

# Assessing Motion, Strength, and Balance

## Goals and Objectives

### Course Description

"Assessing Motion, Strength, & Balance" is an online recorded video of a previously presented live CE webinar for physical therapists and physical therapist assistants. This course examines standard tests and measures utilized to assess patient progress toward therapeutic goals and analyze the effectiveness of interventions performed during research trials. Current research related to equipment including smartphone applications and hand-held dynamometry, technique, and reliability of data collected through goniometry, manual muscle testing, and balance assessment tools is explored.

### Course Rationale

The purpose of this course is to provide a comparative analysis of traditional and contemporary techniques for assessment of range of motion, muscle strength, and balance based on current research to aid the clinician in employing these techniques effectively when assessing patient progress.

### Course Goals and Objectives

Upon completion of this course, participants will be able to:

1. List primary differences between Nagi Disablement Model and International Classification of Functioning as conceptual frameworks in rehabilitation.
2. Identify clinician attitudes toward and barriers to implementation of evidence-based practice.
3. Identify variables contributing to reliability of traditional manual muscle testing.
4. Recognize limitations of hand-held dynamometry to assess muscle strength.
5. Identify and differentiate range of motion measurement methods.
6. Define how smartphone applications utilize phone components to measure joint excursion.
7. Classify various methods of balance assessment.
8. Identify balance assessment tests that contribute to the detection of fall risk.

**Course Provider** – Innovative Educational Services

**Provider Contact Information** – [information@cheapceus.com](mailto:information@cheapceus.com)

**Course Instructor** – Jodi Gootkin, PT, Med, CEAS

**Financial/Non-financial Disclosure** - Neither the Provider nor the instructor have any financial or non-financial conflict of interest related to the presentation of this CE program.

**Target Audience** – Physical Therapists, Physical Therapist Assistants

**Course Educational Level** – This course is applicable for introductory learners.

**Course Prerequisites** – None

**Instructional Method** – Distance Learning – Independent; Asynchronous online video-based home study

**Location** - Cheapceus.com

**Date** – Continuously available on-demand

**PD Activity Completion Requirements / Criteria for Issuance of CE Credits** – Completion of viewing of 1 hour recorded video, and a score of 70% correct or greater on the course post-test.

**Continuing Education Credits** – Three (3) contact hours

**Course Fee** - \$34.95

**Registration Information** – No pre-registration required; available on-demand at Cheapceus.com

**Special Needs Requests** – Email: [information@cheapceus.com](mailto:information@cheapceus.com) or phone: 954-663-4101

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**Cancellation by the Provider** – Registrants for the cancelled activity will be contacted by an IES staff member via phone call or email within 12 hours of the cancellation decision. If the decision to cancel is made less than 14 hours prior to the event, each participant will be contacted no later than 2 hours prior to the scheduled start time of the activity. Registrants will receive a full refund if an activity is cancelled by the Provider. The refund will be processed back to the Registrant within 12 hours of the cancellation.

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# Assessing Motion, Strength, & Balance

Presented By:

Jodi Gootkin, PT, MEd, CEAS

[jodiemail@comcast.net](mailto:jodiemail@comcast.net)

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## Course Overview

- “Assessing Motion, Strength, & Balance” examines traditional and contemporary tools and methodologies used to measure patient range of motion, muscle strength, and balance. This course includes a review of current literature relating to test reliability and validity, as well as discussions relating to practical clinical applications.

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## Course Rationale

- The purpose of this course is to provide a comparative analysis of traditional and contemporary techniques for assessment of range of motion, muscle strength, and balance based on current research to aid the clinician in employing these techniques effectively when assessing patient progress.

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## Goals and Objectives

1. List primary differences between Nagi Disablement Model and International Classification of Functioning as conceptual frameworks in rehabilitation.
2. Identify clinician attitudes toward and barriers to implementation of evidence based practice.
3. Relate the connection between tests and measures and analysis of researched intervention effectiveness.
4. Identify variables contributing to reliability of traditional manual muscle testing.
5. Recognize opportunities for use and limitations of hand held dynamometry to assess muscle strength.
6. Select methods to promote consistency of range of motion measurement using various methods including standard goniometry, visual assessment, inclinometer, and diagrammatic recording.
7. Define how smartphone applications utilize phone components to measure joint excursion.
8. Determine the reliability of electronic goniometric measurement with smartphone applications.
9. Classify various methods of balance assessment including functional based tools and posturography.
10. Identify balance assessment tests that contribute to the detection of fall risk.

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## Course Outline/Schedule

Topic	Time
Conceptual Frameworks in Rehabilitation	0:00-0:10
Evidence Based Practice Attitudes and Beliefs	0:11-0:20
Relevance of Tests and Measures	0:21-0:30
Manual Muscle Testing Technique Analysis	0:31-0:35
Contributors to Reliability of Strength Assessment	0:36-0:50
<b>Interactive Discussion of Clinical Applications</b>	<b>0:51-0:60</b>
Hand Held Dynamometry Equipment and Techniques	1:01-1:10
Reliability of Dynamometry Muscle Grades	1:11-1:20
Limiting Variables in with Standard Goniometry	1:21-1:30
Analysis of Alternative Range of Motion Measurement Techniques	1:31-1:40
Summary of Smartphone Range of Motion Measurement	1:41-1:50
<b>Interactive Discussion of Clinical Applications</b>	<b>1:51-2:00</b>
Comparative Analysis of Smartphone Goniometry Apps	2:01-2:15
Categorizing Balance Assessment Techniques	2:16-2:30
Comparing Reliability of Balance Assessment Tools	2:31-2:40
Balance Assessment as a Predictor of Fall Risk	2:41-2:50
<b>Interactive Discussion of Clinical Applications</b>	<b>2:51-3:00</b>

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- After watching the video go to [www.cheapceus.com](http://www.cheapceus.com)
- Complete the post test with score of at least 70%
  - May be retaken multiple times
- Submit online payment for course
- Print certificate
- Course review and summary for post test at the end of the webinar.



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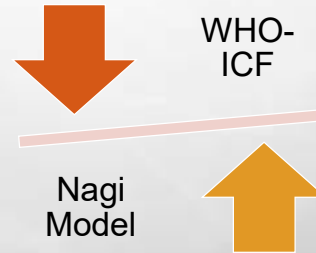
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## Disablement Models

- Two primary conceptual models are utilized to guide clinical practice decisions and research.



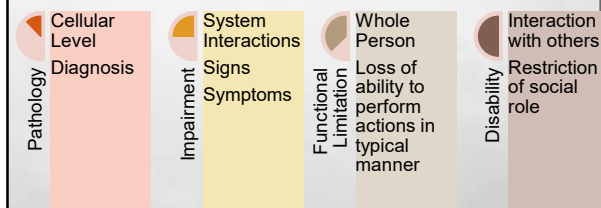
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## Nagi Model

- A medical model with linear thought process.



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## Classification Of Individual Health

### ICD-10

- International Classification of Diseases
- Organizes information on diagnosis and health condition

### ICF

- International Classification Of Functioning, Disability, And Health
- Clarifies function

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## WHO – ICF Model

- World Health Organization - International Classifications of Functioning, Disability, and Health

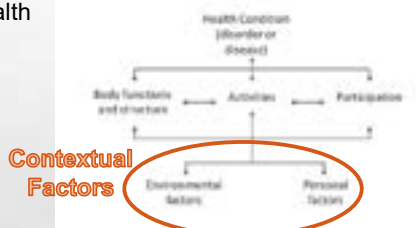


Image from: Salvador-Carulla, Luis, and Carlos Garcia-Gutierrez. "The WHO Construct of Health-Related Functioning (HrF) and Its Implications for Health Policy." *BMC Public Health* 11.Suppl 4 (2011): S9. *PMC*. Web. 7 Aug. 2016.

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## Benefits ICF Framework

- Focus on the individual
- Considers contextual factors
- Emphasis on positive aspects
- Various opportunities to intervene
- Multidimensional process

## BioPsychoSocial Model

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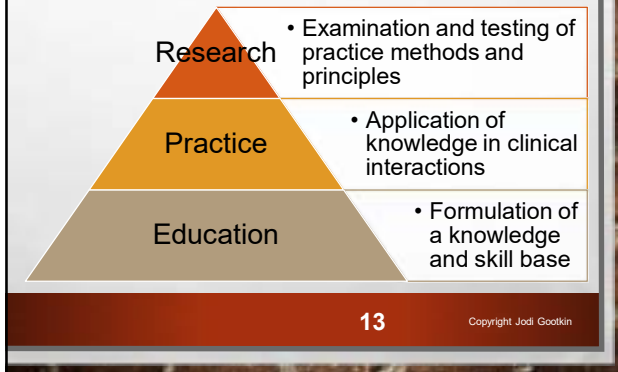
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## Fundamental Components of Allied Health Professions



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## Evidence Based Practice (EBP)

- Diffusion theory is the concept of facilitating consistent application of research finding into clinical practice.



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## Attitudes and Implementation

- Across disciplines, clinicians concur that evidence based practice research:
  - Informs practice patterns for improved outcomes.
  - Is infrequently incorporated into clinical practice.
  - Is challenging for many clinicians to access and interpret.
  - Clinician confidence with integration is low.

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## Increasing Self Efficacy



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## Barriers to EBP

- Optimizing application of research in practice is inhibited due to:
  - Time constraints
  - Colleagues not employing EBP
  - Access to information challenges
  - Interpretation of research challenges
  - Patient preference
  - Individual professional experience

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## Analyzing the Evidence

- Inconsistency in evaluating outcomes diminishes the effectiveness of evidence based practice.
- Uniformity in use of valid and reliable measurement tools is necessary to compare outcomes.
  - Validity – measures what is intended
  - Reliability – test re-test consistency

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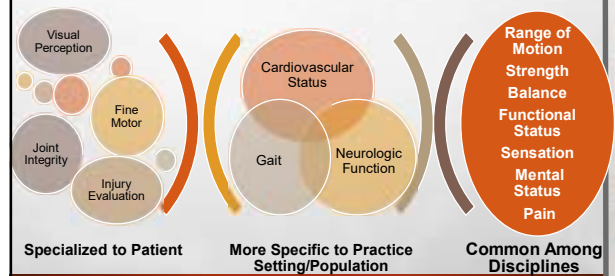
## Data Collection

- Gathering objective reliable information quantifies signs, symptoms, function to:
  - Identify limitations
  - Demonstrate progress or lack of progress
  - Communication with other healthcare providers and payors
  - Evaluate intervention effectiveness in practice and research

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## Common Impairments to Evaluate



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## Standardized Outcome Measures/Assessment Tools

### Classifications

Clinician Based

Patient Based

### Examples

MMT ROM  
Performance Measures

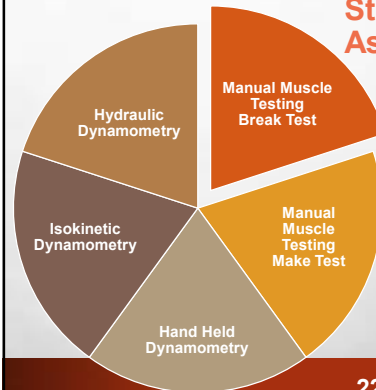
Questionnaires  
Generic/Specific

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## Strength Assessment

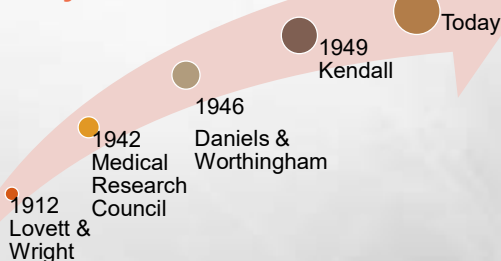
- Objective measurement of performance of an individual or group of muscles in relation to gravity and resistance.



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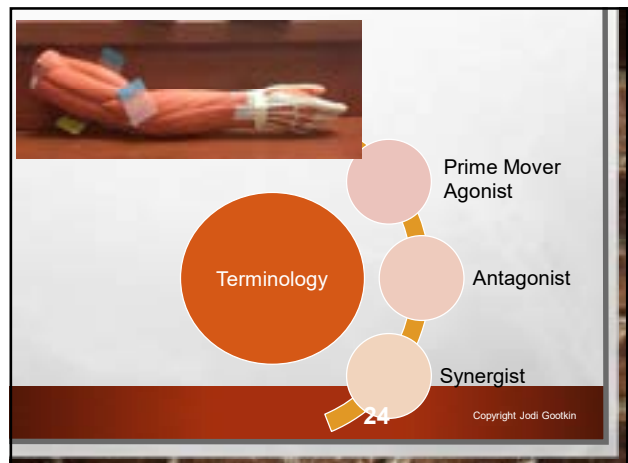
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## Manual Muscle Testing (MMT) History



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### MMT Grades

Grade	Gravity	ROM	Resistance
5	Normal	AG	Full ROM
4+	Good Plus		Maximal
4	Good	AG	Strong
4-	Good Minus		Moderate
3+	Fair Plus		Minimal
3	Fair	AG	Slight
3-	Fair Minus	AG Gradual release OR	Full ROM
2+	Poor Plus	>50% AG ROM No Resistance	
2	Poor	AG Partial ROM < 50% OR GE Full ROM some pressure	
2-	Poor Minus	GE Full ROM	None
1+	Trace Plus	Partial ROM	
1	Trace	GE	< 50% ROM
0	Zero	Palpable or Observed Contraction	
0	Zero	No Contraction	

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### MMT Reliability

- Typically accepted level of agreement for inter or intratester reliability is +/- one muscle grade.

82 – 97%  
Intertester Reliability

96 – 98%  
Intratester Reliability

Good overall Reliability and Validity


Cuthbert SC, Goodheart GJ. On the reliability and validity of manual muscle testing: a literature review. *Chiropractic & Osteopathy*. 2007;15:4. doi:10.1186/1746-1340-15-4.  
Fan, Eddy, et al. "Inter-rater reliability of manual muscle strength testing in ICU survivors and simulated patients." *Intensive Care Medicine* 36.6 (2010): 1038-1043.

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### Rotator Cuff Isolation

- Electromyographic analysis of rotator cuff muscle activation with standard manual muscle test positions confirms activation of prime movers.
  - ABDuction – Supraspinatus
  - External Rotation – Infraspinatus, Teres Minor
  - Internal Rotation - Subscapularis



Brookham, Rebecca L, Linda McLean, and Clark R. Dickerson. "Construct validity of muscle force tests of the rotator cuff muscles: an electromyographic investigation." *Physical Therapy* 90.4 (2010): 572-580.

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### Break vs. Make Testing

**Break**

Patient holds isometric muscle contraction against progressively increasing force provided by examiner.

**Make**

Application of force to the moving body segment during patient performance of motion.

Examiner remains stationary while patient exerts maximal isometric force against them.

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### Make vs. Break Reliability

- Research does not indicate one method is superior to the other.

Motion Tested	Comparative Measure	Reliability Findings
*Elbow Flexion	Digital Hand Held Dynamometer	Greater force generated with Break test.
** Thumb ABDuction	Algometer	Make better interrater reliability

\*Bohannon, Richard W. "Make tests and break tests of elbow flexor muscle strength." *Physical Therapy* 68.2 (1988): 193-194.  
\*\*Lim, J. X., et al. "A comparison of the reliability of make versus break testing in measuring palmar abduction strength of the thumb." *Journal of Hand and Microsurgery* 6.1 (2014): 8-12.

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### MMT Accuracy Variables

- Standardization of procedure increases intra and intertester reliability.

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- Joint Position
- Verbal Cues
- Location of Force Application
- Stabilization
- Interpretation of Values
- Clinician Strength
- Clarification of Make vs.. Break

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### Altering Test Position

- When performing isokinetic strength assessment for sport participation, consider testing at joint angles that replicate specific activity demands.
- Example: Testing for quad hamstring ratio at a greater hip flexion angle alters length tension relationship and peak torque generation of hamstrings.
- Maybe better predictor of potential injury in sprinters.

Gueux, Kenny; Gojanovic, Boris; Millet, Grégoire P. "Influence of hip-flexion angle on hamstrings isokinetic activity in sprinters". *Journal of Athletic Training*, Jul/Aug 2012, Vol. 47 Issue 4, p390-395, 6p.

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### Length Tension Relationship



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### MMT Force Application

- Larger muscle groups require additional force to achieve same muscle grade as smaller muscle groups.
- Application of force variable among testers.
- Ceiling effect of maximum MMT grade does not account for functional strength requirements.

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### Plantarflexion MMT

- MMT ineffective in capturing muscle weakness of the gastroc.
- Single limb heel raise of the gastroc in weight bearing posture can provide information on functional strength necessary for gait.

Fixed Frame Dynamometry	MMT	Single Limb Heel Raises (SLHR)
Varied peak maximum voluntary contraction (MVC) in those performing >25 SLHR	58% of participants who could not perform 1 SLHR achieved full strength with MMT	Ability to perform 1 SLHR warrants more investigation for clinical relevance.

Harris-Love, Michael O., et al. "Are repeated single-limb heel raises and manual muscle testing associated with peak plantar-flexor force in people with inclusion body myositis?" *Physical Therapy* 94.4 (2014): 543-552.

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### Correlating MMT Strength to Function

- Diminished muscle strength impacts functional mobility particularly ambulation in individuals with muscular dystrophies.

Muscle	MRI Fat Infiltration	MMT Alteration	10 Meter Walk Alteration
Hamstring	1 point increase	5 pound decrease	.78 second increase
Quads	1 point increase	13 pound decrease	
Iliopsoas	1 point increase		3.7 second increases

Skalsky, Andrew J., et al. "Regional and whole-body dual-energy X-ray absorptiometry to guide treatment and monitor disease progression in neuromuscular disease." *Physical medicine and rehabilitation clinics of North America* 23.1 (2012): 67-74.

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### Professional Recommendations

- APTA Oncology EDGE Task Force advises use of hand held dynamometry for patients with cancer.

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## Dynamometry

- ❑ Use of specific measurement device to quantify the “break force” when assessing muscle strength.
  - ❑ Hydraulic Dynamometer
  - ❑ Hand Held Dynamometer
  - ❑ Isokinetic Dynamometer

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## Dynamometers Examined in Research

### Hydraulic

- Jamar Technologies
- Baseline Hand

### Isokinetic

- Biodex
- KinCom
- Cybex

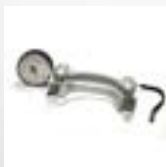
### Hand Held

- MicroFet2
- Lafayette Instrument
- Nicholas Manual Muscle Tester
- Jtech Commander PowerTrack II

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## Hydraulic Dynamometer



[http://www.lafayetteinstruments.com/product\\_detail.asp?itemid=1166](http://www.lafayetteinstruments.com/product_detail.asp?itemid=1166)

- ❑ Shoulder ADDuction
- ❑ Elbow 90° Flexion
- ❑ Wrist 0-30° Extension
- ❑ Wrist 0-15° Ulnar Deviation
- ❑ Utilize average of 3 trials

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## Isokinetic Dynamometer



<http://biodex.com/physical-medicine/products/dynamometers/system-4-quick-set>

- ❑ Machine resistance matches patient effort

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## Hand Held Dynamometry (HHD)

- ❑ Small hand held digital device approximated to moving body segment to read force production.
- ❑ Precise measurement of baseline and minor alterations in muscle strength.
- ❑ Measures Maximum Voluntary Isometric Contraction

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## Hand Held Dynamometer



<http://www.hogganhealth.net/microfet2.php>

- ❑ Measures in pounds, newtons, and kilograms
- ❑ Analysis software for data interpretation
- ❑ Test positions primarily gravity eliminated

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## Hand Held Dynamometer



<http://www.jtechmedical.com/Commander-muscle-tester>



[http://www.lafayetteevaluation.com/product\\_detail.asp?itemID=26](http://www.lafayetteevaluation.com/product_detail.asp?itemID=26)

- Hold maximum isometric contraction for 3 seconds
- Bilateral comparison calculation

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## Limitations of Dynamometry

- Accuracy of measurement can be altered by
  - Calibration errors
  - Limited normal values
  - Positioning of limb and device
  - Isokinetic not recommended for strength below 3/5
  - Ceiling effect due to clinician strength
  - Clarify make vs. break testing

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## Examiner Strength Consideration

- As patient forces increase, reliability for weaker clinicians decreases.
  - Maybe better suited for non-athlete populations.
- Develop greater mechanical advantage to compensate for examiner weakness.
  - Isometric contraction from patient must be achieved to perform HHD testing.

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## HHD Reference Values

- Multiple studies have published normative values referenced with subject age, gender, and anthropometric characteristics.
- Interesting findings:
  - Women weaker
  - Generally dominant side stronger
  - Hip ABDuction and neck flexion weakens with age

Phillips, Beverley A., Sing K. Lo, and Frank L. Mastaglia. "Muscle force measured using "break" testing with a hand-held myometer in normal subjects aged 20 to 69 years." *Archives of Physical Medicine and Rehabilitation* 81.5 (2000): 653-661.

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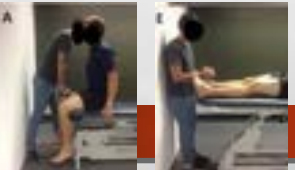
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## HHD Reliability Comparison to Other Instruments

Comparative Instrument	Motions	Reliability Findings
*KinCom Isokinetic Dynamometry	Hip, Knee, Ankle All Planes	Good to excellent except ankle dorsi/plantarflexion

Muscle Groups	Intra-rater reliability	Assessor-A		Assessor-B		KinCom
		Lafayette	Hoggan	Lafayette	Hoggan	
ADF	Day 1—Mean (SD)	19.19 (4.92)	20.89 (3.64)	27.47 (5.96)	30.68 (6.89)	18.47 (6.87)
	Day 2—Mean (SD)	17.83 (4.35)	20.92 (4.11)	27.42 (5.85)	29.93 (5.49)	17.52 (6.30)



Mentipley BF, Perraton LG, Bower KJ, Adair B, Pua YH, et al. (2015) Assessment of Lower Limb Muscle Strength and Power Using Hand-Held and Fixed Dynamometry: A Reliability and Validity Study. *PLoS ONE* 10(10): e0140822. doi:10.1371/journal.pone.0140822 <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0140822>

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## HHD Reliability Comparison to Other Instruments Continued

Comparative Instrument	Motions	Reliability Findings
Biodex	Knee Extension	Good correlations between measures

Martin, Yule, Sdall, et. al. "Is hand held dynamometry useful for the measurement of quadriceps strength in older people?" *Gerontology*. (2006) Vol. 52 No. 3.

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## HHD Intertester Reliability

Participants	Motions	Reliability Findings
*Physical Therapist Athletic Trainers	Hip, Knee, Ankle All Planes	Good intratester reliability regardless of experience
**Skilled Professor Physical Therapist	Elbow Flexion/Extension Wrist Extension	Intertester correlation below acceptable limits
*** Orthopedist Chiropractor	Hip All Planes	Poor reproducibility with large limit of agreement ranges

\*Kellin, Brent M., et al. "Hand-held dynamometry: reliability of lower extremity muscle testing in healthy, physically active, young adults." *Journal of Sport Rehabilitation* 17.2 (2006): 160.  
 \*\*Aufesser, P., Michael Horvat, and Ruth Austin. "The reliability of hand held muscle testers with individuals with spinal cord injury." *Clinical Kinesiology* 57.4 (2003): 71.  
 \*\*\*Poulsen, Erik et al. "Reproducibility of range of motion and muscle strength measurements in patients with hip osteoarthritis – an inter-rater study." *BMC Musculoskeletal Disorders* 13 (2012): 242. PMC. Web. 31 Aug. 2016.

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## Underestimation of Strength

Study Information	Motions	Reliability Findings
*Healthy older adults comparison of HHD to Biodex	Knee Extension	Good correlation but underestimated in stronger patients
**Physical Therapists performing HHD on healthy young adults	Hip Flexion, Extension, ABDuction, Knee Flexion/Extension	Excellent intertester reliability except fair for knee extension
***Nurses performing HHD on patients following SCI	Elbow Flexion/Extension, Hip Flexion, Knee Extension	Inaccurate due to examiner weakness compared to subject.

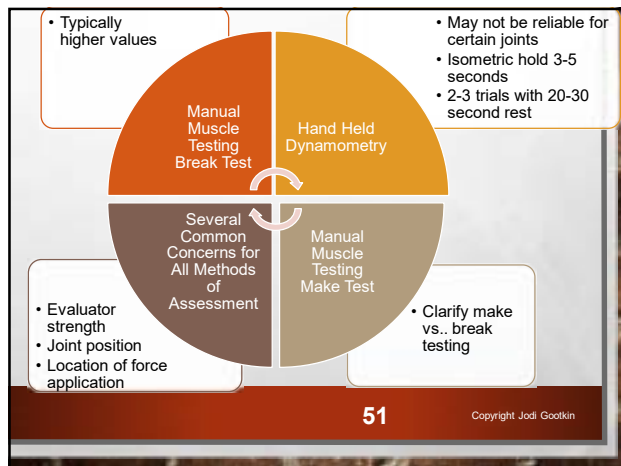
\*Marin, Yule, Sddall, et. al. "Is hand held dynamometry useful for the measurement of quadriceps strength in older people?" *Gerontology* (2006) Vol. 52 No. 3.  
 \*\*Lu, Yen-Mou, Lin, Jau-Hong; et al "The relative and absolute reliability of leg muscle strength testing by a handheld dynamometer." *Journal of Strength and Conditioning Research* 25.4 (Apr. 2011): 1065-1071.  
 \*\*\*Lu, Gopin, et al. "A simple way to improve the relative and absolute reliability of hand-held dynamometer measurements using learners." *International Journal of Clinical and Experimental Medicine* 9.1 (2016): 199-208.

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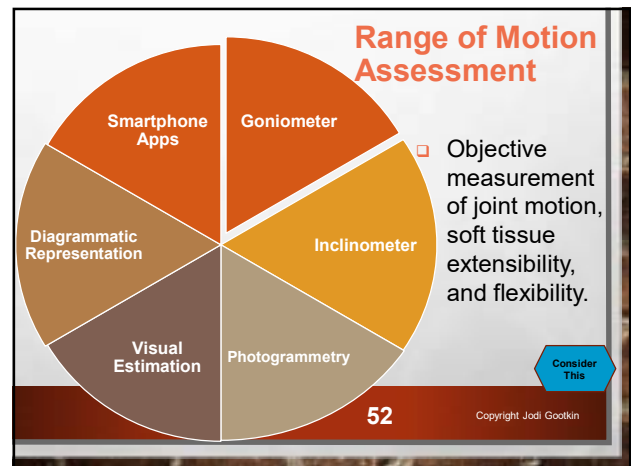
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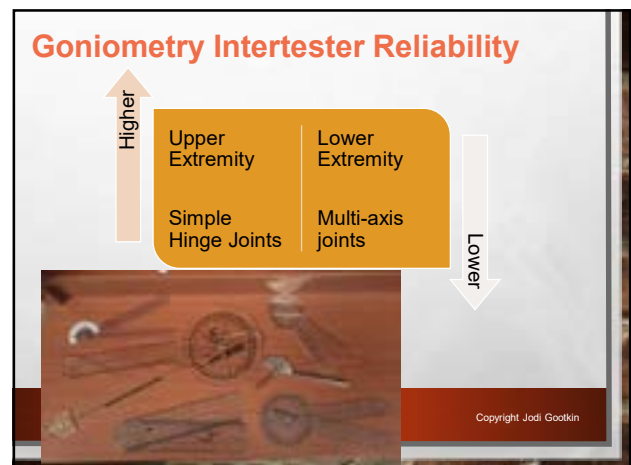
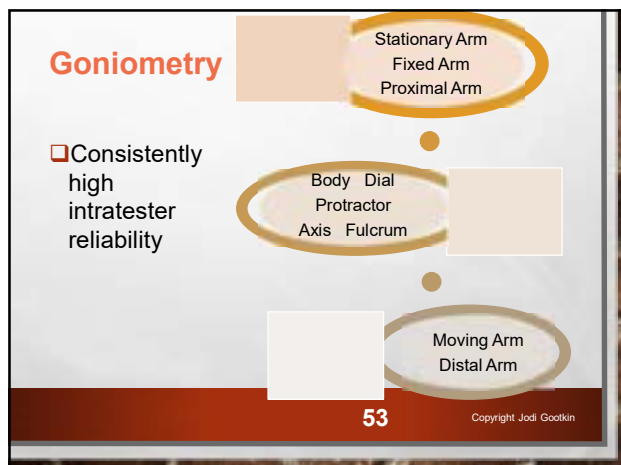
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## Plus or Minus Five Degrees

**SEM**

**Standard Error of Measurement**

Distribution of repeated ROM values using the same instrument.

**MDC**

**Minimal Detectable Change**

Smallest change in value that can be measured beyond error.

**MCID**

**Minimal Clinically Important Difference**


Smallest change in ROM value that is beneficial to the patient.

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## Small Joint Intertester Reliability

Joint Motions Measured	Reliability Conclusion
*Q angle	Positive reliability




\*Weiss, Lawrence, et al. "Reliability of goniometry-based Q-angle." *PM&R* 5.9 (2013): 763-768.

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## Small Joint Intertester Reliability

Joint Motions Measured	Reliability Conclusion
**Finger MCP extension, PIP flexion, DIP extension	High to very high intertester reliability
***MCP, DIP, PIP flexion	SEM for diagrammatic representation equivalent to goniometer



\*\*Engstrand, Christina, Barbro Krevers, and Joanna Kvist. "Interrater reliability in finger joint goniometer measurement in Dupuytren's disease." *American Journal of Occupational Therapy* 66.1 (2012): 98-103.  
 \*\*\*Macionis, Valdas. "Reliability of the standard goniometry and diagrammatic recording of finger joint angles: a comparative study with healthy subjects and non-professional testers." *BMC Musculoskeletal Disorders* 14.1 (2013): 1.  
<https://doi.org/10.1186/1471-2284-14-1>

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## Large Joint Intertester Reliability

Joint Motions Measured	Reliability Conclusion
*Shoulder Horizontal ABD, ADDuction, Extension, Internal Rotation	Poor intertester reliability
**Hip All Planes	Poor to moderate intertester reliability

\*Riddle, Dan L., Jules M. Rothstein, and Robert L. Lamb. "Goniometric reliability in a clinical setting shoulder measurements." *Physical Therapy* 67.5 (1987): 669-673.  
 \*\*Poulsen, Erik, et al. "Reproducibility of range of motion and muscle strength measurements in patients with hip osteoarthritis—an inter-rater study." *BMC Musculoskeletal Disorders* 13.1 (2012): 1.  
 \*\*Owen, Janice, Derek Stephens, and James G. Wright. "Reliability of hip range of motion using goniometry in pediatric femur shaft fractures." *Canadian Journal of Surgery* 50.4 (2007): 251.


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## Goniometer Size

Size of the goniometer does not appear to impact consistency of measurement.

Goniometer Evaluated	Joint Motions Measured	Reliability Conclusion
Metal – 2 degree increment	Elbow flexion/extension	High intratester and intertester reliability
Large Plastic 1-degree increment	Knee flexion/extension	
Small Plastic 5-degree increment		
Large Plastic	Shoulder flexion, ABDuction, External Rotation	High intratester and intertester reliability
Small Plastic		



Rothstein, Jules M., Peter J. Miller, and Richard F. Roetinger. "Goniometric reliability in a clinical setting elbow and knee measurements." *Physical Therapy* 63.10 (1983): 1611-1615.  
 Riddle, Dan L., Jules M. Rothstein, and Robert L. Lamb. "Goniometric reliability in a clinical setting shoulder measurements." *Physical Therapy* 67.5 (1987): 668-673.

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## Contributors to Inconsistency

- Standardization of clinical procedures should minimize variability in technique.
- Potential contributors to inconsistency include:
  - Patient position
  - Body segment stabilization
  - Examiner force application
  - Improper alignment of goniometer

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## Patient Position

- Joint excursion values can be inflated or diminished due to alterations in muscle length.
- Documentation should include body position during joint measurement.
  - Knee Extension – Hamstring length
  - Ankle Inversion/Eversion - Subtalar neutral
  - Shoulder ABDuction – Scapular substitution

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## Stabilization

- Failure to measure only isolated joint motions contributes to overestimation of ROM.
  - Hip ABDuction/Flexion – Pelvic motion



Holm, Inger, et al. "Reliability of goniometric measurements and visual estimates of hip ROM in patients with osteoarthritis." *Physiotherapy Research International* 5.4 (2000): 241-248.

Nussbaumer, Silvio, et al. "Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients." *BMJ Musculoskeletal Disorders* 13.1 (2010): 1. <https://doi.org/10.1136/bmjmus-2010-000001>

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## Examiner Force Application

- Consistency in measuring only desired motion requires clinician attentiveness to end feel.

Hard

Boggy

Empty

Firm

- Muscular
- Capsular
- Ligamentous

Soft

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## Goniometer Alignment

- Palpation ensures proper identification of bony landmarks for the axis, moving, and stationary arms.
- Adding a level to the goniometer can assist in determining true vertical and horizontal increasing accuracy.

Small landmark Error

=

Substantial Measurement Error

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## Goniometer Increments

- Use of 1-degree increment goniometers is most appropriate to minimize inaccuracy.



5 degree increment dial

+

+/- 5 degree intertester reliability

Potential 10 degree measurement variability

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## Inclinometer

- Tool measuring the ROM angle with respect to gravity.
  - Bubble and digital types available
- Clinician must establish zero at start position to read end position as full ROM.
- Different landmarks utilized which can result in altered end feel compared to traditional goniometry.
- Body type may contribute to malalignment and altered measurement.



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## Shoulder Inclinometry

- Poor intertester reliability with significant range of disagreement (SEM).

Compared to traditional goniometry	Intertester Reliability	MDC
2 – 20 degree SEM*	20-25 degree SEM**	If measured by different clinicians, must have at least 20 degree of change in ROM.
Document method of ROM measurement	Reevaluation should be by same clinician	

\*Kober, Morey J., and William J. Hanney. "The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical note." *International journal of sports physical therapy* 7.3 (2012): 306.  
\*\*De Winter, Andrea F., et al. "Inter-observer reproducibility of measurements of range of motion in patients with shoulder pain using a digital inclinometer." *BMC Musculoskeletal Disorders* 5.1 (2004): 1.

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## Spine ROM with Inclinometer

Joint Motions Measured	Validity Conclusion
*Cervical Flexion, Extension, Lateral Bending, and Rotation.	Excellent correlations to radiographs
**Lumbar Flexion, Extension	High correlation between palpation for landmarks, fluoroscopy identification of landmarks, and radiography measurement.

\*Mayer, Tom, et al. "Noninvasive measurement of cervical tri-planar motion in normal subjects." *Spine* 18.15 (1993): 2191-2195.  
\*\*Saur, Petra MM, et al. "Lumbar range of motion: reliability and validity of the inclinometer technique in the clinical measurement of trunk flexibility." *Spine* 21.11 (1996): 1332-1338.

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## Inclinometer Placement on Spine

- Dual inclinometers applied simultaneously for accurate measurement.

Landmark Identification Method	Lower	Upper
Palpation	S1	T12
Schober Test	S2	10 cm above S2
Modified Modified Schober	S2	15 cm above S2

MacDermid, Joy, et al. "Reliability of three landmarking methods for dual inclinometry measurements of lumbar flexion and extension." *BMC Musculoskeletal Disorders* 16.1 (2015): 1.

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## Visual Estimation

- Often considered unreliable when precise measurement values are necessary.
- May be acceptable method for specific motions.
  - Hip Flexion

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## Visual Estimation Reliability

Participants	Motions Measured	Reliability Findings
*Orthopedists Physical Therapists	Shoulder flexion, ABDuction, External Rotation	Fair to Good intratester and intertester reliability
**Orthopedic surgeons Physical Therapists	Hip All planes	Good intertester reliability except ABDuction
*** Physical Therapists	Knee flexion and Extension	Fair intertester reliability

\*Hayes, Kimberley, et al. "Reliability of five methods for assessing shoulder range of motion." *Australian Journal of Physiotherapy* 47.4 (2001): 289-294.  
\*\* Holm, Inger, et al. "Reliability of goniometric measurements and visual estimates of hip ROM in patients with osteoarthritis." *Physiotherapy Research International* 5.4 (2000): 241-248.  
\*\*\*Watkins, Michael A., et al. "Reliability of goniometric measurements and visual estimates of knee range of motion obtained in a clinical setting." *Physical Therapy* 71.2 (1991): 90-96.

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## Visual vs.. Goniometry

- SEM analysis indicates that accuracy is directly dependent upon experience of tester.

Surgeon  
Physician Assistant  
Clinical Fellow  
Inexperienced Evaluator

Goni: 5-7  
Visual: 10  
Goni: 6-10  
Visual: 13  
Goni: 14-17  
Visual: 26

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## Photogrammetry

- Digital photographs calculated with software or printed paper photos measured with a goniometer.
- Beneficial applications include:
  - Telemedicine
  - Proof of progress to patients
  - Standardization among multi-clinician settings
  - Maximizing hands on time during visit

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## Image Analysis Software Utilized in Research

- SAPO Software
- CorelDraw
- ALCImagem

<http://demotu.org/sapo-en/>



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## Printed Photogrammetry

- Research supporting the technique is valid and produces more consistent results than goniometry.

Participants	Motions Measured	Equipment
*Orthopedists Physical Therapists	Shoulder flexion, ABDuction, External Rotation	Polaroid
**Athletic Trainers	Modified Thomas Test	Printed Photos

\*Hayes, Kimberley, et al. "Reliability of five methods for assessing shoulder range of motion." *Australian Journal of Physiotherapy* 47.4 (2001): 289-294.  
\*\*Peeler, Jason, and Jeff Leiter. "Using digital photography to document rectus femoris flexibility: a reliability study of the modified Thomas test." *Physiotherapy theory and practice* 29.4 (2013): 319-327.

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## Digital Photogrammetry

- Reliable but requires additional technology skills and time to manage software.

Participants	Motions Measured	Equipment
*Surgeon Medical Student	Elbow , Forearm, Wrist all planes	iPhone Camera
**Clinician	Shoulder Rotation	Digital Camera
***PT, PT Students, Hand Therapist	Thumb ABDuction, PIP flexion, MCP flexion	Digital Camera

\*Crasto, Jared A., et al. "Comparative analysis of photograph-based clinical goniometry to standard techniques." *Hand* 10.2 (2015): 248-253.  
\*\*Antonietti, Leandro, et al. "Reliability Index of inter-and intra-rater of manual goniometry and computerized biophotogrammetry to assess the range of motion of internal and external shoulder rotation." *MedicalExpress* 1.2 (2014): 95-99.  
\*\*\*De Carvalho, Rosana Martins Ferreira, Nilton Mazzari, and Claudio Henrique Barbieri. "Analysis of the reliability and reproducibility of goniometry compared to hand photogrammetry." *Acta Ortopedica Brasileira* 20.3 (2012): 139-149.

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## OpenSim

- Create models of musculoskeletal motion

<https://simtk.org/projects/opensim>

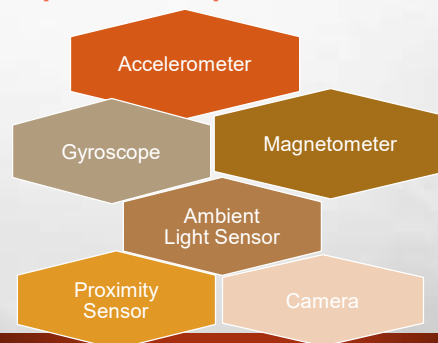
Delp, Scott L., et al. "OpenSim: open-source software to create and analyze dynamic simulations of movement." *IEEE transactions on biomedical engineering* 54.11 (2007): 1940-1950.

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## Smartphone Components



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### Smartphone Applications Examined in Research

<b>Magnetometer</b>	<ul style="list-style-type: none"> <li>iShould</li> </ul>
<b>Accelerometer</b>	<ul style="list-style-type: none"> <li>Knee Goniometer</li> <li>Simple Goniometer</li> </ul>
<b>Camera Based</b>	<ul style="list-style-type: none"> <li>mROM</li> <li>DrGoniometer</li> </ul>
<b>Inclinometer Based</b>	<ul style="list-style-type: none"> <li>iHandy Level</li> <li>Clinometer</li> <li>GetmyROM</li> <li>Physio2Go</li> <li>Scoliguage</li> <li>Hip ROM Tester</li> </ul>
<b>Two Dimensional Motion Analysis</b>	<ul style="list-style-type: none"> <li>Coach's Eye</li> </ul>

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### Accelerometer Based Apps

- Screen image mimics universal goniometer.
- Phone's accelerometer measures the joint angle through position changes.
- Software uses trigonometric equation to calculate joint motion.



<http://safetyinhealth.biomedcentral.com/articles/10.1186/s40885-015-0003-4>

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### Camera Based App

- Uses integrated camera for photo.
  - Phone's built in inclinometer guides alignment.
- On the image, the clinician drags/drops to mark the three anatomical reference points.
- The angle reflecting ROM is then calculated by the app.


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### Camera Based Apps Extremity ROM

- Consistent with other methods of measurement.

Motion Measured	Comparative Tool
*Shoulder ABDuction	Inertial sensors
**Knee Flexion	Goniometry



Cuesta-Vargas, Antonio I., and Cristina Roldán-Jiménez. "Validity and reliability of arm abduction angle measured on smartphone: a cross-sectional study." *BMC Musculoskeletal Disorders* 17.1 (2016): 1. <http://bmcmusculoskeletaldisorders.biomedcentral.com/articles/10.1186/s12891-016-0957-3>

\*\*Farrero, Giorgio, et al. "Reliability of a smartphone-based goniometer for knee joint goniometry." *International Journal of Rehabilitation Research* 36.2 (2013): 146-151.

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### Camera Based Apps Potential Error

- Two potential sources of error:
  - Alignment when taking image
  - Alignment while positioning virtual goniometer

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### Inclinometer Based Apps

- Phone's built in accelerometer is used to sense motion.
- The digital display mimics bubble goniometer or produces values for angle measured.



<http://www.ihandysoft.com/apps.html>

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## Inclinometer Based Apps Extremity ROM

- Consistent with other methods of measurement for most motions.
- Similar to Goniometry, less reliable
  - Hip ABDuction
  - Hip External Rotation

Motion Measured	Comparative Tool
*Hip All Planes	Bubble Inclinometer Three Dimensional Motion Analysis
**Shoulder All Planes	Universal Goniometer

\*Charlton, Paula C., et al. "Reliability and concurrent validity of a Smartphone, bubble inclinometer and motion analysis system for measurement of hip joint range of motion." *Journal of Science and Medicine in Sport* 18.3 (2015): 262-267.  
\*\*S. H. Shin, D. H. Ro, O.-S. Lee, J. H. Oh, and S. H. Kim. "Within-day reliability of shoulder range of motion measurement with a smartphone." *Manual Therapy*, vol. 17 no. 4, pp.298-304, 2012

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## Inclinometer Based Apps Spine ROM

- Consistent with other methods of measurement for most motions for sagittal and frontal plane motions.

Motion Measured	Comparative Tool
*Trunk Flexion, Extension, Lateral Flexion	Bubble Inclinometer

\*Kolber, Morey J., and William J. Hanney. "The reliability and concurrent validity of shoulder mobility measurements using a digital inclinometer and goniometer: a technical report." *International Journal of Sports Physical Therapy* 7.3 (2012): 306.

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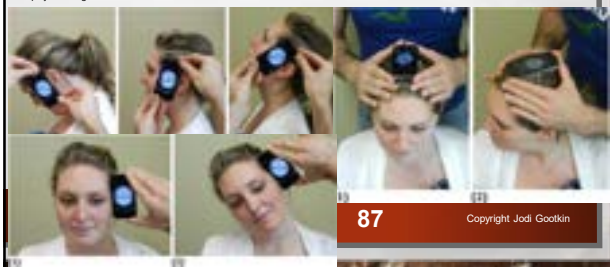
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## Cervical ROM Inclinometer App

- Does not appear to be valid for cervical rotation.

Motion Measured	Comparative Tool
**Cervical Rotation, Flexion, Extension, Lateral Flexion	Glasses with Inclinometers Three Dimensional Motion Analysis

\*\*Mourcou Q, Fleury A, et al. "Mobile phone-based joint angle measurement for functional assessment and rehabilitation of proprioception." *BioMed Research International*, vol. 2015, Article ID 328142, 15 pages.  
<http://neuroengrehab.biomedcentral.com/articles/10.1186/1743-0003-10-69>



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## Inclinometer Based Apps Potential Error

- Zero start position must be established.
- Method of phone placement can vary.
  - Port vs. Power
- Calculation may be necessary:
  - Start value + End value = Total ROM
- Infection control and hygiene concerns
- Scoliosis alignment

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## Scoliosis Apps

- Thoracic rotation evaluated to determine severity of postural deformity.
- Measurements with smartphone apps can be made with confidence.
- Stabilization with a holder may be necessary for sufficient phone length to measure rib hump.

Izatt, Maree T., Gary R. Bateman, and Clayton J. Adam. "Evaluation of the iPhone with an acrylic sleeve versus the Scolometer for rib hump measurement in scoliosis." *Scoliosis* 7.1 (2012): 1.  
<https://scoliosisjournal.biomedcentral.com/articles/10.1186/1748-7161-7-14>



## Two Dimensional Motion Apps

- Video recording of active motion with software analysis.
- Comparable analysis to more expensive three dimensional analysis systems.
- Adding reflective markers for anatomical landmarks enhances accuracy.



<https://www.coachseye.com/>

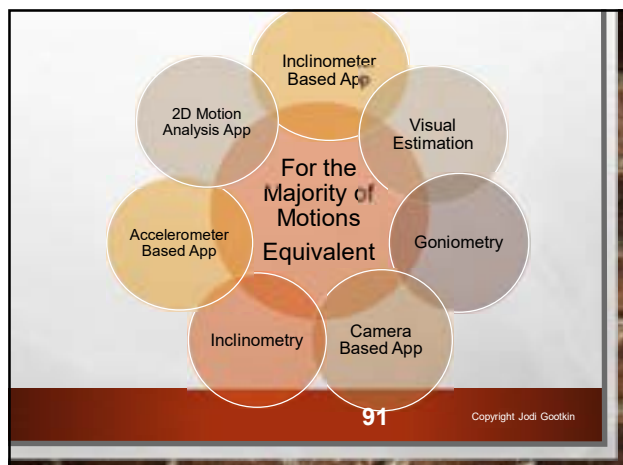
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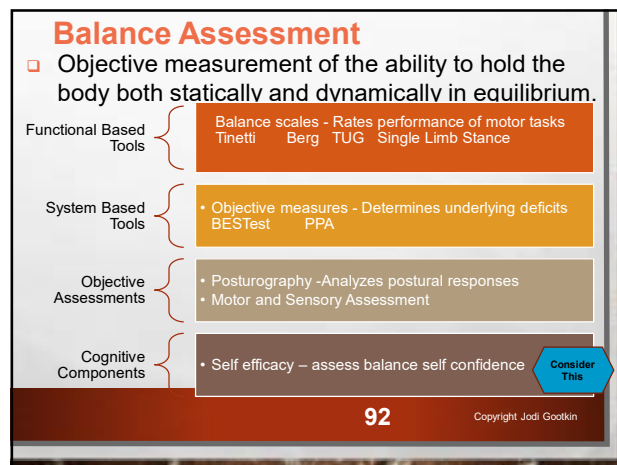
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### Tinetti Balance and Gait Test

- Task oriented test measuring balance and gait
- Combined mobility score less than 18/28 predictive of multiple falls.
- Good intertester reliability
- Excellent sensitivity

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### Berg Balance Scale (BBS)

- 14 item scale scored with 5 point scale (0-4)
- Maximum score 56
  - Less than 45 indicates risk of falling in older adults
- Higher score reflective of better performance
- Excellent intertester reliability
- Minimal clinically important difference is 8-point change
- Not a good predictor for falls due to lack of reactive postural control assessment.

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### Timed Up and Go Test (TUG)

- Stand, walk 3 meters, turn, walk back, sit
- Stop watch determined time is objective measurement as opposed to scales.
  - 13.5 second fall risk
- Cognitive TUG incorporates counting backwards
  - 15 second increased fall risk
- Manual TUG has subject carry glass of water while completing assessment.
  - 14.5 second increased fall risk
- Smartphone inertial sensors can be used as kinematic analysis tool to assess balance.

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### Single Leg Stance

- Excellent reliability as it is timed with stopwatch

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### Functional Reach Test

- ❑ Evaluates limits of stability in standing by forward, lateral, and backwards reaching.

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### Balance Evaluation Systems Test (BESTest)

- ❑ Assesses six different balance control systems to determine underlying postural or physiological system contributing to the balance deficits.
  - ❑ Biomechanical Constraints
  - ❑ Stability Limits/Verticality
  - ❑ Anticipatory Postural Adjustments
  - ❑ Postural Responses
  - ❑ Sensory Orientation
  - ❑ Stability in Gait

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### MiniBESTest

- ❑ 14 task clinical balance scale that rates items on a 3-point scale (Normal, Moderate, Severe)
- ❑ Maximum score 28
- ❑ Higher score indicates better performance
- ❑ Takes 10-15 minutes to complete

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### Physiological Profile Approach (PPA)

- ❑ Organized based on physiologic impairment that contribute to fall risk:
  - ❑ Postural sway
  - ❑ Hand reaction time
  - ❑ Knee extension strength
  - ❑ Leg proprioception
  - ❑ Visual edge contrast sensitivity
- ❑ Identifies fall risk, but does not direct treatment



<http://www.cdc.gov/steadi/materials.html>

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### Fullerton Advanced Balance (FAB)

- ❑ Each of the 10 items requires static and dynamic postural control.
- ❑ Scored on a 5 point scale (0-4)
- ❑ Maximum score 40
- ❑ Higher score indicates better balance
- ❑ Takes 10 – 12 minutes to complete
- ❑ Excellent reliability
- ❑ Quicker to complete than MiniBESTest and BBS

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### Static Posturography

- ❑ Static analyzes postural sway
- ❑ Angular velocity sensors on trunk or head can obtain measurements
- ❑ Higher velocity of center of pressure (COP) displacement associated with aging, neuropathy, Parkinson's disease, vestibular loss, and stroke.

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## Dynamic Posturography

- Dynamic assesses response to external perturbations, surface changes, and/or visual condition changes.
- Moveable surface creates disequilibrium to measure response.

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## Alternative Methods of Posturography

- Gaming systems are an inexpensive and alternative to posturography systems.

System	Population	Findings
*Wii Balance Board	Individual Post Stroke Healthy Participants	Concurrent validity with posture equipment. Excellent reliability and sensitivity.
**Microsoft Kinect	Healthy Participants comparison to 3D Motion Analysis System	Comparable intertester reliability. Can accurately assess kinematic control of posture.

\*Llorens, Roberto, et al. "A low-cost Wii Balance Board-based posturography system: An efficacy study with healthy subjects and individuals with stroke." *Virtual Rehabilitation Proceedings (ICVR), 2015 International Conference on*. IEEE, 2015.

\*\*Clark, Ross A., et al. "Validity of the Microsoft Kinect for assessment of postural control." *Gait & Posture* 36.3 (2012): 372-377.

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## Falls

### Screen

Identifies someone at risk for falls

Has the individual had 2 or more falls in the prior 12 months?

Does the individual present with an acute fall?

Does the individual have a self-reported or is there an observed difficulty with walking or balance?

### Assessment

Multifaceted measurement to determine interventions needed

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## Predicting Falls

- Postural assessments alone are not sufficient as they do not consider the multiple systems and contributors to falls.
- MiniBESTest prospective prediction with accuracy for 6 months from completion.

Tools Compared	Population	Findings
FAB MiniBESTest BBS	Patients with Parkinson's Disease	Similar ability to identify fallers with one or more falls from non fallers

Performing worse on specific items was associated with higher risk of fall:

- Tandem stance/walk
- Compensatory stepping backward
- Turning 360 degrees
- Placing foot on stool
- One leg stance
- Rise to toes

Schlensedt, C., et al. "Comparison of the Fullerton Advanced Balance Scale, Mini-BESTest, and Berg Balance Scale to predict falls in parkinson disease." *Physical Therapy* (2016)96(4), 494-501.

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## Sideline Concussion Assessment Elements

- Vital Signs
- Mental Status Exam
- Neurologic Exam/Cranial Nerve Exam
- Musculoskeletal Exam/Reflexes
- Balance/Coordination Exam
- Vestibuloocular Exam

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## SCAT3 Assessment

- Sport Concussion Assessment Tool (SCAT3) is utilized for concussion assessment. Components include:
  - Symptom Evaluation
  - Glasgow Coma Scale (GCS)
  - Maddocks Score
  - Standardized Assessment of Concussion (SAC) Cognitive Assessment
  - Coordination Assessment
  - Balance Examination

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### SCAT3 Balance Examination

- ❑ Modified Balance Error Scoring System (BESS)
  - ❑ Double leg stance
  - ❑ Single leg stance
  - ❑ Tandem stance
- ❑ Limited intertester reliability, high false positive rate, and limited discrimination

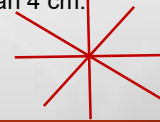
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### Star Excursion Balance Test (SEBT)

- ❑ Eight direction star tape pattern created on floor.
- ❑ Reaching assessed by sequentially reaching in each direction.
- ❑ Predictor of potential injury if anterior left right difference greater than 4 cm.



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### Conclusion

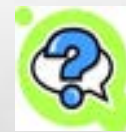
- ❑ Traditional range of motion, strength, and balance assessment tools continue to be valid.
- ❑ As staffing patterns continue to shift, awareness of strategies to ensure intertester reliability of data collection will preserve accurate assessment of patient progress.
- ❑ Opportunities to utilize new technology will continue to grow as the practice environment expands beyond the traditional workplace.

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### Interactive Discussion and Clinical Applications



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1. Which disability model includes personal and environmental factors?
  - A. Nagi disablement model
  - B. International Classification of Function
  - C. Multidisciplinary Impact assessment
  - D. Disability Influence Factoring

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2. Which statement about rehab professional's beliefs toward evidence based practice is FALSE?

- A. Research guided patient care decisions can improve clinical outcomes
- B. Most clinician's lack confidence in their ability to access and interpret research
- C. Evidence based practice is the standard but infrequently used
- D. All intervention decisions must be supported by evidence

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3. Why is establishing valid and reliable measures an important element of evidence based practice?

- A. Consistent measurement tools should be utilized to compare outcomes
- B. To improve reimbursement from insurance companies
- C. Subjective data collection has strong inter-tester reliability
- D. Data collection is not sufficiently emphasized in rehabilitation

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4. Which of the following increases manual muscle testing inter-tester reliability?

- A. Standardized joint position
- B. Location of resistance force
- C. Joint stabilization
- D. All of the above

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5. Which statement is true regarding hand held dynamometry?

- A. Only "make testing" can be performed
- B. Clinician strength may alter accuracy
- C. It is most accurate for grades below 2/5
- D. The patient must always be positioned supine

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6. Which of the following is NOT a recognized method of assessing range of motion?

- A. Visual estimation
- B. Volumetric excursion
- C. Electronic measurement
- D. Diagrammatic representation

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7. What smartphone component is used by goniometry apps to detect position changes?

- A. Accelerometer
- B. Level
- C. Microphone
- D. Dynamometer

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8. Which statement accurately reflects current evidence on goniometry?

- A. Variability exists in standard goniometry techniques across disciplines
- B. Passive range of motion assessment always produces lower measurement values
- C. Smartphone applications appear to be as reliable as traditional measurement
- D. Smartphone methods do not require the clinician to be attentive to alignment

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9. Which balance assessment tool identifies the underlying postural or physiological systems contributing to balance deficits?

- A. Berg
- B. TUG
- C. BESTest
- D. Tinetti

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10. Which of these balance measures are best at predicting future falls?

- A. Sit to stand and tandem stance
- B. One leg stance and sit to stand
- C. Compensatory stepping backwards and functional reach
- D. Tandem stance and compensatory stepping backwards

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