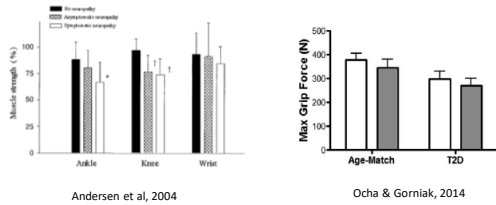
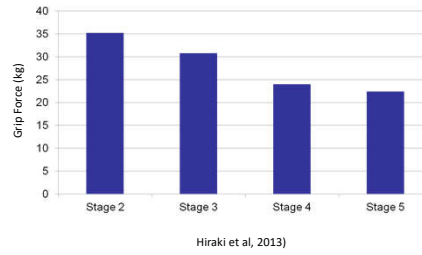




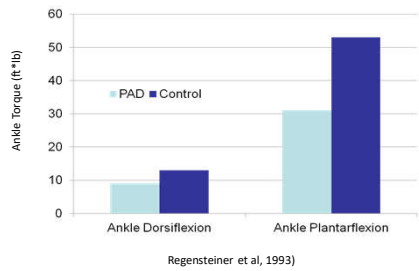
### Muscle Weakness: Beyond the Expected (Type 2 Diabetes)



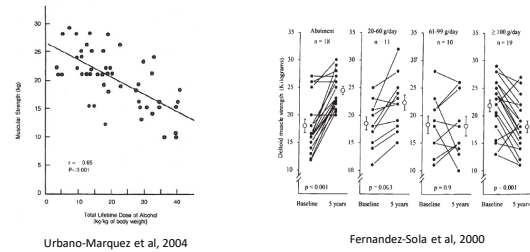
### Muscle Weakness: Beyond the Expected (Renal Disease)



### Muscle Weakness: Beyond the Expected (PAD)

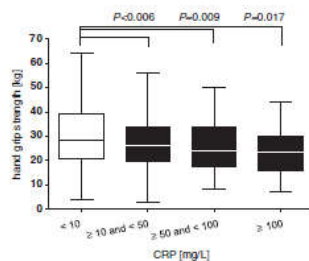


### Muscle Weakness: Beyond the Expected (Alcohol Consumption)

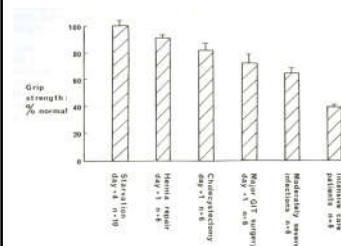


### Muscle Weakness: Beyond the Expected (Inflammation)

“Our data demonstrate the independent association between inflammation and hand-grip strength in non-critically ill patients.” (Norman et al, 2013)



### Muscle Weakness: Beyond the Expected (Surgery, Infection, & ICU Admission)



Mean grip strength reduced >25% with major abdominal surgery, 35% with acute infection and 60% with severe illness and ICU admission (Martin et al, 1985)

### There's a Place for Manual Muscle Testing- Properly Conducted

- Determine available range
- Demonstrate motion
- Have patient perform action
- If test motion is complete (usually against gravity), stabilize patient & do break test
- Make judgment as to test force resisted



### Manual Muscle Testing Should be Scored Systematically

Standard Grading Scheme	
Grade	Description
0 (0)	No notable contraction
1 (1)	Contraction but no mvt
1+ (2)	No gravity, <50% range
2- (3)	No gravity, >50% range
2 (4)	No gravity, full range
2+ (5)	Gravity, < 50% range
3- (6)	Gravity, > 50% range
3 (7)	Gravity, full range
3+ (8)	Gravity, full range, min resist
4- (9)	Gravity, full range, near mod resist
4 (10)	Gravity, full range, mod resist
4+ (11)	Gravity, full range, near max resist
5 (12)	Gravity, full range, max resistance

Most Common Alternative Grading Scheme	
Grade	Description
0	No notable contraction
1	Contraction but no mvt
2	<100% range
3	Full range
3+	Full range, min resist
4-	Full range, near mod resist
4	Full range, mod resist
4+	Full range, near max resist
5	Full range, max resist

Unique Grading Schemes

### Manual Muscle Test Scores Can be Consolidated into Index Scores

#### Motricity Index

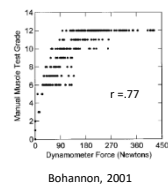
- Shoulder elevation
- Elbow flexion
- Prehension
- Hip flexion
- Knee extension
- Ankle dorsiflexion

#### Motor Index Score

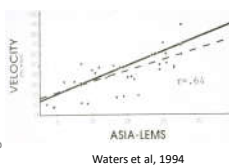
- Elbow flexion (C5)
- Wrist extension (C6)
- Elbow extension (C7)
- Finger flexion (C8)
- Finger abduction (T1)
- Hip flexion (L2)
- Knee extension (L3)
- Ankle dorsiflexion (L4)
- Great toe extension (L5)
- Ankle plantarflexion (S1)

### Manual Muscle Test Scores Are Valid

Relative to Dynamometry



Relative to Gait Speed

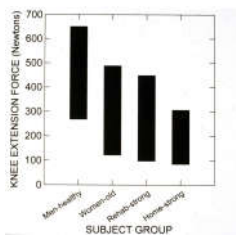


Relative to Sit-to-Stand Independence

STS State	MMT Cut	AUC	Sen	Spec
Hands -	20.5	0.91	88.0	82.5
Hands+	18.5	0.88	75.3	79.4

Eriksrud & Bohannon, 2003

### Manual Muscle Test Scores Lack Sensitivity



Criterion (dynamometry)	MMT (%)
Between side difference (15%)	62.9
Between side difference (30%)	72.3
Below average strength (15%)	60.9
Below average strength (30%)	70.3

Bohannon, 2005

Bohannon & Corrigan, 2000

### There are Practical Alternatives to Manual Muscle Testing

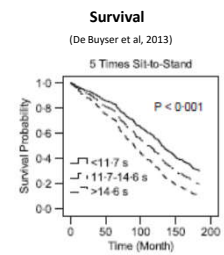
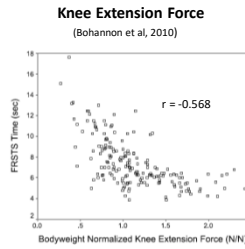
- Field Tests
- Hand-grip dynamometry
- Hand-held dynamometry
- Fixed force gauges
- Weights
- Isokinetic dynamometers

### Field Tests: Five-Times Sit-to-Stand

- Stable standard height armless chair or equivalent
- Start well forward in chair
- Instruct to stand-up & sit down all the way without delay as fast as possible.
- Begin watch on “go”
- Count stand-ups aloud
- Stop watch on fifth complete stand.



### Sit-to-Stand Performance is Related to



### Sit-to-Stand Performance is

- Reliable: 10 study summary showed ICCs of .64 to .96 (mean .81) (Bohannon, 2011)
- Responsive: 5 study summary showed MDCs Of 1.2 to 8.1 sec
- Interpretable (Bohannon, 2006) : Meta-analysis showed upper limit times of
  - 11.4 (60-69)
  - 12.6 (70-79)
  - 14.8 (80-89)

### Field Tests: Heel-Raise Test

- Wall against which to lean
- Knees and hips extended
- Raise up on toes Bilaterally
- Raise up on toes unilaterally once
- Determine number of times able to raise unilaterally on toes at a rate of once/sec to grade.

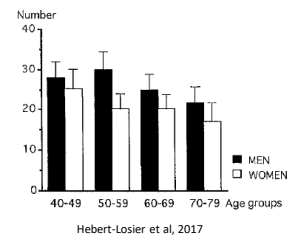


### Heel-Raise Performance is Valid & Reliable

- Repetitions correlate significantly with gait speed in patients with myositis (Davenport et al, 2014)
- Repetitions SGNF lower for
  - Patients with venous disease (14.6) than for controls (23.5) (van Uden et al, 2005)
  - Patients with heart failure (16/17) than for controls (18.5/21) (Cider et al, 2006)
  - Adults 61-80y than for adults 21-40y (Jan et al, 2005)
- Reliability: Test-retest
  - Cider et al (2006)
    - CHF left/right: ICC = .94/.98
    - Healthy left/right: ICC = .93/.94
  - Hebert-Losier et al (2017): Healthy adults: ICC (left & right) = .96
  - Segura-Orti & Martinez-Olmos (2011): Patients on dialysis left/right: ICC = .94/.97

### Heel Raise Performance is Responsive & Interpretable

- Responsiveness
  - Between-day SEM = 2.2 (Hebert-Losier et al, 2017)
- Interpretable
  - Actual counts
    - Mean 27.9 (CI low 25) for 20-59 years (Lunsford & Perry, 1995)
    - Mean 25 (Svantesson et al, 2011)
  - Conversion to MMT scores



### Field Tests: Curl-ups

- Procedure
- Grading
- Considerations
- Validity
  - EMG of all abdominal muscles high when arms crossed and feet restrained (Burden & Redmond, 2013)
  - Curl-up performance correlates SGNF with mortality
    - Canadians (Katzmarzyk & Craig (K & C), 2002)
    - Japanese (Fujita et al, 1995)
- Interpretation
  - Homecare patients (n=31): 55% scored 1/5 or 2/5 (Bohannon, 2017)
  - Community dwelling adults



Strata	K & C	Oda	Fujita
60-69 F	9	2.4	4.4
60-69 M	11	10.8	11.1
≥ 70 F		0.9	2.7
≥ 70 M		9.3	7.1

### Field Tests: Prone Bridge



- Procedure
  - Position
  - Instructions & timing
- Considerations
  - Uses abdominals, but other muscles also
  - Reasons for failure not always abdominal fatigue

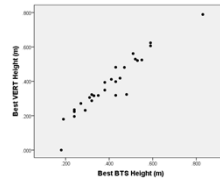
- Validity (Bohannon et al, 2017)
  - Bridge time correlates SGNF with self-reported fitness & exercise participation, engagement in abdominal exercise, and adiposity (eg, waist circumference)
  - Times for older adults SGNF < for younger adults
- Reliability: Test-retest ICC = .91
- Responsiveness: MDC(%) = 39.7
- Interpretation (Mean time)
  - Women 20-35 = 152.3s
  - Women 60-79 = 124.7s
  - Men 20-35 = 176.7s
  - Women 60-79 = 127.4

### Field Tests: Vertical Jump (Bohannon et al, 2017)



- Procedures
  - Instrumentation
    - VERT & belt
    - VERT App
  - Instructions
- Considerations
- Validity
  - VERT determined height correlates SGNF (strong) with motion capture determined height

### Vertical Jump Height is Valid, Reliable & Interpretable



- Validity (cont)
  - Height SGNF lower for
    - Women (32.6cm) than men (48.8cm)
    - Older (30.1cm) than younger (51.4cm)
- Reliability
  - Parallel ICC = .99
  - Test-retest (1 week) ICC = .97
- Interpretation
  - 60-75 y (Bohannon et al, 2017)
    - Men = 35.7cm, Women = 27.3cm
  - 60-69 y (Fujita et al, 1995)
    - Men = 34.8cm, Women = 22.3cm

### Hand-grip Dynamometry



- Procedure
  - Dynamometer
  - Adjustment
  - Position
    - Body
    - Upper limb
  - Support

### Hand-grip Dynamometry: Reliability & Validity

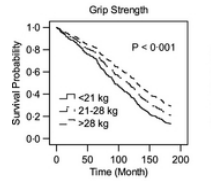
- Reliability:
  - Healthy( NIH Toolbox, Test-retest 4-10 days): ICC = .94-.96 (Bohannon et al, 2011)
  - Stroke (Weekly sessions): ICC = .86 (weak) & .91 (strong) (Boissy et al, 1999)
- Validity: Known Groups
  - Controls vs stroke (weak side), stroke (weak side) vs stroke (strong side) (Boissy et al, 1999)
  - Able vs unable to perform heavy tasks with hands (Wang & Chen, 2010)
- Validity: Convergent
  - Post-stroke correlations with pinch, ARAT, Jebsen, 9HPT, & SIS hand:  $r_s = .61$  to  $.92$  (Beebe & Lang, 2009)

### Hand-grip Dynamometry: Predictive Validity

• Validity: Predictive

- Hospitalization (Cawthon et al, 2009)
- Hospital length of stay (Mendes et al, 2014; Keevil et al, 2013)
- Future disability (Di Manaco et al, 2014,2015)
- Mortality (Alet et al, 2010, Ling et al, 2010, De Buysse et al, 2013)

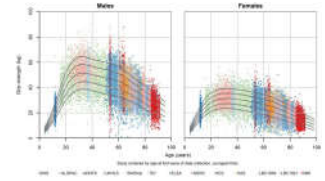
Grip strength a stronger predictor of all-cause and cardiovascular mortality than systolic BP (Leong et al, 2015)



### Hand-grip Dynamometry: Interpretability

• Normative values

- Population-based studies: PURE (n=125,472) (Leong et al, 2016)
- Consolidated (Bohannon et al, 2006; Dodds et al, 2014)
- T-scores (Bohannon & Magasi, 2015; Dodds et al, 2014)
- Cut-scores for mobility limitations
  - Men 37kg, women 21kg (Sallinen et al, 2010)
  - Men 26kg, women 17kg (Vasconcelos et al, 2016)
  - Men 32kg, women 18kg (Dong et al, 2014)
  - Men 32kg, women 22kg (Bahat et al, 2017)

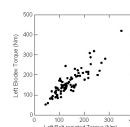


### Hand-held Dynamometry



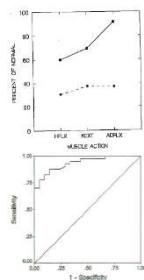
- Instrumentation
- Procedures
  - Gravity-eliminated
  - Position
  - Distal
  - Perpendicular
- Instructions
- Stabilization

### Hand-held Dynamometry: Convergent Validity



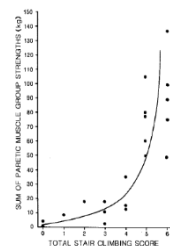
- **HHD vs Cybex**
  - 20 healthy women
  - No significant difference
  - ICC = .797
- **HHD vs Cybex**
  - 26 stroke patients
  - No significant difference
  - ICC = .940
- **HHD (belt-resisted) vs Biodex**
  - 86 healthy men and women
  - Significant difference
  - ICC = .854 (L) & .771 (R)

### Hand-held Dynamometry: Known Groups Validity

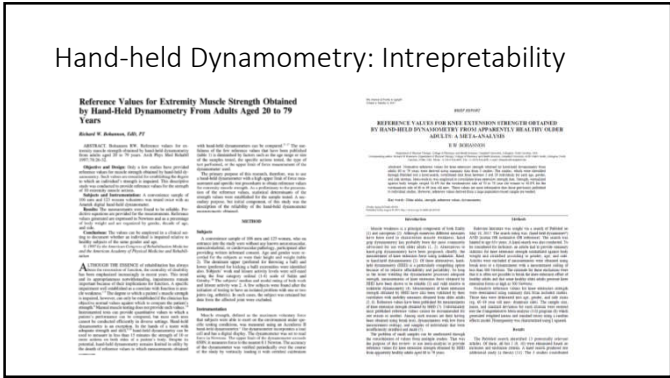
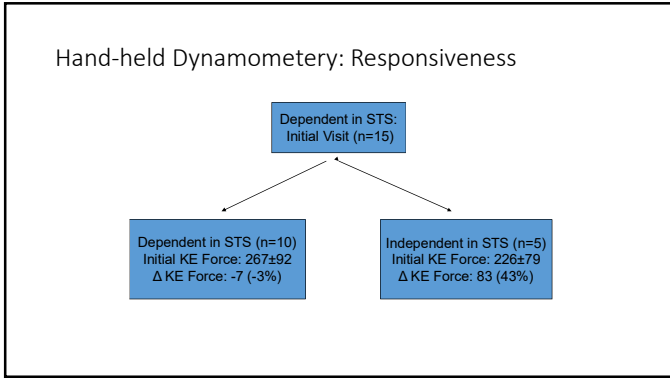


- **Patients vs controls**
- **Involved vs uninvolved sides**
- **Independent vs dependent in sit-to-stand**
  - Rehabilitation inpatients (n=107): AUC=92.8%
  - Patients with stroke (n=61): AUC=92.3%
  - Home-care patients (n=31): AUC=93.7%

### Hand-held Dynamometry: Relationship with Function



- Older adults (n=10): Normalized knee extension strength & gait speed (r = .792)
- Transplant candidates (n=26): Normalized knee extension strength & gait speed (r = .749[D], .624[N])
- Stroke patients (n=20): Sum of 5 paretic muscle groups & stair climbing (r = .860)



### Problems with Hand-held Dynamometry

Action	Tester	Force	ICC
SER	S	128	.932
	M	118	
	W	115	
EFX	S	236	.779
	M	170	
	W	172	
KEX	S	430	.226
	M	258	
	W	225	

Force (No belt): r=-.71 (Sex), .78 (Grip), .66 (Push)

### Summary and Questions