Are You Over or Underestimating Your Patient’s Strength? New Technology for Today’s PT’s

Kevin Robinson, PT, DSc, OCS
Why do we perform strength assessments?

- Screening tool as part of assessment
- Baseline value during initial exams
- To determine progress with our patients
The need for strength assessment

- Hip- and knee-strength assessment has been shown to be relevant in football, ice-hockey, and track and field to quantify muscle strength deficits
- Thornberb 2013 Knee Surg Sports Traumatol Arthrosc
Strength assessment used to predict injury

- Crow et al 2009 J Sci Med Sport (Rugby groin injuries)
- Nadler 2000 Clin J Sport Med (predicted lower back injuries in womens basketball)
- Robinson et al 2018 Open Access Library Journal (ballet)
The percentages of the total number of functional problems (n = 76) after total hip arthroplasty (THA).

Problems Occurring after THA

- Hip Abductor Weakness: 47%
- Limb Length Difference: 13%
- Muscle Contracture: 28%
- Malalignment: 12%
The percentages of the total number of functional problems (n = 68) after total knee arthroplasty (TKA).
**Results:** Hip muscles showed a remaining 6% weakness compared to the contralateral healthy limb 2 years after THA. Preoperatively and 6 months postoperatively, that deficit was 18% and 12%, respectively. Knee extensors fully recovered a pre-operative 27% deficit after 2 years. Gait analysis demonstrated a shorter single stance phase for the OA limb compared to healthy limb pre-operatively, that had already recovered at the 6-month follow-up. Balance of two-foot standing showed improvement both sagittal and lateral sway after operation. All clinical scores improved.
Interpretation: Muscle strength data demonstrated a slow but full recovery of muscles acting about the knee, but there was still a deficit in hip muscle strength 2 years after the THA.

To accelerate improvement in muscular strength after THA, postoperative training should probably be more intense and target hip abductors.
Why do these deficits remain to be an issue? Even after rehab?

If we see these findings in the literature, then why are our patients still struggling?

Is it the way we are assessing them?

What if we were over estimating our patient’s strength?
Typical Gait Study That I See

• **History:** This 63 year old lady presents with complaints of a significant limp with her gait. She reports no pain, but states that her limp is preventing her from returning to her normal physical routine. She previously was very active, walked a great deal and now she is unable to do so.

• **Surgical history:**

  • She underwent a left total knee arthroplasty in November, 2018. She states that she has continued her outpatient rehab until this past Monday, March 4, 2019.

• **Chief Complaint:** Difficulty walking community distances, ascending and descending stairs
Physical exam:

Hand dynamometer was used to assess strength of the hip and knee musculature.

<table>
<thead>
<tr>
<th></th>
<th>Right</th>
<th></th>
<th>Left</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Hip Abduction</strong></td>
<td>30.0 lbs.</td>
<td>21.89%</td>
<td>31.2 lbs.</td>
<td>22.7%</td>
</tr>
<tr>
<td><strong>Hip Extension</strong></td>
<td>32.4 lbs.</td>
<td>23.6%</td>
<td>27.7 lbs.</td>
<td>20.21%</td>
</tr>
<tr>
<td><strong>Knee Extension</strong></td>
<td>29.4 lbs.</td>
<td>21.4%</td>
<td>27.7 lbs.</td>
<td>20.21%</td>
</tr>
</tbody>
</table>

Positive Thomas Test: Right 14 degrees, Left 12 degrees
The issues with manual assessment

A ceiling effect occurs when patients attain the maximum score on a given test (Doherty 2004, Bohannon, 1990)

Patients are often given a maximal score despite potential strength deficits that could be detected with more objective test (Hayes, 2002)

This effect also limits the ability of MMT to detect changes over time (Hayes, 2002)
HOW ARE WE ASSESSING STRENGTH IN OUR PATIENTS?
# MMT Scales

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Function Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Normal</td>
<td>Completes ROM against gravity with maximal resistance</td>
</tr>
<tr>
<td>4+</td>
<td>Good Plus</td>
<td>Completes ROM against gravity with moderate-maximal resistance</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
<td>Completes ROM against gravity with moderate resistance</td>
</tr>
<tr>
<td>4-</td>
<td>Good Minus</td>
<td>Completes ROM against gravity with minimal-moderate resistance</td>
</tr>
<tr>
<td>3+</td>
<td>Fair Plus</td>
<td>Completes ROM against gravity, and able to hold against minimal resistance</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>Completes ROM against gravity but cannot hold against manual resistance</td>
</tr>
<tr>
<td>3-</td>
<td>Fair Minus</td>
<td>Does not complete the FULL range of motion against gravity, but does complete more than half of the range</td>
</tr>
<tr>
<td>2+</td>
<td>Poor Plus</td>
<td>Able to initiate movement against gravity ($\frac{1}{2}$ the range)</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Completes full range of motion with gravity eliminated</td>
</tr>
<tr>
<td>2-</td>
<td>Poor Minus</td>
<td>Completes partial ROM in a gravity eliminated position</td>
</tr>
<tr>
<td>1</td>
<td>Trace</td>
<td>Muscle contraction can be palpated, but there is no joint movement</td>
</tr>
<tr>
<td>0</td>
<td>Zero</td>
<td>Patient demonstrates no palpable muscle contraction</td>
</tr>
</tbody>
</table>
Reliability of a Manual Muscle Test

- MMT uses a limited ordinal scale with 6-14 categories
  - More categories may increase sensitivity to change, however they also increase subjectivity & decrease the reliability of the scale

- The lower grades of an MMT are more reliable because they have precise definitions based on positioning, however above a fair grade (3/5), when the test depends on manual force, the grading becomes inaccurate & very subjective

- Beasley found that therapists could not distinguish among knee extensor forces that varied by as much as 25% AND that they graded patients as “normal” when they had lost as much as 50% of the muscles tension production
Reliability of a Manual Muscle Test

- Frese & colleagues looked at reliability of a middle trapezius test & gluteus medius test and found 28%-45% agreement for the same grade
  - Reliability further decreases for muscles of the LE

- Mulroy and colleagues found that female therapists over-graded the strength of the quads in 14 of 19 patients (mostly due to patient stronger than therapist)
  - While male therapists over-graded strength in 2 of 19 patients
Other Issues with MMT

• Lacks objectivity (based on judgement of examiner)

• Therapists are unreliable at distinguishing between a 4/5 and 5/5

• Ceiling effect occurs with grade of 5/5
  • Pt.’s may have a 5/5 per MMT score, yet still have deficits in strength that have functional consequences

• Test procedures vary between therapists!
HOW DO YOU TEST THE GLUTEUS MEDIUS?
Gluteus Medius

- 4/5 at knee
- 5/5 at ankle

HIP ABDUCTION

(Gluteus medius and Gluteus minimus)

Grade 5 (Normal), Grade 4 (Good), and Grade 3 (Fair)

Position of Patient: Side-lying with test leg uppermost. Start test with the limb slightly extended beyond the midline and the pelvis rotated slightly forward (Figure 6-36). Lowermost leg is fixed for stability.

Position of Therapist: Standing behind patient. Hand used to give resistance is contoured across the lateral surface of the knee. The hand used to palpate the gluteus medius is just proximal to the greater trochanter of the femur (see Figure 6-36). No resistance is used in a Grade 3 test.

To distinguish a Grade 5 from a Grade 4 result, first apply resistance at the ankle and then at the knee (Figure 6-37). Applying resistance at the ankle creates a longer lever arm, thus requiring more patient effort to resist the movement. If the patient cannot hold the limb in the test position with the resistance at the ankle but can at the knee, the grade is Grade 4. The therapist is reminded always to use the same lever in a given test sequence and in subsequent comparison tests.

Test: Patient abducts hip through the complete available range of motion without flexing the hip or rotating it in either direction. Resistance is given in a straight downward direction.

Instructions to Patient: “Lift your leg up in the air. Hold it. Don’t let me push it down.”

Grading

Grade 5 (Normal): Completes available range and holds end position against maximal resistance.

Grade 4 (Good): Completes available range and holds against heavy to moderate resistance or with resistance given at the knee.

Grade 3 (Fair): Completes range of motion and holds end position without resistance (Figure 6-38).
WHAT ABOUT THE GASTROC?
Gastroc Testing

• Latest edition (9th):
  • 5/5 = 25 reps
  • 4/5 = 2-24 reps
  • 3/5 = 1 rep
  • 2/5 = unable to do heel rise; takes resistance in prone
  • 2-/5 = partial ROM in prone

• Prior editions:
  • 5/5 = 25 reps
  • 4/5 = 10-24 reps
  • 3/5 = 1-9 reps
  • 2+/5 = barely clear heel in standing -or- takes max resistance in prone
  • 2/5 = takes no resistance
  • 2-/5 = partial ROM in prone

ANKLE PLANTAR FLEXION
(Gastrocnemius and Soleus)

Grade 5 (Normal), Grade 4 (Good), and Grade 3 (Fair) Continued

Grading

Grade 5 (Normal): Patient successfully completes a minimum of 25 heel rises through full range of motion without a rest between rises and without fatigue. Twenty-five heel rises elicit approximately 60% of the maximum electromyographic activity of the plantar flexors. Linsenfeld and Perry suggest a normal response requires 25 complete heel rises. In the current standardized tests that have been in use for many years, 25 repetitions is the accepted norm. However, a more recent study suggests that the average number of repetitions in the sample studied is less than 25 repetitions (Table 6-1). The therapist should be aware that strength deficits in the plantar flexors are common, particularly with advancing age, and strength deficits will affect the heel rise portion of the gait cycle and thus reduce gait speed.

Grade 4 (Good): A Grade of 4 is conferred when the patient completes between 2 and 24 correct heel rises at a consistent rate of one rise every 2 seconds using correct form in all repetitions. The criterion for Grade 4 is not well defined.

Grade 3 (Fair): Patient completes one heel rise correctly.

If the patient cannot complete at least one correct full-range heel rise in the standing position, the grade must be less than 3 (Fair). Regardless of any resistance to a nonstanding position for any reason, the patient must be given a grade of less than 3.

Grade 2 (Poor): Patient is able to lift heel from floor in standing position and must be tested in a non-weight-bearing position (Figure 6-97).

ANKLE PLANTAR FLEXION
(Gastrocnemius and Soleus)

GASTROCNEMIUS AND SOLEUS TEST

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Grade 2 (Poor): Patient is able to lift heel from floor in standing position and must be tested in a non-weight-bearing position (Figure 6-97).
EXAMPLES
Size/Strength of the Tester Matters!

Graded a 5/5
Size/Strength of the Tester Matters!

Still a 5/5.......
Size/Strength of the Tester Matters!

Graded a 4/5
IS THERE A BETTER OPTION?

Hand-Held Dynamometry (HHD)
What is Hand-Held Dynamometry (HHD)?

- HHD is a reliable and objective method of measuring a patient’s strength, that is:
  - Easy to use
  - Portable
  - Inexpensive
  - And requires little training for proficient application

- It is not new technology, however the technology is becoming more user-friendly

- Hand held dynamometry (HHD) is a more objective way to quantify muscle force production (MP) compared to traditional manual muscle testing.

LET’S LOOK AT THE DIFFERENCE WHEN TESTING HIP ABDUCTION
Testing hip abduction using HHD
Is HHD Reliable?

• Intrarater reliability: ICC values of .77-.97

• Very reliable tool for repeated measures performed on the same day with the same subject

• These reliable results with HHD appear to be achievable for a given tester regardless of experience in manual muscle testing and/or use of a HHD

Kelln BM, McKeon PO, Gontkof LM, Hertl J. Hand-Held Dynamometry: Reliability of Lower Extremity Muscle Testing in Healthy, Physically Active, Young Adults. *Journal of Sport Rehabilitation, 2008;17:160-170*
Is HHD Reliable?

• Interrater reliability: ICC values of .65 - .92
  • Interrater Reliability decreases when the movements are difficult to control or the strength of the muscle exceeds the strength of the tester
    • However Intrarater reliability remains good even when movements are difficult to control.

• As long as testers have a mechanical advantage over a subject along with the necessary strength to isometrically resist a given movement’s maximal contraction, reliable measures can be expected.

Underestimating Strength with HHD

- When testing strength using HHD, an external fixation should be used when testing forces > 200 N (about 45 lbs.) to avoid underestimating strength

- Tester strength is an issue when using HHD when the patient’s strength exceeds 120 N (about 27 lbs.) for a given muscle

- Inter-rater Reliability using a belt fixation was found to have ICC values of .76 - .95
  - More closely approaches an equal value to intra-rater reliability values
Using HHD without Belt

Strength: 51.7 lbs  
% BW: 25%

(Should be about 42% BW)
Using HHD with belt

Strength: 89.7 lbs
% BW: 44%

(Should be about 42% BW)
Is HHD a Valid Measure of Strength?

  
  “19 studies compared HHD with an identified reference standard (isokinetic muscle strength testing) and the results demonstrated minimal differences between HHD and isokinetic testing”

• Conclusion:
  
  “Considering hand-held dynamometry's ease of use, portability, cost, and compact size, compared with isokinetic devices this instrument can be regarded as a reliable and valid instrument for muscle strength assessment in a clinical setting.”

• No statistically significant difference in reliability of the Kin-Com and HHD data
  
A Make-Test vs. a Break-Test

• The force produced by a break-test tends to be higher than that of a make-test
• The reliability of the make-test is higher than that of a break-test
Are there normative values?

- Established in gravity-minimized positions (not the same as MMT positions)

- Gender, age and weight have an effect
  - Normalized by % body weight

- Broken down by
  - Age group
  - Dominant vs. Non-Dominant sides
  - Males vs. Females

- Norms shown in table are for the dominant extremity and were performed as a “make-test”
## Normative values for 40-49 year old’s

<table>
<thead>
<tr>
<th>Motion/Muscle</th>
<th>Sex</th>
<th>Pound-Force (average)</th>
<th>Force/body weight (%)</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Abduction</td>
<td>Male</td>
<td>55 lbs.</td>
<td>29%</td>
<td>Supine. Shoulder abducted 45 degrees; elbow extended</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>31 lbs.</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Shoulder ER</td>
<td>Male</td>
<td>42 lbs.</td>
<td>22%</td>
<td>Supine. Shoulder abducted 45 degrees; elbow at 90 degrees</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>25 lbs.</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>Elbow Flexion</td>
<td>Male</td>
<td>60 lbs.</td>
<td>33%</td>
<td>Supine. Shoulder neutral, elbow at 90 degrees, forearm supinated</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>34 lbs.</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Knee Extension</td>
<td>Male</td>
<td>131 lbs.**</td>
<td>70%</td>
<td>Sitting. Hips and knees flexed to 90 degrees</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>85 lbs.</td>
<td>62%</td>
<td></td>
</tr>
<tr>
<td>Hip Abduction</td>
<td>Male</td>
<td>70 lbs.</td>
<td>37%</td>
<td>Supine. Hips neutral, knees extended</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>49 lbs.</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>*Shoulder Flexion</td>
<td>Male</td>
<td>60 lbs.</td>
<td>32%</td>
<td>Supine. Shoulder flexed to 90 degrees, elbow extended</td>
</tr>
<tr>
<td>(Age 50-59)</td>
<td>Female</td>
<td>36 lbs.</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>*Shoulder IR</td>
<td>Male</td>
<td>43 lbs.</td>
<td>23%</td>
<td>Supine. Shoulder abducted 45 degrees; elbow at 90 degrees</td>
</tr>
<tr>
<td>(Age 50-59)</td>
<td>Female</td>
<td>22 lbs.</td>
<td>15%</td>
<td></td>
</tr>
</tbody>
</table>

Values are from: Bohannon, R. Reference values for extremity muscle strength obtained by hand-held dynamometry from adults aged 20-79 years. *Arch Phys Med Rehabil* 1997; 78: 26-32.

Things to Consider When Using HHD

- Tool being used
  - Comfort level
- Strength of the Tester
  - Belt usage
- Keeping tool in place
  - Maintaining perpendicular alignment
- Maximum value for tool
  - Quads
- Positioning of patient
  - Comparison to norms
- Make-test vs. Break-test
HHD vs. MMT

- HHD & MMT measure the same constructs but MMT overestimates strength in comparison with HHD
- MMT scores are based on the break-test vs. HHD which is typically a make-test. Break-test force typically exceeds make-test force, which also may explain part of why MMT scores tend to be higher than HHD values.
- HHD of patients with OA identified measurable weakness in knee extensors that was not detected by MMT
- HHD measurements are less subjective than MMT grades, especially in stronger subjects (however tester still needs to have enough strength or a belt fixation must be used)

CURRENT RESEARCH USING HHD
Advantages to objective testing

• We can set goals tailored to the patient (expressed in %BW) and show objective changes over time with treatment.

• Provides an objective standard for return to work or sport.

• Can objectively determine if an intervention is effective in causing the desired strengthening outcome.

• Can actually compare different athletes or patients by converting to %BW.

• Reimbursement??
Retrospective Analysis of the Pre-Season Screen Used in a Professional Ballet Company with Recommendations for Improvements in the Screen (2018)

Fig. 3: Manual strength test of the gluteus medius and gluteus maximus with the hand dynamometer.

<table>
<thead>
<tr>
<th></th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluteus Maximus</td>
<td>25.49</td>
<td>28.49</td>
</tr>
<tr>
<td>Gluteus Medius</td>
<td>27.37</td>
<td>25.31</td>
</tr>
</tbody>
</table>

Normative % BW value for Glut Med for 20-30 year olds

p = 0.001

p = 0.004
The Use of Proximal Hip Strength and Kinematic Motion to Identify at Dancers at Risk for Lower Extremity Injury
Different Tools

ActivForce Dynamometer

0-200 lbs. (890 N)
Can add % BW

Lafayette HHD

0-300 lbs. (1335 N)
Thank you for attending!!

STRENGTH DOESN'T COME FROM THE THINGS YOU CAN DO

IT COMES FROM OVERCOMING THE THINGS YOU ONCE THOUGHT YOU COULDN'T DO
References