

Assessing Motion, Strength, & Balance

Live Interactive Webinar Presented By:
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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

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

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Course Outline/Schedule 3 hour live interactive webinar

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
Interactive Discussion of Clinical Applications	0:51-0:60
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
Interactive Discussion of Clinical Applications	1:51-2:00
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
Interactive Discussion of Clinical Applications	2:51-3:00

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- After the live interactive webinar and **prior to 11:59 pm TONIGHT** go to www.cheapceus.com
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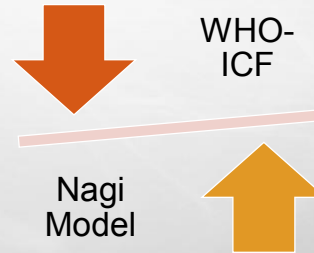
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Disablement Models

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

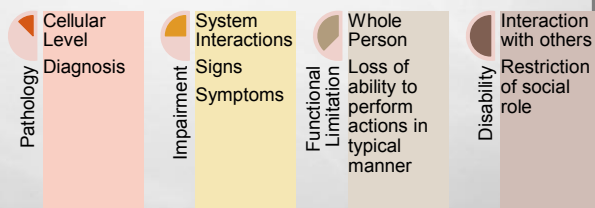


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Nagi Model

- 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

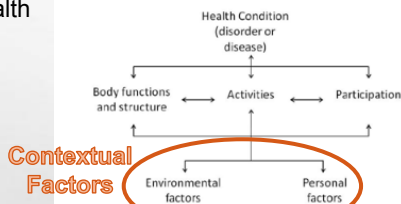


Image from: Salvador-Carulla, Luis, and Carlos Garcia-Gutierrez. "The WHO Construct of Health-Related Functioning (HF) and its Implications for Health Policy." *BMC Public Health* 11. Suppl 4 (2011): S9. *PMC*. Web. 7 Aug. 2016.

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Benefits ICF Framework

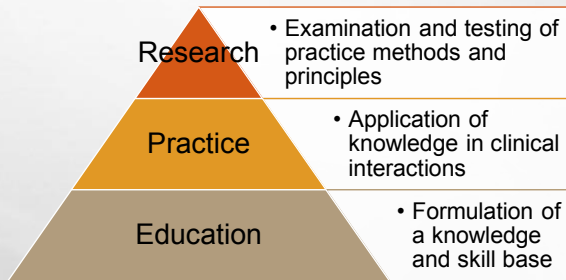
- Focus on the individual
- Considers contextual factors
- Emphasis on positive aspects
- Various opportunities to intervene
- Multidimensional process

BioPsychoSocial Model

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Fundamental Components of Allied Health Professions

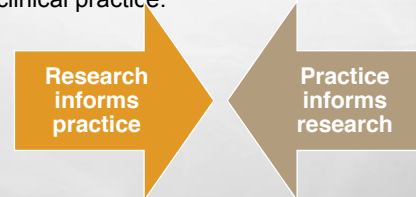


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Evidence Based Practice (EBP)

- 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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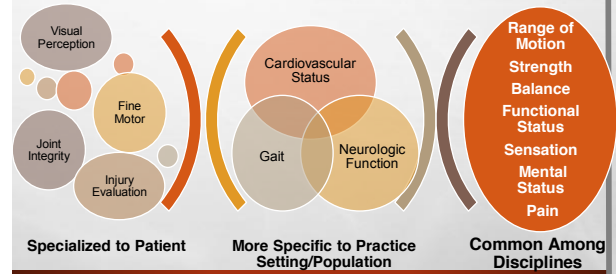
Data Collection

- 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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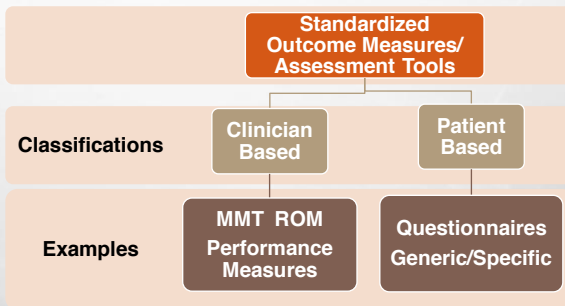
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Common Impairments to Evaluate



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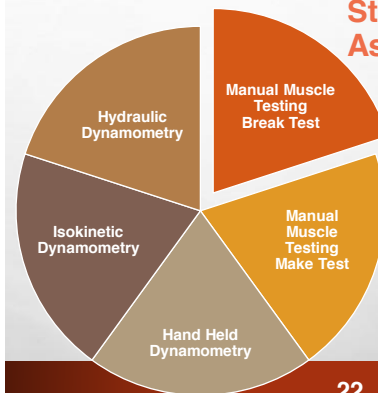


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Strength Assessment

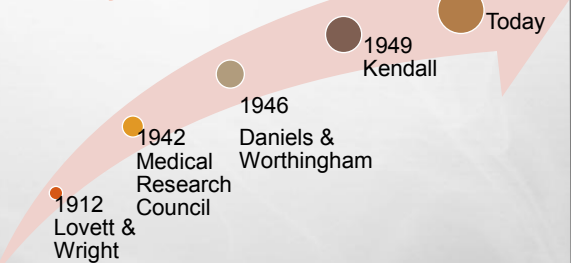
- Objective measurement of performance of an individual or group of muscles in relation to gravity and resistance.



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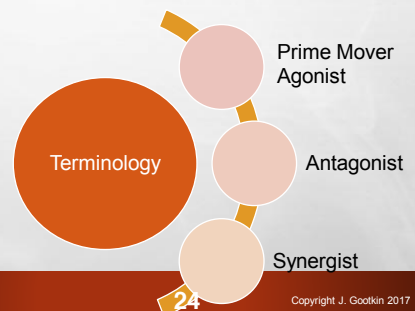
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Manual Muscle Testing (MMT) History



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MMT Grades

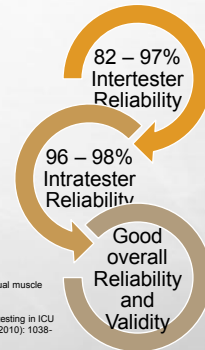
Grade	Gravity	ROM	Resistance
5	Normal	AG	Full ROM
4+	Good Plus		Maximal
4	Good	AG	Strong
4-	Good Minus		Moderate
3+	Fair Plus		Minimal
3	Fair	AG	Slight
3-	Fair Minus	AG Gradual release	None
2+	Poor Plus	AG Partial ROM < 50% OR GE Full ROM some pressure	>50% AG ROM No Resistance
2	Poor	GE	Full ROM
2-	Poor Minus	GE	Partial ROM
1+	Trace Plus	GE	None
1	Trace	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 +/- on muscle grade.



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

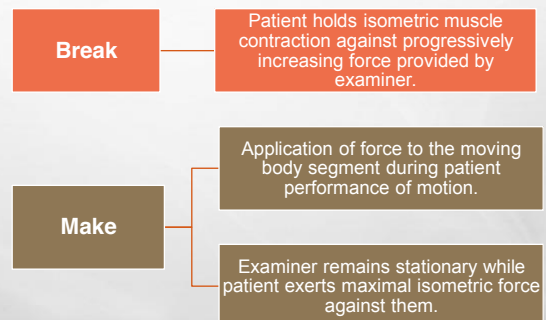
- Electromyographic analysis of rotator cuff muscle activation with standard manual muscle test positions confirms activation of prime movers.
 - ABDuction – Supraspinatus
 - External Rotation – Infraspinatus, Teres Minor
 - Internal Rotation - Subscapularis

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



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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

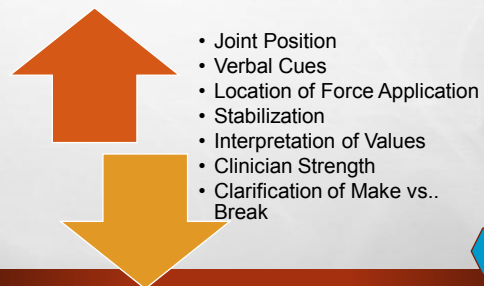
*Bollmann, Richard W. "Make tests and break tests of elbow flexor muscle strength." *Physical Therapy* 68.2 (1988): 193-194.
 **Lim, J. X., et al. "A comparison of the reliability of make versus break testing in measuring palmar abduction strength of the thumb." *Journal of Hand and Microsurgery* 6.1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

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MMT Accuracy Variables

- Standardization of procedure increases intra and intertester reliability.



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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.

Guex, 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

Stalaky, 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): 67-73.

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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

- 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

- 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

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

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Hand Held Dynamometer

- 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

Consider This

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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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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

Mentplay 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=info:doi/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, Siddall, 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 (2008): 160.
 **Aufessser, P., Michael Horstl, and Ruth Augin. "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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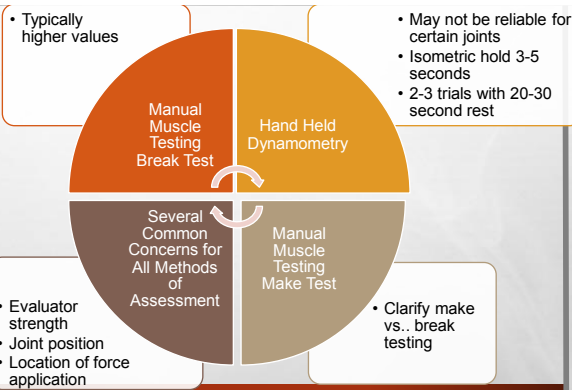
Underestimation of Strength

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.

*Martin, Yule, Siddall, 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
 ***Li, Geilio, et al. "A simple way to improve the relative and absolute reliability of handheld dynamometer measurements using learners." *International Journal of Clinical and Experimental Medicine* 9.1 (2016): 199-208

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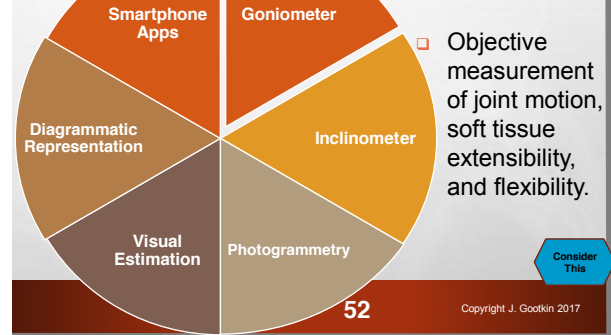
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Range of Motion Assessment

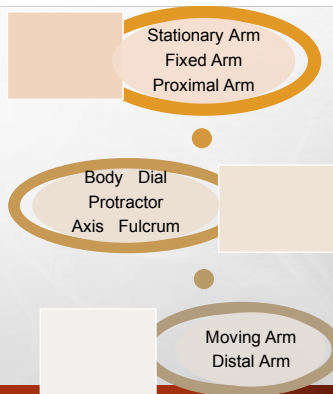


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Goniometry

Consistently high intratester reliability



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Goniometry Intertester Reliability



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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 Kivist. "Interrater reliability in finger joint goniometer measurement in Dupuytren's disease." *American Journal of Occupational Therapy* 66.1 (2012): 98-103.

***Macdonis, Valdas. "Reliability of the standard goniometry and diagrammatic recording of finger joint angles: a comparative study with healthy subjects and non-professional raters." *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): 668-673.

**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): 1675-1678.

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.

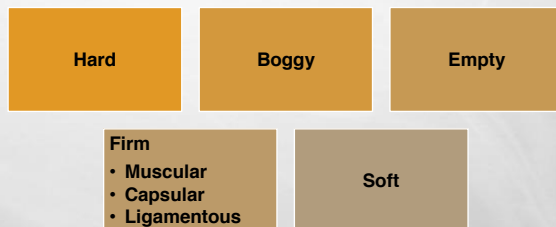
Nussbaumer, Silvio, et al. "Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients." *BMC Musculoskeletal Disorders* 11.1 (2010): 1. <https://doi.org/10.1186/1471-2475-11-144>

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Examiner Force Application

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



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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.

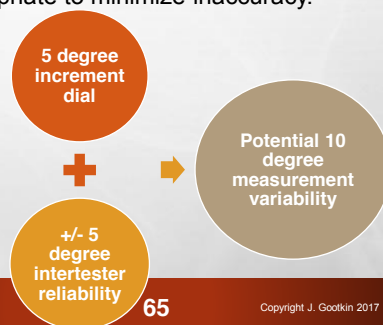


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Goniometer Increments

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



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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

2 – 20 degree SEM*

Document method of ROM measurement

Intertester Reliability

20-25 degree SEM**

Reevaluation should be by same clinician

MDC

If measured by different clinicians, must have at least 20 degree of change in ROM.

*Kober, 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.
**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 M.M., 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.

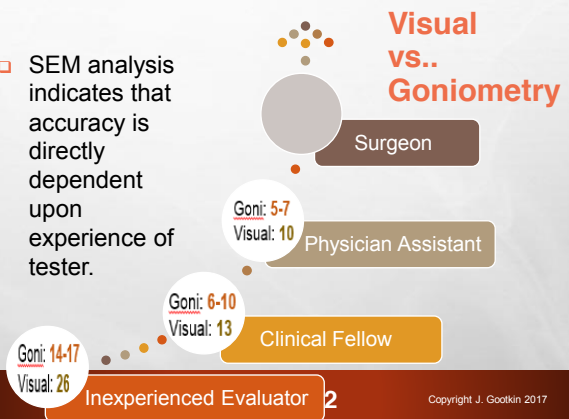
**Holm, Inger, et al. "Reliability of goniometric measurements and visual estimates of hip ROM in patients with osteoarthritis." *Physiotherapy Research International* 5.4 (2000): 241-248.

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



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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 Lester. "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

*Cresto, 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, Nilson Mazzer, 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

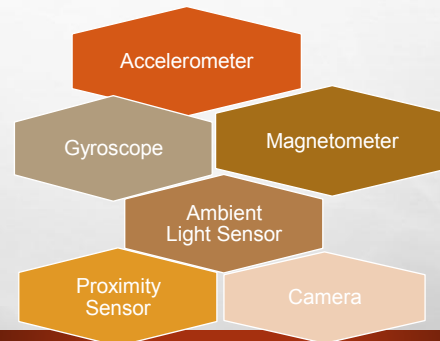
- ❑ Create models of musculoskeletal motion

<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

Magnetometer	• iShould
Accelerometer	• Knee Goniometer • Simple Goniometer
Camera Based	• mROM • DrGoniometer
Inclinometer Based	• iHandy Level • Clinometer • GetmyROM • Physio2Go • Scoliguage • Hip ROM Tester
Two Dimensional Motion Analysis	• Coach's Eye

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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.

Consider This

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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://bmcmsculoskeletaldisord.biomedcentral.com/articles/10.1186/s12891-016-0957-3>
**Femero, 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.

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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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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://journals.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 Scollometer for rib hump measurement in scoliosis." *Scoliosis* 7.1 (2012): 1. <https://scoliosisjournal.biomedcentral.com/articles/10.1186/1743-0003-7-14>

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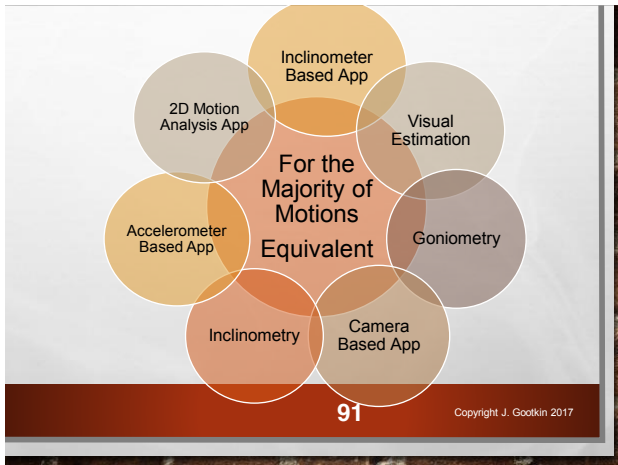
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Two Dimensional Motion Apps

- ❑ 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.

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Balance Assessment

- Objective measurement of the ability to hold the body both statically and dynamically in equilibrium.

Functional Based Tools	<ul style="list-style-type: none"> Balance scales - Rates performance of motor tasks Tinetti Berg TUG Single Limb Stance
System Based Tools	<ul style="list-style-type: none"> Objective measures - Determines underlying deficits BESTest PPA
Objective Assessments	<ul style="list-style-type: none"> Posturography -Analyzes postural responses Motor and Sensory Assessment
Cognitive Components	<ul style="list-style-type: none"> Self efficacy – assess balance self confidence

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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

Consider This

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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

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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.
- MiniBEST prospective prediction with accuracy for 6 months from completion.

Tools Compared	Population	Findings
FAB MiniBEST 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

Consider This

Schlenker, 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.

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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Assessing Motion Strength and Balance Resource Links

Disablement Frameworks

The International Classification of Diseases 11th Revision Information

<http://www.who.int/classifications/icd/revision/en/>

ICD-11 Beta Draft

<http://apps.who.int/classifications/icd11/browse/l-m/en#/>

International Classification of Functioning, Disability, and Health

<http://www.who.int/classifications/icf/en/>

ICF Checklist

<http://www.who.int/classifications/icf/icfchecklist.pdf?ua=1>

Mapping Therapy Goals with ICF

https://www.cms.gov/Medicare/Billing/TherapyServices/Downloads/Mapping_Therapy_Goals_ICF.pdf

Manual Muscle Testing

Jamar Hydraulic Dynamometer Normative Values

<https://www.si-instruments.com.au/download-centre.html?task=document.viewdoc&id=116>

Biodex Isokinetic Dynamometer Normative Values

Adult - <http://biodex.com/sites/default/files/manual-clinical-resources-normative.pdf>

Pediatric - <http://biodex.com/sites/default/files/manual-clinical-resources-pediatric-normative-data-05231.pdf>

Demonstration Video - <https://youtu.be/AIIRLjqUbR8?t=1m21s>

MicroFet2 Hand Held Dynamometer Test Positions

<https://youtu.be/8G2x1VYsFGU>

Jtech Commander PowerTrack II Sample Report

<http://www.jtechmedical.com/category/26-downloader?download=72>

Hand Held Dynamometer Reference Values

1997 Bohannon Adult UE/LE

https://www.physiosupplies.eu/downloads/dl/file/id/419/product/2421/hhd_norms_apmr1997_with_wt_and_ht_info.pdf

2000 Phillips Adult UE/LE

[http://www.archives-pmr.org/article/S0003-9993\(00\)90050-9/pdf](http://www.archives-pmr.org/article/S0003-9993(00)90050-9/pdf)

2015 Van Harlinger Adult UE

<http://www.sciencedirect.com/science/article/pii/S1934148214013811>

2015 Hebert Pediatric

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4581449/pdf/ppyty-27-414.pdf>

Goniometry

Baseline Bubble Inclinometer Measurement Chart -

<https://content.pattersonmedical.com/PDF/spr/Product/338937.pdf>

OpenSim Software Overview - <https://simtk.org/projects/opensim>

Video - <https://youtu.be/ME0VHfCtIM0?t=1m59s>

Balance Tools

Tinetti

<http://hdcs.fullerton.edu/csa/Research/documents/TinettiPOMA.pdf>

Berg

<http://geriatrictoolkit.missouri.edu/Berg-Balance-Scale.doc>

TUG

http://www.cdc.gov/steady/pdf/tug_test-a.pdf

BESTest and MiniBESTest

<http://bestest.us/training/>

PPA

<http://www.slips-online.co.uk/forms/ppa.aspx>

FAB

<http://hhd.fullerton.edu/csa/documents/fabscalescoringformwithout-offvalues.pdf>

STEADI CDC Balance Resources

<http://www.cdc.gov/steady/index.html>

SCAT3

<http://bjsm.bmj.com/content/47/5/259.full.pdf>