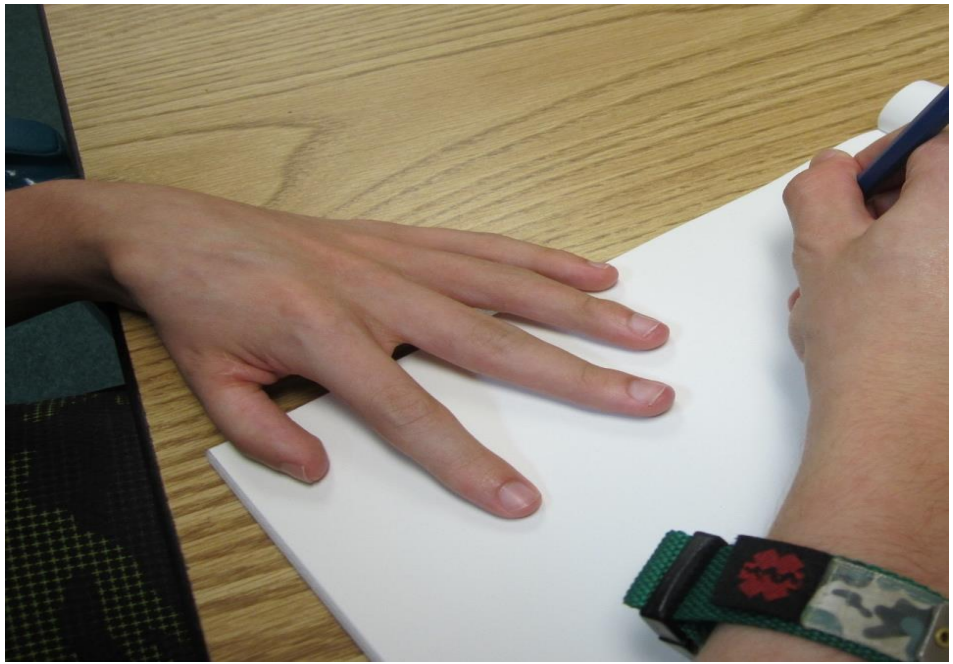
Standard Grasp Patterns	Variation Grasp Patterns
No Grasp, Passive Stabilization (0 points) Passive stabilization using fingertips or side of hand 	**None** No variation for No Grasp, Passive Stabilization
Palmar Grasp, Finger Flexion (1 point) Finger flexion, all fingers to palm  	**Distal Flexion of Fingers (1 point)** Finger flexion without use of palm 
Ulnar Scissor Grasp (2 points) Finger stabilization between small/ring fingers If four web spaces are present; also between ring/long fingers  	**Scissors Multiple Fingers (2 Points)** Weaves objects between multiple fingers 
Radial Scissor Grasp (3 points) Finger stabilization between the index/long fingers  	**Distal Finger Scissoring (3 points)** Distal pinch between non-adjacent finger tips 

Grasp Pattern Hierarchy: Use of Thumb

T-GAP Scoring: 4 - 7 Points

Standard Grasp Patterns	Variation Grasp Patterns
Cylindrical Grasp (4 points) Thumb opposition with proximal grasp of all fingers  	**Distal Cylindrical (5 points)** Thumb opposition with distal grasp of all fingers 
Lateral Key Pinch (5 points) Thumb opposition to side of index finger or index to side of thumb  	**Lateral Cylindrical (5 points)** Encircling grasp of thumb and index finger 
Tip Pinch (6 points) Thumb opposition to tip of index finger  	**Tip to Non-Index Finger (5 points)** Thumb opposition to tip of ring, long or small finger 
Tripod Pinch (7 points) Thumb opposition to index and long fingers  	**Proximal Tripod Pinch (6 points)** Thumb opposition with proximal index/long fingers 

0 Points:
No grasp or pinch
Passive stabilization of hand



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1 Point:
Palmar Grasp, Finger Flexion; No Thumb Use

Variation

Palmar Grasp, Finger Flexion (1 point)

Finger flexion; all fingers to palm

Distal flexion of fingers (1 point)

Finger flexion without use of palm

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2 Points:
Ulnar Scissor Grasp; No Thumb Use

Variation

Ulnar Scissor Grasp (2 points)

Finger stabilization between small/ring.

If 4 web spaces present also between ring/long fingers

Scissors Multiple Fingers (2 Points)

Weaves objects between multiple fingers

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3 Points:
Radial Scissor Grasp; No Thumb Use

Variation

Radial Scissor Grasp (3 points)

Finger stabilization between the index/long for long/ring fingers

Distal Finger Scissoring (3 points)

Distal pinch between non adjacent finger tips

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4 Points:
Cylindrical Grasp

Variation

Cylindrical Grasp; Thumb To All Fingers (4 points)

Opposed thumb with proximal grasp of all fingers

Distal Cylindrical (5 points)

Distal grasp of all fingers to opposed thumb

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5 Points:
Lateral Key Pinch

Variation

Lateral Key Pinch (5 points)

Opposes thumb to side of index finger

Lateral Cylinder (5 points)

Encircling grasp of thumb and index finger

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6 Points:
Tip Pinch

Variation

Tip Pinch (6 points)

Opposes thumb to side or tip of index finger

Tip to Non-Index Finger (5 points)

Opposes thumb to tip of ring, long or small finger

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7 Points:
Tripod Pinch

Variation

Tripod Pinch (7 points)

Thumb opposition to index and long fingers

Proximal Tripod Pinch (6 points)

Thumb opposition with proximal index/long fingers

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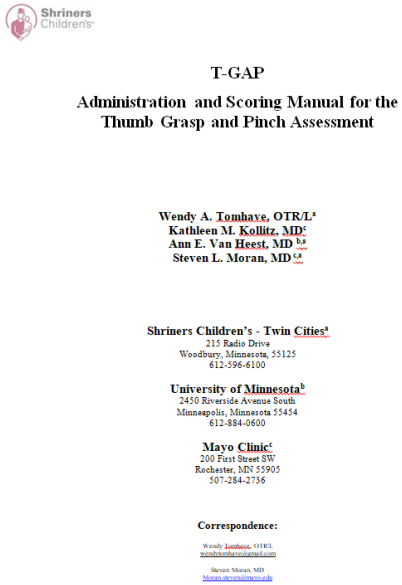
T-GAP Training: Self Study Format

Test Kit Handouts are available free of charge:

https://www.shrinerschildrens.org/en/our-care-providers/wendy-a-tomhave-otr-14705

- Administration and scoring manual
- Administration Presentation (Part 1)
- Photo scoring examples (Part 2)
- Video scoring examples (Part 3)

- Administration and test kits (3 age groups)
- Score forms (3 age groups)
- Two page scoring guide



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T-GAP

Administration and Scoring Manual for the Thumb Grasp and Pinch Assessment

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SCIENTIFIC ARTICLE

Validity and Reliability of the Thumb Grasp and Pinch Assessment for Children After Reconstruction of Congenital Hypoplastic Thumbs

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Purpose The Thumb Grasp and Pinch Assessment (T-GAP) is a new instrument for evaluating thumb use in children with congenital hypoplastic thumbs. The assessors video-record the children while they perform nine specific activities and score their grasp types using T-GAP. A high T-GAP score indicates more mature grasp patterns. The developers reported the instrument's validity and reliability for index finger pollicization. This study investigated T-GAP's validity and reliability in children with reconstructed hypoplastic thumbs.

Methods Four hand surgeons and two hand therapists from two hospitals rated video clips of 20 Manske type II and IIIa hands twice in 17 patients who performed the T-GAP at least 1 year after opposition transfer and thumb ligament reconstruction. To investigate the validity, we calculated correlation coefficients for T-GAP scores and clinical outcomes, including thumb ROM, grip and pinch strength, and visual analog assessments of thumb function and appearance. To estimate T-GAP's inter- and intrarater reliability, we calculated intraclass correlation coefficients and their 95% confidence intervals (CIs).

Results Thumb Grasp and Pinch Assessment score showed a strong linear correlation ($r = 0.815–0.944$) and a moderate to strong nonlinear correlation ($\rho = 0.527–0.744$) with visual analog scale assessments of thumb function and appearance, respectively; a moderate nonlinear correlation ($\rho = 0.464$) with grip strength; and a moderate nonlinear correlation ($\rho = 0.541$) with thumb MCP joint range of motion. The intraclass correlation coefficient for the interrater reliability was 0.892 (95% CI, 0.768–0.954) in round 1 and 0.898 (95% CI, 0.754–0.959) in round 2, and for intrarater reliability, the mean was 0.882 (95% CI, 0.785–0.980).

Conclusions Thumb Grasp and Pinch Assessment score had a moderate to strong construct validity and a moderate concurrent validity. Both inter- and intrarater reliability was strong.

Clinical relevance This study supports the T-GAP instrument's validity and reliability for assessing functional outcomes in congenital hypoplastic thumb reconstruction. *(J Hand Surg Am. 2023;■(■):1.e1-e8.*

Key words Congenital thumb hypoplasia, reliability, Thumb Grasp and Pinch Assessment, validity.

Online Exclusive

CREDIBLE EVALUATION OF TREATMENT outcomes is crucial in studies on children with congenital upper limb anomalies (CULA). During the last decades, researchers have increasingly used patient-reported outcome measures (PROMs) to supplement objective measurements of

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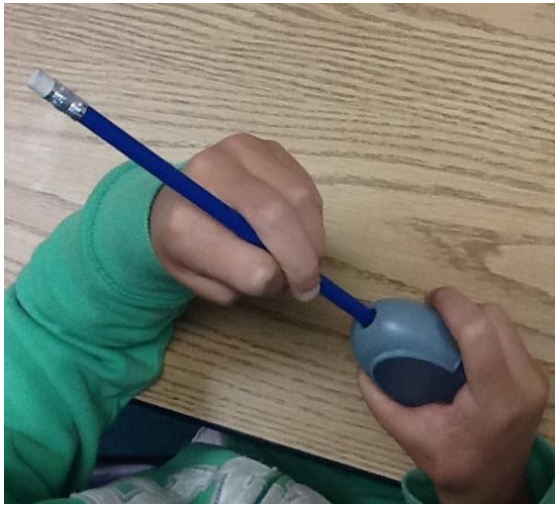
Thank you for your attention!



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