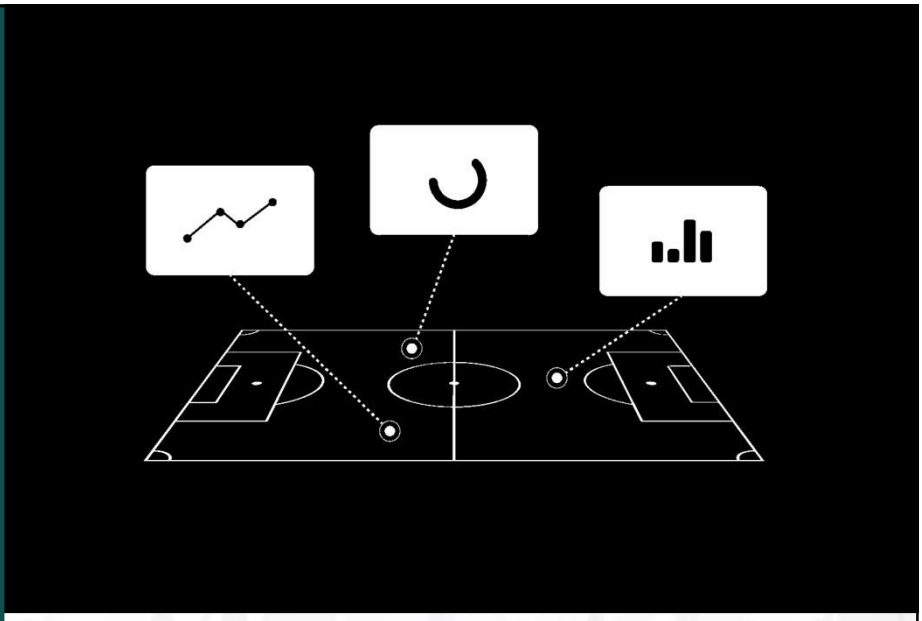
WHAT THE TECH HHDS AND FORCE PLATES IN SPORTS REHAB



Vien Vu, DPT, SCS, CSCS, CPSS
March 14th, 2026

Gundersen Health Systems

Wifi name:
Wifi password:

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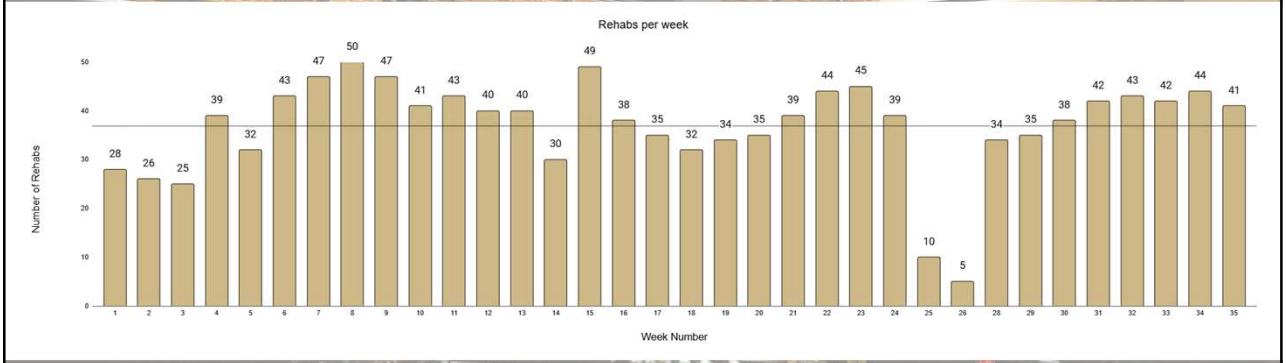
1

ABOUT ME



WF WAKE FOREST

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- Sports residency-trained (Gundersen Health Systems)
- D1 fellowship-trained (Wake Forest University)
- Associated faculty with Tufts University DPT program
- Guest lecturer for Ohio University, UNC-Chapel Hill, and Creighton University sports elective
- Con ed Instructor– “Get with the Guidelines!” with Todd Davenport
- NATA Collegiate Standard of Care Committee
- Authored some stuff

My DPT application from 2014!

Along with working with individuals coming back from injury, physical therapists can have an impact on fully functional individuals as well. With the future changes in health care, direct access, having services for functional individuals is crucial. After recognizing abnormal movement, physical therapists can teach people proper biomechanics. Although an individual may be functional, their movements may still need refining. With technology developing, there may be different ways to do the same. I hope to apply my research and schooling by utilizing new technology to create accessible programs to fully functional or injured individuals.

“…I hope to apply my research and schooling by utilizing new technology to create accessible programs to fully functional or injured individuals.”

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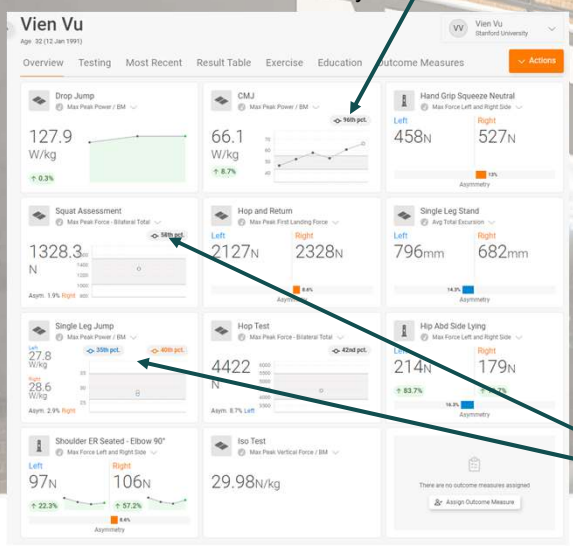
3

About me

I use tech daily!

Peep my hops



People contact me for help with tech

Hello Vien,
I wanted to reach out a… familiar with your expertise in the handhe…
We just recently got a…
would be keen to hear…
practice. Would you h…
formal consult with sc…

She was the VALD rep we spoke to today.... i would love to pick your brain sometime you're free? I'm not sold on it… lecks but others

What I'm your opinion is the best force plate system for a small PT clinic?
I'm seeing the VALD come up in a lot of posts

Hey vien. Hope you are well. I had a question. When you are doing isometric testing for the quad I assume that you are using some sort of strap around the ankle to hook up to. The ankle straps we have been using tend to wear out fast. Do you have this problem? Any brand that you are using that holds up?

Hi quick question
What strap do you attach tindeq to?
Hi
I have a chain but it's heavy and annoying
Have carabiner and chain right now but def need a strap
I like the microfet but I just feel like I have more human error with it

Ignore everything else

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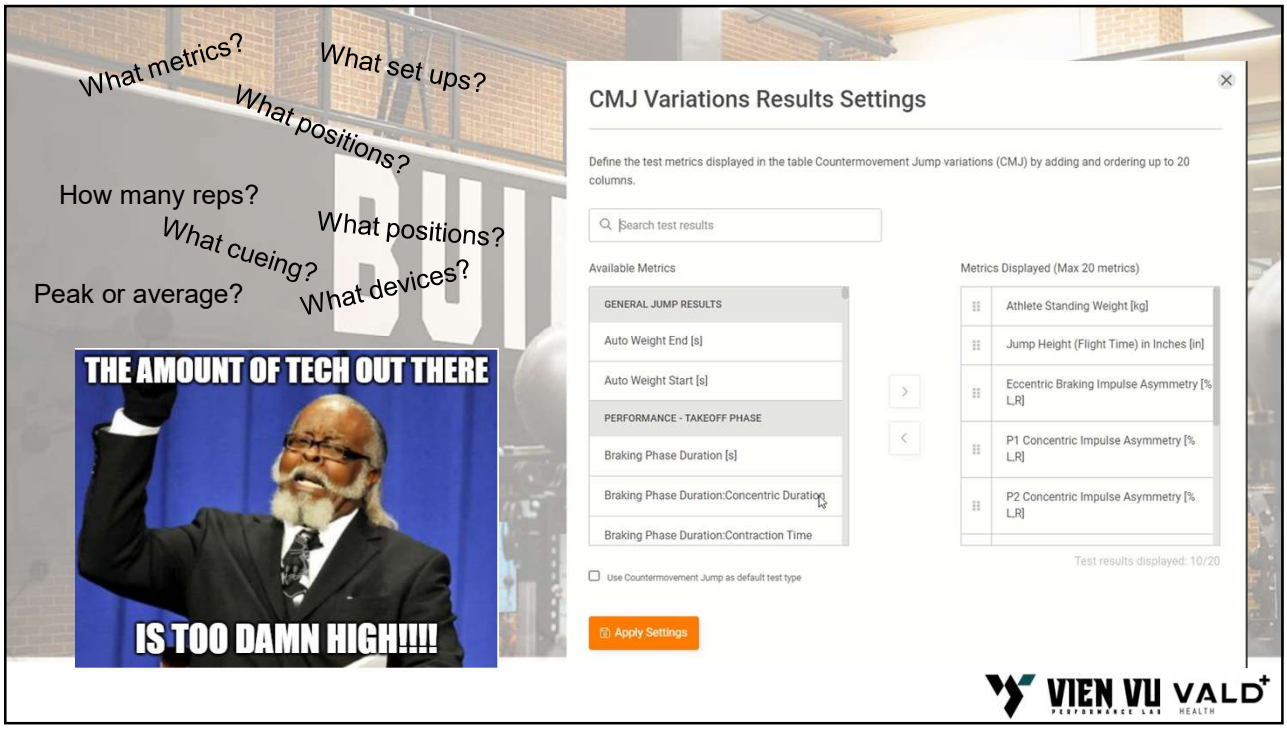

5

DISCLOSURES

I have relevant financial relationships to be discussed, directly or indirectly, referred to or illustrated with or without recognition within the presentation as follows:

- Advisory Board: ModelHealth
- Consultant: SimpliFaster, Kinvent
- Free goods: Peak Force, Kinvent, VALD, SimpliFaster, SportReact

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OBJECTIVES

- Develop and demonstrate efficient hip, knee, shoulder testing using a handheld dynamometer (HHD)
- Determine what force plate metrics are important in rehab
- Understand how to integrate data into clinical practice for both treatment and testing

7

HOUSEKEEPING

- Safe space
- Interruptions welcome
- You paid me to answer questions
- Snacks and beverages welcome

8

SCHEDULE

8:30 am Intro and Overview
9:00 am Why technology?
9:30 am HHD Lecture: Hip
10:00 am HHD Lab: Hip
10:45 am Break
11:00 am HHD Lecture: Knee
11:30 am HHD Lab: Knee
12:00 pm Lunch (on your own)
12:30 pm Testing the complex ankle
1:00 pm Force Plate Lecture: Lower Extremity
1:30 pm Force Plate Lab: Lower Extremity
2:00 pm Break
2:15 pm HHD and Force Plate Lecture: Upper Extremity
2:45 pm HHD and Force Plate Lab: Upper Extremity
3:30 pm Case Studies
5:00pm Dismissal

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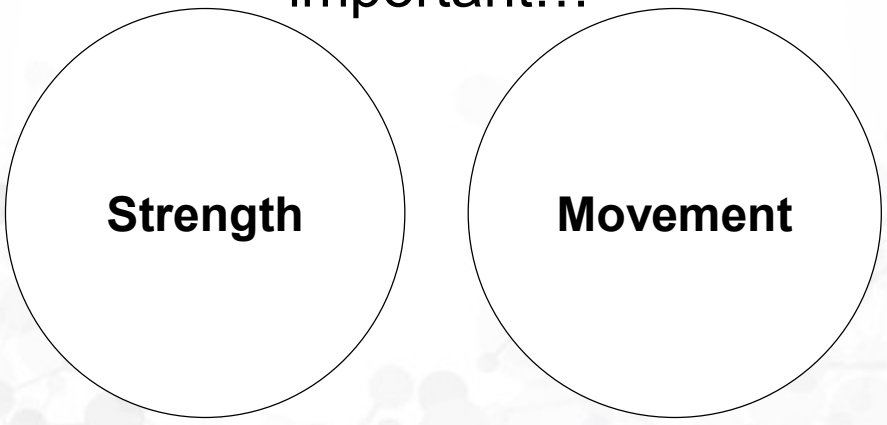
What this course covers is important…



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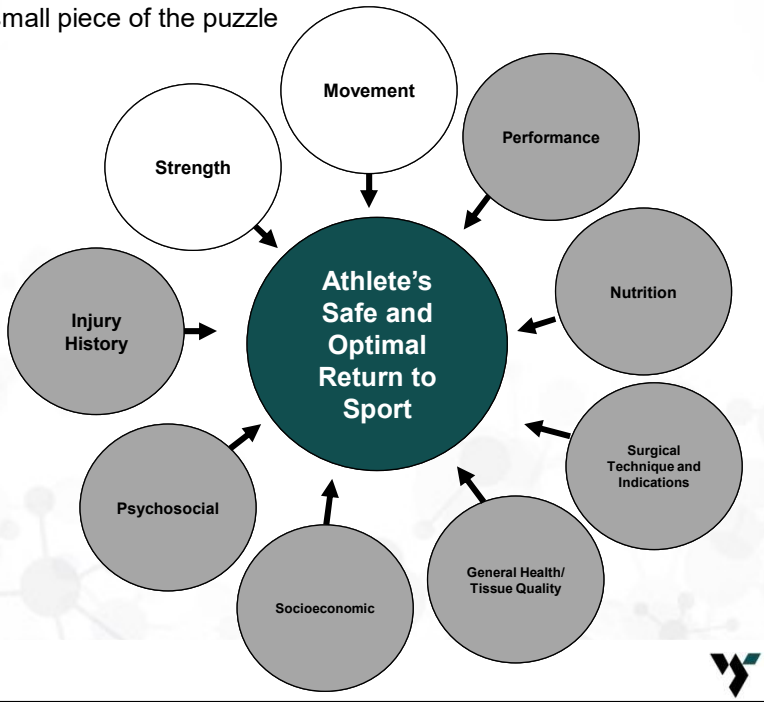
…but just a small piece of the puzzle



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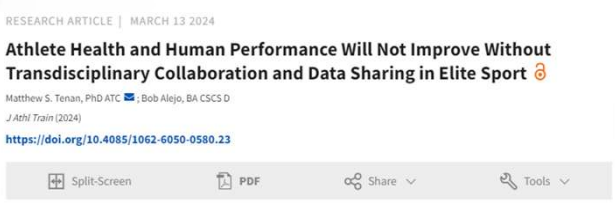
DATA COMPETENCY IS A MUST-HAVE IN ELITE ATHLETICS


RESEARCH ARTICLE | MARCH 13 2024

Athlete Health and Human Performance Will Not Improve Without Transdisciplinary Collaboration and Data Sharing in Elite Sport

Matthew S. Tenan, PhD ATC ; Bob Alejo, BA CSCS D

J Athl Train (2024)

https://doi.org/10.4085/1062-6050-0580.23

Split-Screen PDF Share Tools

CERTIFIED PERFORMANCE & SPORT SCIENTIST — NSCA — CPSS Est. 2021 SM

"[Rehab professionals] have ceded considerable input in the areas of injury mitigation to sport scientists and sport-specific rehabilitation to strength and conditioning personnel who may have a lower level of formal medical training than [rehab professionals] but a greater focus on sport specific performance."

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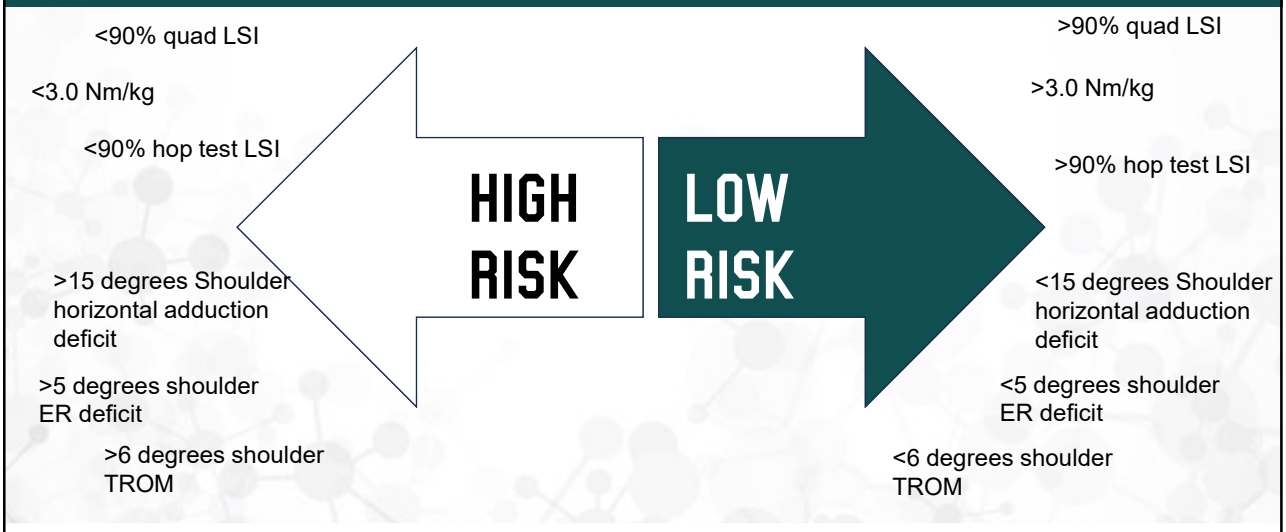
UNDERSTANDING TECHNOLOGY AND STATISTICS ALLOWS US TO MAKE REASONABLE DECISIONS

Losciale, et al, 2024

13

UNDERSTANDING TECHNOLOGY AND STATISTICS ALLOWS US TO MAKE REASONABLE DECISIONS



Losciale, et al, 2024

14

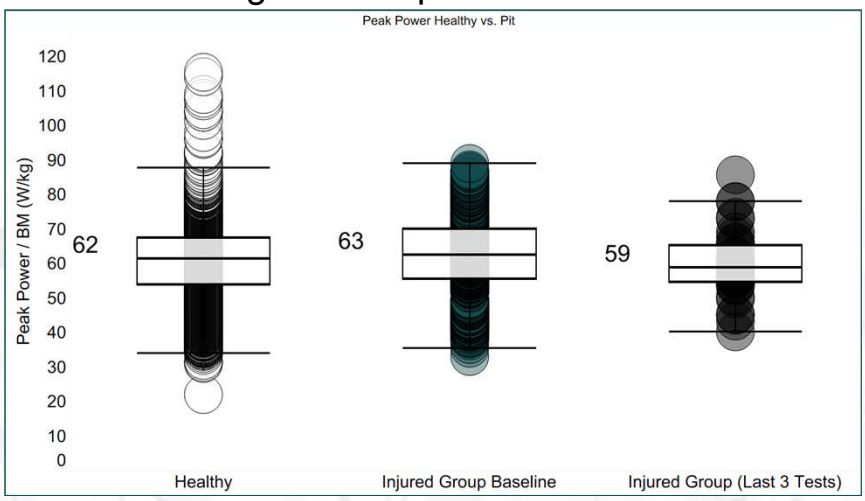
UNDERSTANDING TECHNOLOGY AND STATISTICS ALLOWS US TO MAKE REASONABLE DECISIONS

Losciale, et al, 2024

15

DATA AND STATITICS KEEPS US HONEST AND MAKES US BETTER

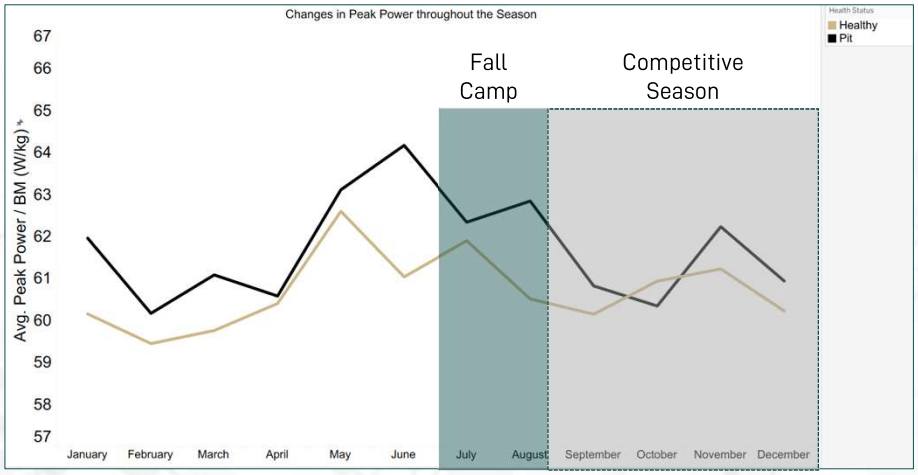
Is this athlete coming back as powerful as the rest of the team?



16

DATA AND STATITICS KEEPS US HONEST AND MAKES US BETTER

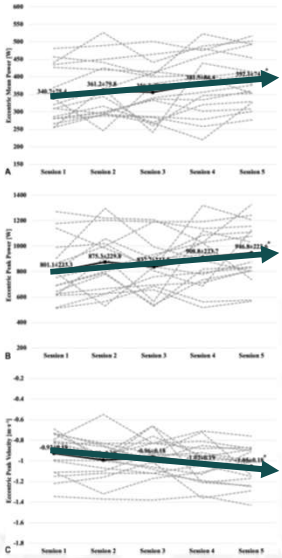
Is this athlete coming back as powerful as the rest of the team?



17

DATA AND STATITICS KEEPS US HONEST AND MAKES US BETTER

Are the team and individuals' findings consistent with other cohorts? Can we do better?



Other teams' power and speed improve during the year, and so does ours.

Cabarkapa et al, 2024

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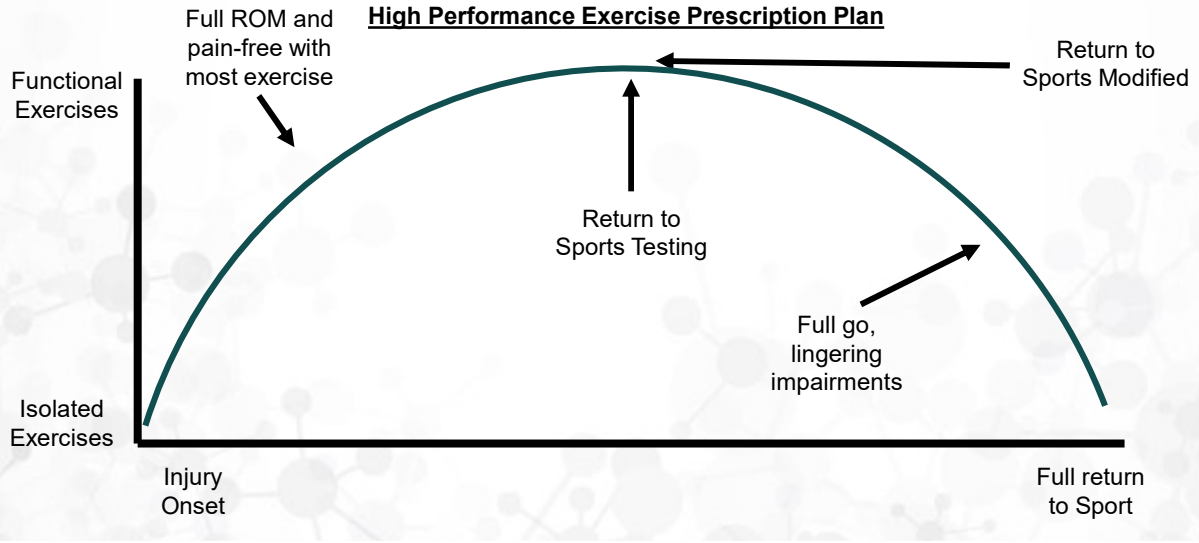
OBJECTIVE TESTING MAKES CARE CONCISE, AND HELPS COLLABORATE WITH OTHERS



19

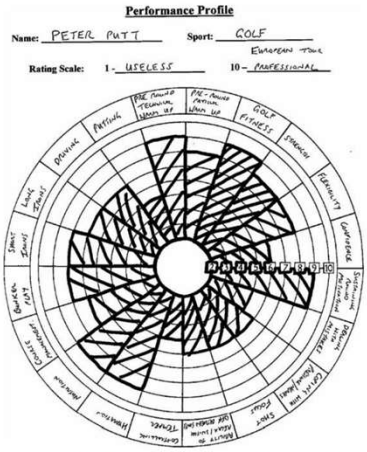
IT DOES NOT PREVENT INJURY…YET, BUT IT MAY DECREASE THE ODDS

Review

Why screening tests to predict injury do not work—and probably never will…: a critical review

Roald Bahr[1,2]

Increase self-awareness:

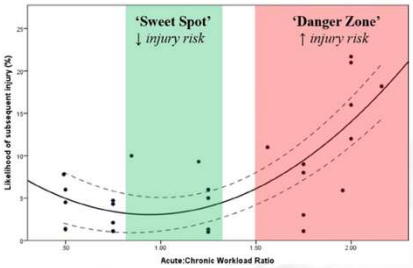


Weston (2012) - A review of Butler and Hardy's (1992) performance profiling procedure within sport

20

IT IMPROVES OUR OUTCOMES IN FUNCTION AND RE-INJURY RATES

The training—injury prevention paradox: should athletes be training smarter and harder?



Ups and downs, uncontrollable factors, re-aggravations

Rehab	Return to Sport	Return to Performance

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IT IMPROVES OUR OUTCOMES IN FUNCTION AND RE-INJURY RATES

Int J Sports Physiol Perform. 2020 Jun 5;15(6):907-913. doi: 10.1123/ijspp.2019-0864. Print 2020 Jul 1.

Acute:Chronic Workload Ratio: Conceptual Issues and Fundamental Pitfalls

Franco M Impellizzeri, Matthew S Tenan · Review · Open Access J Sports Med. 2020 Feb 24;11:51-75. doi: 10.2147/OAJSM.S231405. eCollection 2020.

PMID: 32502973 DOI: 10.1123/ijspp.2

The Relationship Between Acute: Chronic Workload Ratios and Injury Risk in Sports: A Systematic Review

Danny Maupin [1], Bo · J Athl Train. 2020 Sep 1;55(9):931-943. doi: 10.4085/1062-6050-473-19.

Affiliations + expand

PMID: 32158285 P

Global Positioning System-Derived Workload Metrics and Injury Risk in Team-Based Field Sports: A Systematic Review

Natalie Kupperman [1], Jay Hertel [1]

Affiliations + expand

PMID: 32818957 PMCID: PMC7534932 DOI: 10.4085/1062-6050-473-19

TOP STORIES

NBA sends teams the results found in load management study

The study showed no link between load-managed players and a decreased risk of injury.

Average games missed by start players

1990's		2020's
10.6	⇨	23.9

Ups and downs, uncontrollable factors, re-aggravations

Rehab	Return to Sport	Return to Performance

Slightly longer integrated approach, but thoroughly tested

Rehab	Return to Sport	Return to Performance

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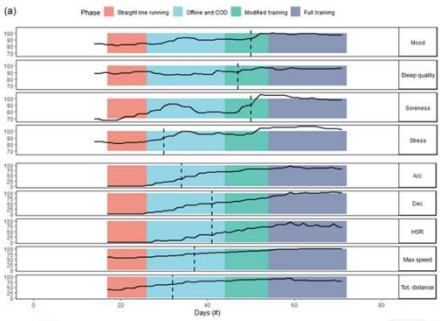
IT IMPROVES OUR OUTCOMES IN FUNCTION AND RE-INJURY RATES



Ups and downs, uncontrollable factors, re-aggravations

Rehab	Return to Sport	Return to Performance

Slightly longer integrated approach, but thoroughly tested

Rehab	Return to Sport	Return to Performance

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PROMOTES PRINCIPLES OF OPEN SCIENCE

Sport	Position	Avg. Peak Power/BW (W/kg)	Avg. Concentric Impulse Asymmetry (%)	Avg. Eccentric Braking Asymmetry(%)	Avg. Landing Impulse Asymmetry%)
Track	Jumps	71.4	3	5	10
	Sprints	70.5	4	8	13
	Pole Vault	64.5	0	10	17
	Throws	47.2	4	5	28
WVB	Setter	60.4	15	4	34
	Opposite	60.0	-3	9	19
	Middle	55.8	7	5	27
	Outside	55.3	5	3	23
	Libero/Defensive Specialist	53.0	0	7	6
FH	Midfield	54.7	2	2	9
	Goalkeeper	49.2	7	-2	4
	Forward	48.5	0	3	17
	Defense	46.6	-1	6	22
WTEN	n/a	44.5	3	10	29

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HANDHELD DYNAMOMETRY

Labral injuries, tendinopathies, and groin injuries

25

ARTHROSCOPIC HIP SURGERY RESULTS IN MUSCLE WEAKNESS AND ATROPHY DUE TO TISSUE DAMAGE

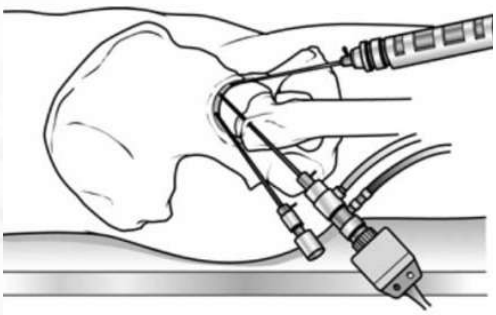

Image credit: http://orthoinfo.aaos.org/topic.cfm?topic=A00572

- Hip abductors
  - Gluteus medius
- Hip flexors
  - Tensor fasciae latae
  - Sartorius
  - Rectus femoris
  - Iliopsoas

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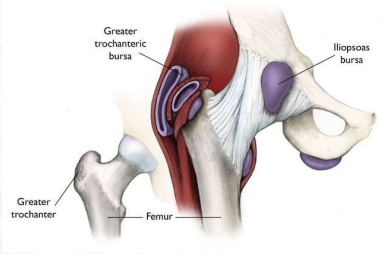
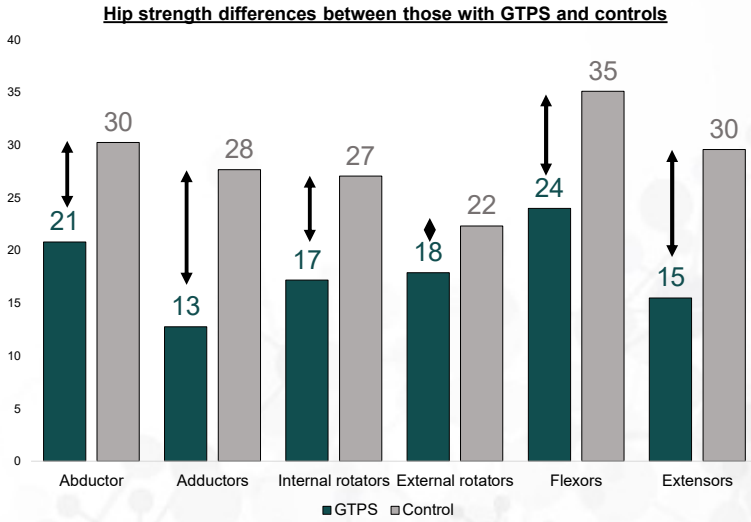
THOSE WHO HAVE GREATER TROCHANTERIC PAIN SYNDROME OFTEN HAVE STRENGTH DEFICITS

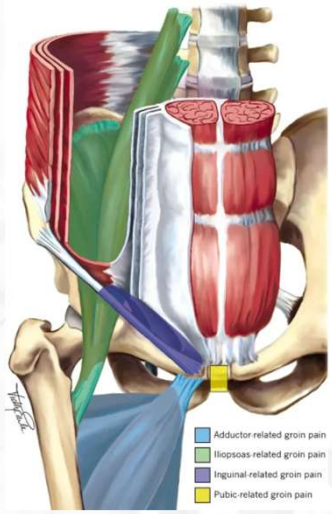




Miyaski et al, 2021

27

THERE IS OVERWHELMING EVIDENCE OF GROIN STRENGTH'S ASSOCIATION WITH GROIN INJURIES



PRE-SEASON ADDUCTOR STRENGTH AND STRENGTH THROUGHOUT THE SEASON RESULTS IN LESS GROIN INJURY AND TIME-LOSS.

Quintana-Cepedal et al, 2024

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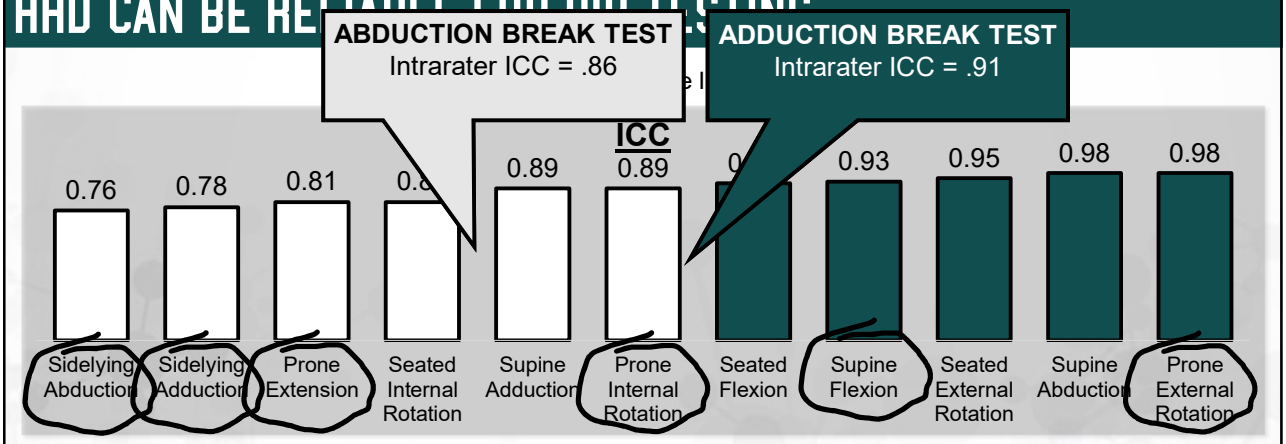
HHD CAN BE RELIABLE FOR HIP TESTING



Handheld dynamometers (make test) are reliable for measuring hip strength given the tester is the same.

Brindle et al, 2018; Thorborg et al, 2010

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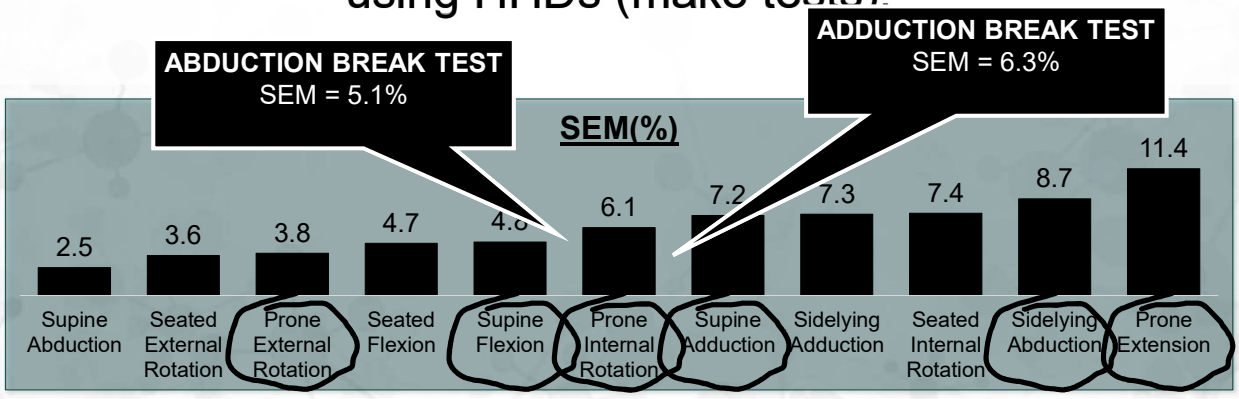
HHD CAN BE RELIABLE FOR HIP TESTING

A 90% Limb Symmetry Index (LSI) cutoff is appropriate using HHDs (make tests)



Thorborg et al, 2011; Thorborg et al, 2010

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HHD MAY BE ACCURATE COMPARED TO ISOKINETICS

ADDUCTION MAKE TEST
InterDevice ICC = .94-.95

ABDUCTION MAKE TEST
InterDevice ICC = .88 - .89

ER MAKE TEST
r = .49

IR MAKE TEST
R = .51

FLEXION MAKE TEST
InterDevice ICC = .94

EXTENSION MAKE TEST
InterDevice ICC = .88-.90

MOST STUDIES ASSESSING INJURY RISK AND HIP STRENGTH USE HANDHELD DYNAMOMETERS, NOT ISOKINETICS.

Chamorro et al, 2017; Kim et al, 2015

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RELIABILITY VARIES BY SET UP

MARINA C. WAITEMAN, MS, PT[1,2] • MICAH C. GARCIA, PhD[2] • RONALDO V. BRIANI, PhD, PT[1] • GRANT NORTE, PhD, ATC[3]
NEAL R. GLAVIANO, PhD, ATC[4] • FÁBIO M. DE AZEVEDO, PhD, PT[1] • DAVID M. BAZETT-JONES, PhD, ATC, CSCS[2]

Can Clinicians Trust Objective Measures of Hip Muscle Strength From Portable Dynamometers? A Systematic Review With Meta-analysis and Evidence Gap Map of 107 Studies of Reliability and Criterion Validity Using the COSMIN Methodology


TABLE 3 Evidence Gap Map for Reliability and Criterion Validity Outcomes

Waitemen et al, 2023

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THEY MAY NOT BE ACCURATE IN RELATION TO ISOKINETICS

MARINA C. WAITEMAN, MS, PT[1,2] • MICAH C. GARCIA, PhD[2] • RONALDO V. BRIANI, PhD, PT[1] • GRANT NORTE, PhD, ATC[3]
NEAL R. GLAVIANO, PhD, ATC[4] • FÁBIO M. DE AZEVEDO, PhD, PT[1] • DAVID M. BAZETT-JONES, PhD, ATC, CSCS[2]

Can Clinicians Trust Objective Measures of Hip Muscle Strength From Portable Dynamometers? A Systematic Review With Meta-analysis and Evidence Gap Map of 107 Studies of Reliability and Criterion Validity Using the COSMIN Methodology

TABLE 3 Evidence Gap Map for Reliability and Criterion Validity Outcomes (continued)

Criterion Validity	Hip Muscle Groups: Flexors	Extensors	Abductors	Adductors	Internal Rotators	External Rotators
Portable dynamometers with isokinetic dynamometer						
Manual resistance						
Prone		?				
Prone standing		?				
Seated	?					
Side-lying				↔		
Standing	?	?	?			
Supine	?	↓	?			
External fixation						
Prone		?				
Seated	?				↔	↔
Side-lying			↔	?		
Standing	?	?	↔	⊕		
Supine	↔	⊕	?	?		

Overall rating: ⊕ - sufficient; ↓ - insufficient; ? - indeterminate; ↔ - inconsistent.
Levels of evidence: No evidence, gray; very low, red; low, orange; moderate, blue; high, green.
Domains:
- ***Risk of bias*** *multiple studies of doubtful quality available, or only one study of adequate quality (↓); multiple studies of inadequate quality, or only one study of doubtful quality available (↓↓); only one study of inadequate quality available (↓).*
- ***Inconsistency*** *pooled results rated as inconsistent (↔); unpooled results rated as indeterminate (?).*
- ***Imprecision*** *total N<50 (↓); total N<50 (↓).*
- ***Indirectness*** *study population or outcomes do not align with the purpose of the study's review (↓).*

Waitemen et al, 2023

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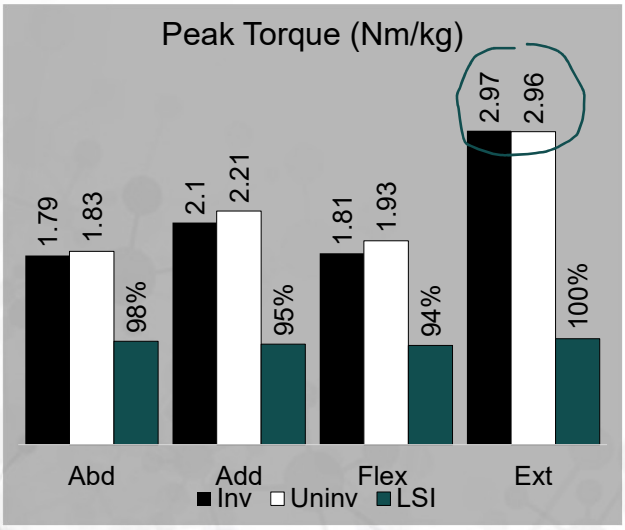
PEAK TORQUE SEEMS TO BE A PREDICTOR OF FUNCTION



Patients should have 90% symmetry across all hip muscle groups at the completion of their rehab.

However, symmetry is not a predictor of function; absolute strength is.

Ishoi et al, 2021

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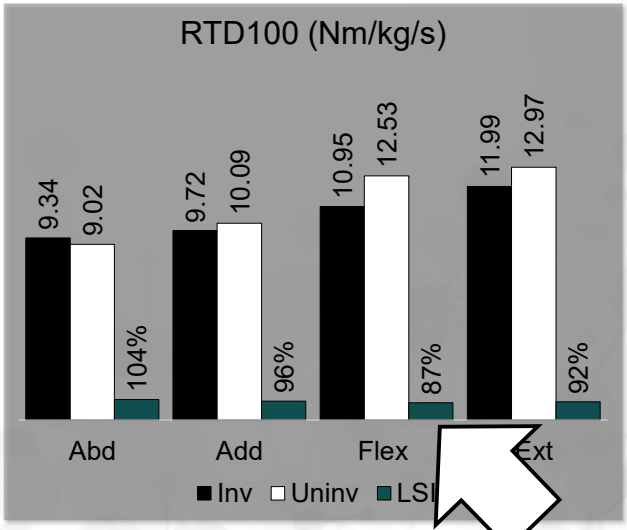
RATE OF TORQUE DEVELOPMENT WAS NOT A PREDICTOR OF FUNCTION

When looking at rate of torque development (RTD) at 100 and 200 msec, flexion was significantly different.

However, neither was found to be predictive of function.



Ishoi et al, 2021

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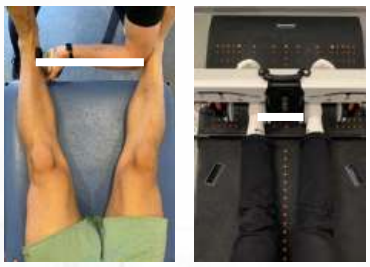
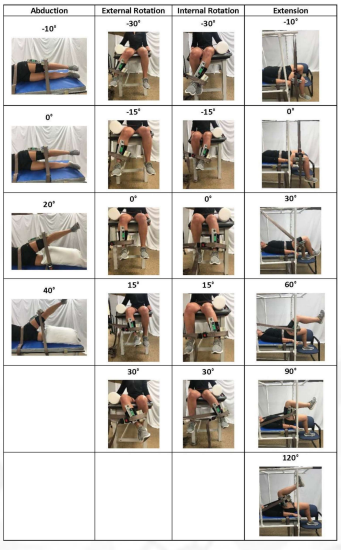
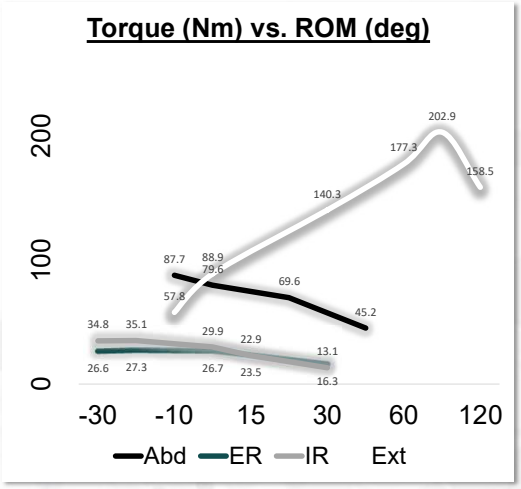
HIP POSITION MATTERS - CONSIDER PROVIDERS' FOREARM SIZE



5 Second Squeeze Test

- Patient squeezes practitioner's forearm with both legs for 5 seconds
- Patient reports pain 0-10
- HHD optional
- Hip angle seems to matter





Nielsen et al, 2022; Ishoi et al, 2021; Worner et al, 2019; Krause et al, 2014

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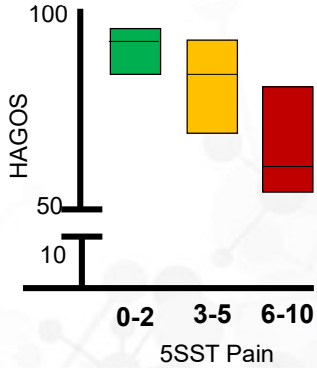
STRENGTH VALUES MAY BE AS IMPORTANT AS PAIN VALUES

5 Second Squeeze Test

- Patient squeezes practitioner's forearm with both legs for 5 seconds
- Patient reports pain 0-10
- HHD optional
- Hip angle seems to matter

The 5SST may be useful in participation decisions



5SST strength and pain may be predictive of PLOF, running, swimming, skating, and kicking

3.15 Nm/kg, 2/10

: 2.82 Nm/kg, 1/10

:2.76 Nm/kg, 1/10

Nielsen et al, 2022; Ishoi et al, 2021; Worner et al, 2019

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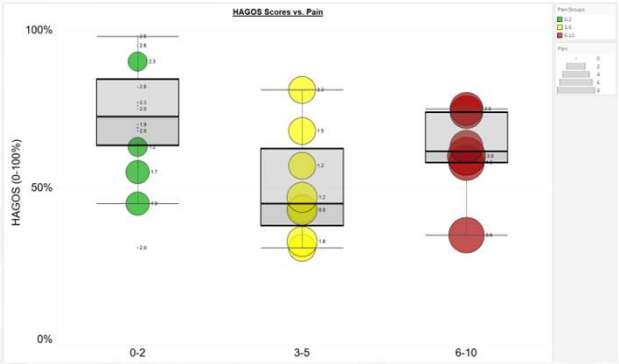
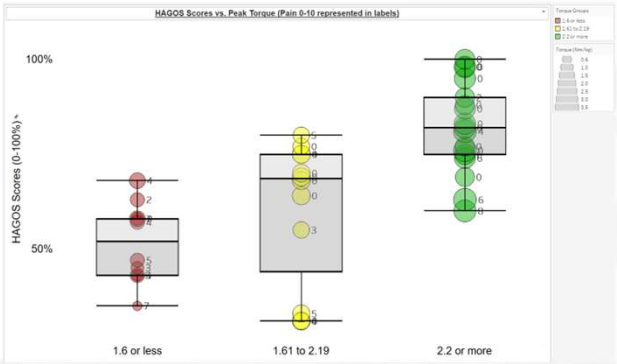
IN ATHLETIC AND HIGH-STAKES COHORTS, STRENGTH MAY BE MORE INDICATIVE THAN PAIN

HAGOS vs. Pain



HAGOS vs. Torque



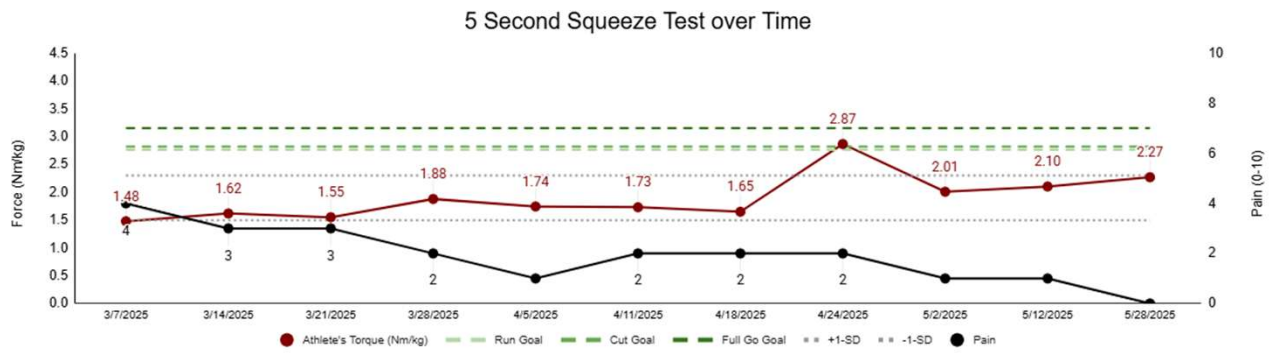
$R = .27, R^2 = .23$

$R = .63, R^2 = .39$

Me, unpublished

38

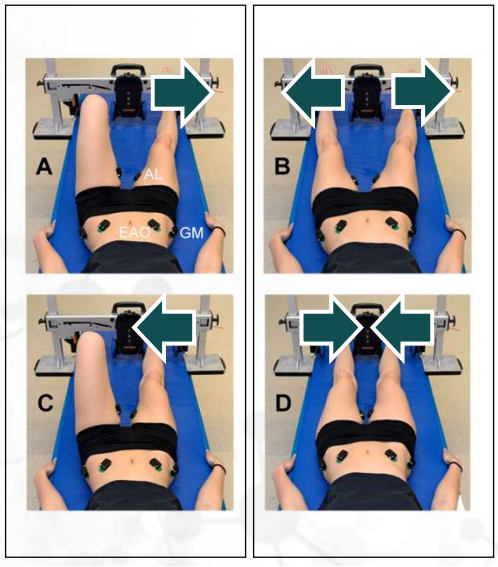
WHEN APPLIED, 2.2 WORKED WELL

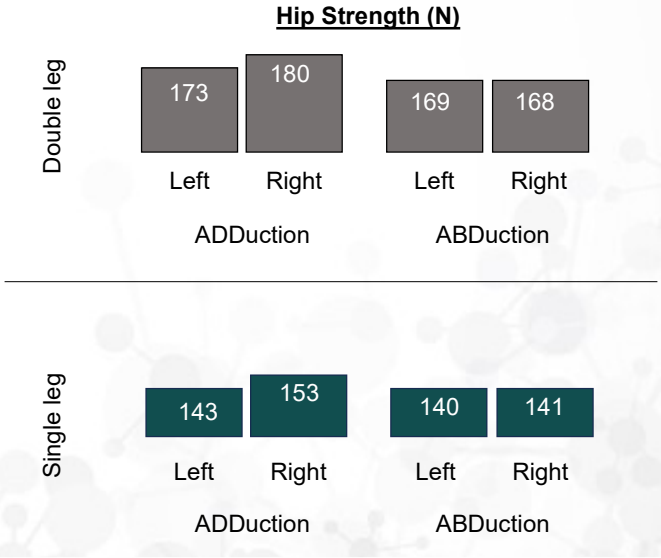


Me, unpublished

39

SINGLE LEG TESTING REVEALS DEFICITS MORE THAN DOUBLE LEG TESTING

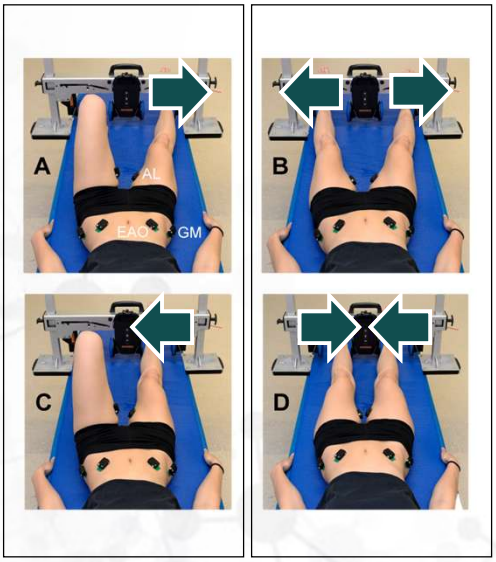




Nielsen et al, 2022; Ishoi et al, 2021; Worner et al, 2019

40

SINGLE LEG TESTING REVEALS DEFICITS MORE THAN DOUBLE LEG TESTING



EMG % MVIC

		Unilateral testing leg	Unilateral non-testing leg	Bilateral testing legs
ABDuction	Gluteus medius	73	71	84
	External abdominal Oblique	78	32	66
	Adductor longus	13	49	9
		Unilateral testing leg	Unilateral non-testing leg	Bilateral testing legs
ADDuction	Gluteus medius	23	32	22
	External abdominal Oblique	35	82	57
	Adductor longus	70	49	86

Nielsen et al, 2022; Ishoi et al, 2021; Worner et al, 2019

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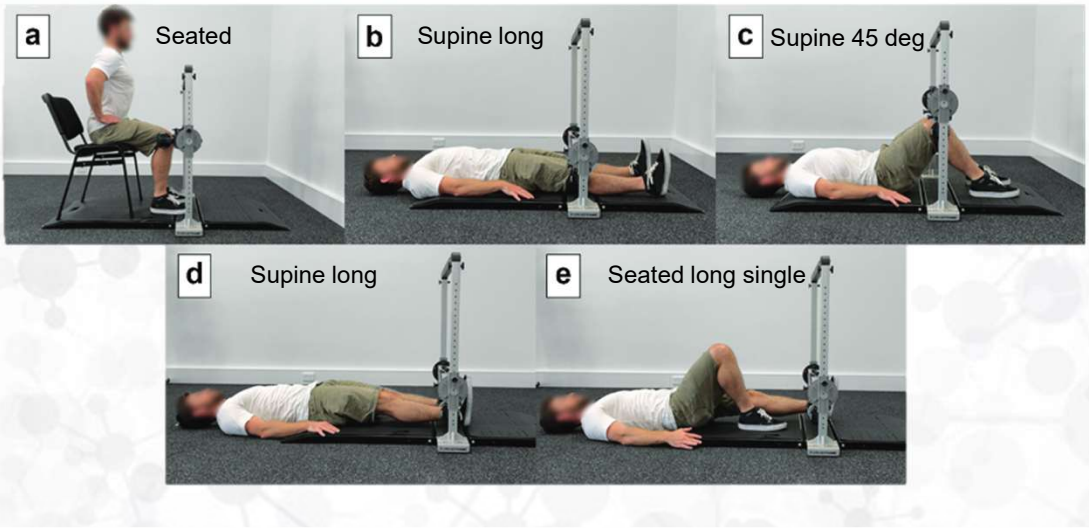
SINGLE LEG TESTING REVEALS DEFICITS MORE THAN DOUBLE LEG TESTING



Secomb et al, 2024

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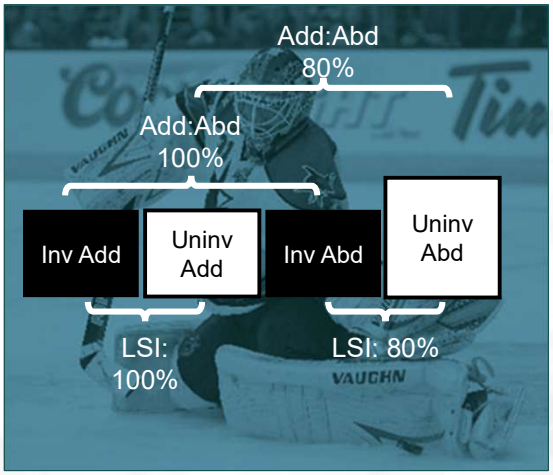
HIP RATIOS MAY BE IMPORTANT, BUT THERE'S A LOT OF NUANCE WITH RATIOS

There is a **17x higher risk** of hip injury
if Adduction to Abduction is less than 80%

*If abduction strength is symmetrical

…in hockey players



Tyler et al, 2001

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HOW MANY REPS ARE BEST

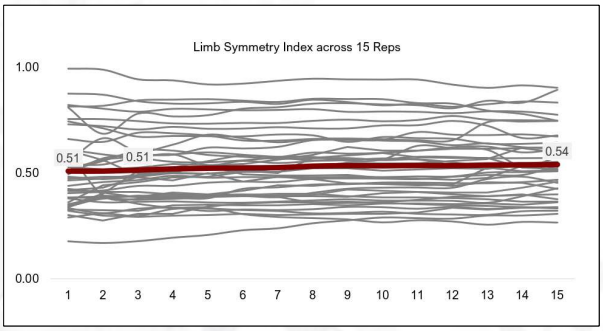
Best of 3

44

PEOPLE GET STRONGER AS MORE REPS ARE PERFORMED

Best of 4

~~Best of 3~~



Hip force was significantly higher when taking the best of 4 reps, but only by 4%

Differences in LSI are significant, but not meaningful

	p-value
15th rep vs. 1st rep	**.03**
15th rep vs. Average of 3	**.01**
15th rep vs. Max of 3	.60

Vien Unpublished 2019—2023; Thorborg et al, 2010

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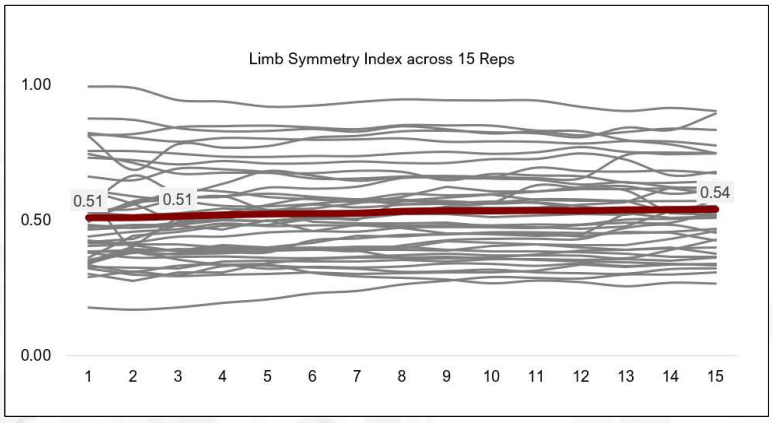
FOR SYMMETRY, MAX VALUES DIFFER FROM VALUES ACHIEVED FROM LOWER REPS



	p-value
15th rep vs. 1st rep	**.03**
15th rep vs. Average of 3	**.01**
15th rep vs. Max of 3	.60

Vien Unpublished 2019—2023; Thorborg et al, 2010

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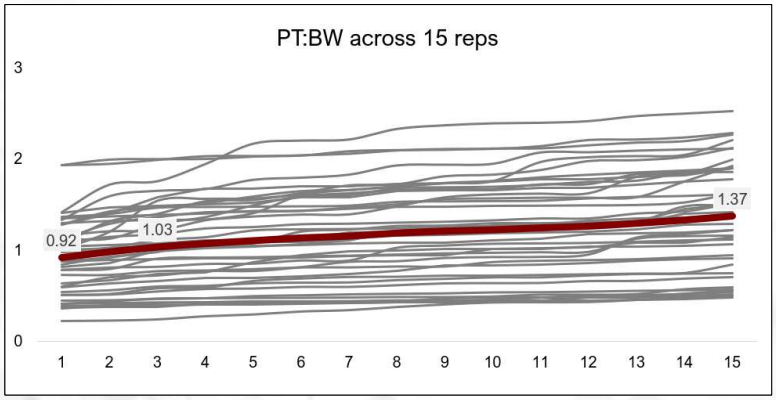
FOR UNILATERAL STRENGTH (%BW OR NM/KG), FORCE GOES UP WITH MORE TRIALS…TAKE THE MAX



	p-value
15th rep vs. 1st rep	<.0001
15th rep vs. Average of 3	<.0001
15th rep vs. Max of 3	<.0001

Vien Unpublished 2019—2023; Thorborg et al, 2010

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TAKING PEAK TORQUE IS YOUR BEST BET

LSI

	p-value
1st Rep vs. Average of 3	0.77
1st Rep vs. Max of 3	**<.01**
Average of 3 vs. Max of 3	**<.0001**

Peak Torque to Bodyweight Ratio

	p-value
1st Rep vs. Average of 3	<.0001
1st Rep vs. Max of 3	<.0001
Average of 3 vs. Max of 3	<.0001

Vien Unpublished 2019—2023

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REST DOESN'T SEEM TO MATTER - TRENDS ARE INCONSISTENT

When rest period is short and varied, muscle groups fatigue/improve differently

Compared to longer and standardized rest, there seems to be no difference

Combined (n = 55): +0.3%

Abduction (n = 12): +2.0%

Adduction (n = 8): +8.7%

External rotation (n = 9): -6.1%

Flexion (n = 8): -1.1%

5SST (n = 3): -5.6%

Knee extension (n = 8): +15%

Knee flexion (n = 12): -1.6%

Vien Unpublished 2019—2023

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INJURY DOES NOT INFLUENCE THE REST AND FORCE RELATIONSHIP EITHER

Both analysis show that an injured and uninjured leg seem to behave the same way as reps increase despite varied "short" vs standardized "long" rest

Injured (n = 26): +0.2%

Uninjured (n = 29): +0.9%

Vien Unpublished 2019—2023

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TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
- **To determine return to play:** During appropriate timelines
- **To monitor annual changes:** When stakeholder deem appropriate

Have to determine if hypothesized changes are pain, neuromuscular, or size related changes

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TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
- **To determine return to play:** During appropriate timelines
- **To monitor annual changes:** When stakeholder deem appropriate

In healthies, there was only a 1.5% change in strength 1 week later. What about injured?

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TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
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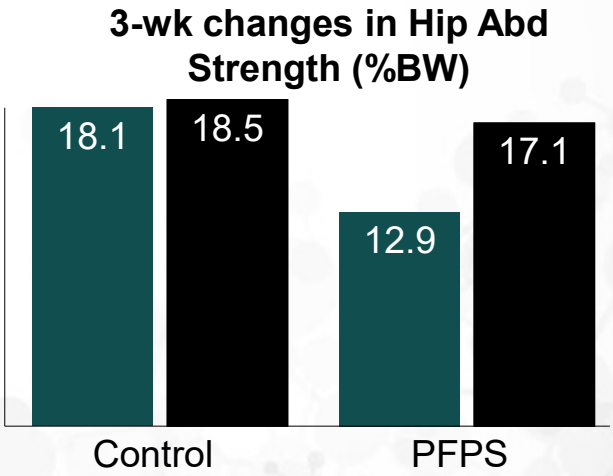

Ferber et al, 2011

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TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
- **To determine return to play:** During appropriate timelines
- **To monitor annual changes:** When stakeholder deem appropriate

Consider timelines and scenarios of patient's not meeting criteria

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TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
- **To determine return to play:** During appropriate timelines
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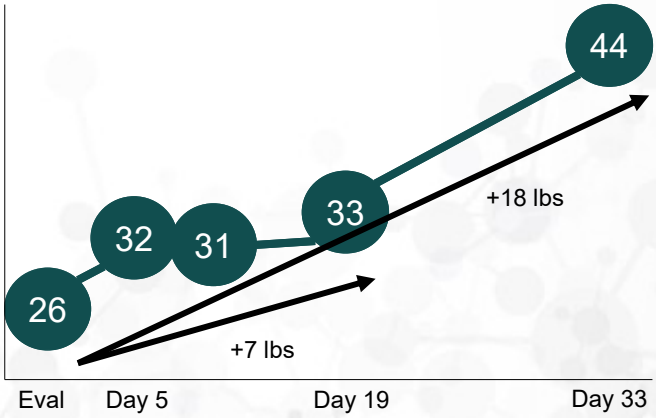

55

TESTING IS DEPENDENT ON PURPOSE AND OPERATIONS

- **To determine training intensity:** Per session to week
- **To assess improvements:** 2-4 weeks
- **To determine return to play:** During appropriate timelines
- **To monitor annual changes:** When stakeholder deem appropriate

Largely dependent on athlete/staff availability and how meaningful data is

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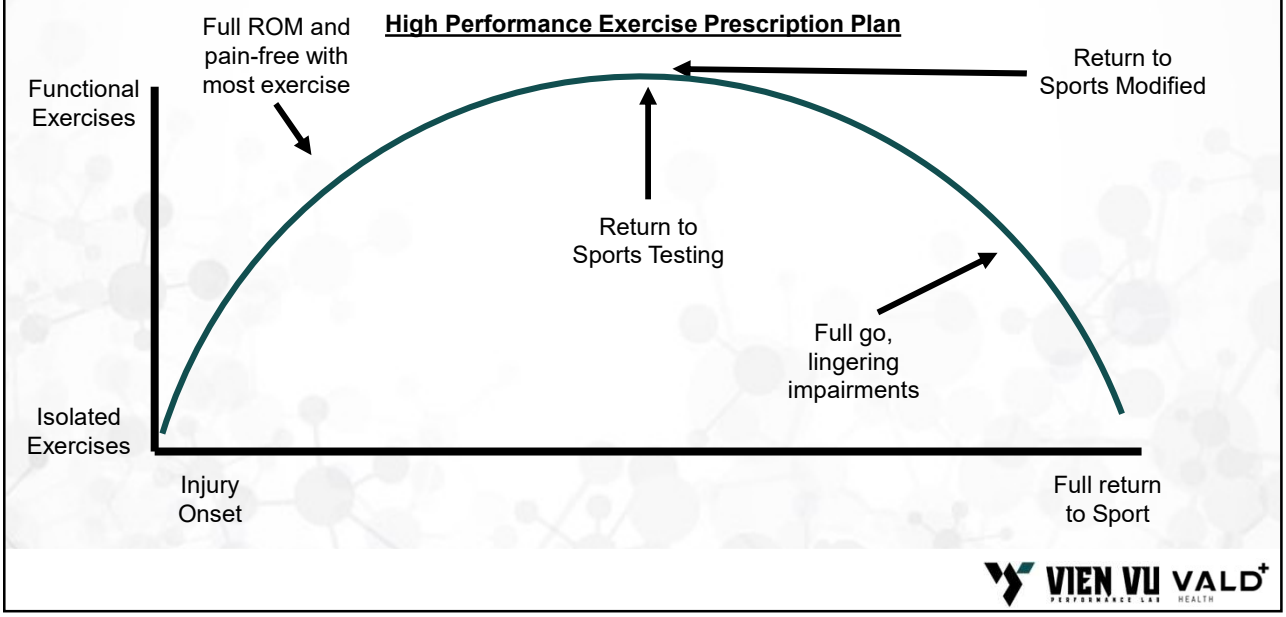
TO TEST OR NOT TO TEST



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ALL PROTOCOLS HAVE PROS AND CONS

Hip Strength Symmetry ≥90%	Healthies across all sports have >90% symmetry
	Symmetry not shown to be predictive of function
Adduction to Abduction Ratio ≥80%	Prospective study showed injury risk reduction
	Study only looked at hockey players and has not been reproduced
Patient Positioning	Sidelying used in studies assessing function and injury risk
	Sidelying doesn't have excellent reliability
Break vs. Make Test	Break used in studies assessing injury risk and looks at eccentric
	Not as reliable as make test

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MY HIP STRENGTH CRITERIA

- Return to Run
  - >75% limb symmetry index in all muscle groups for interval running clearance
  - 1.8 Nm/kg and <3/10 pain on 5 Second Squeeze Test
- Return to Sport
  - >90% limb symmetry index in all muscle groups for full clearance
  - Normative data (level 1 cutting sports; Larson et al, 2022)
    - Hip abduction (Nm/kg): .6-1.2 (youth), 2.35 – 2.6 (adults)
    - Hip adduction (Nm/kg): .9 (youth), 2.45 – 3.0 (adults)
  - >2.2 Nm/kg and <3/10 pain on 5 Second Squeeze Test

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LAB ACTIVITY ONE
45 MIN

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HANDHELD DYNAMOMETRY

Tendinopathies, patellofemoral pain syndrome, and ligamentous injuries

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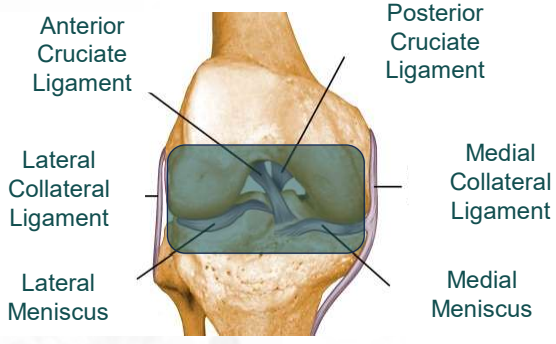
INTRA-ARTICULAR INJURIES DECREASE QUAD STRENGTH



	Pre-effusion	Post-effusion	% change
MVIC	3.51	3.17	-11%
VGRF	12.16	10.99	-9%
IKEM	0.46	0.39	-12%
KFA	24.75	25.92	9%

- MVIC – maximal voluntary isometric contraction (Nm/kg)
- VGRF – peak vertical ground reaction force (N/kg)
- IKEM – peak internal knee extension moment
- KFA – knee flexion angle

Pietrosimone at al, 2014

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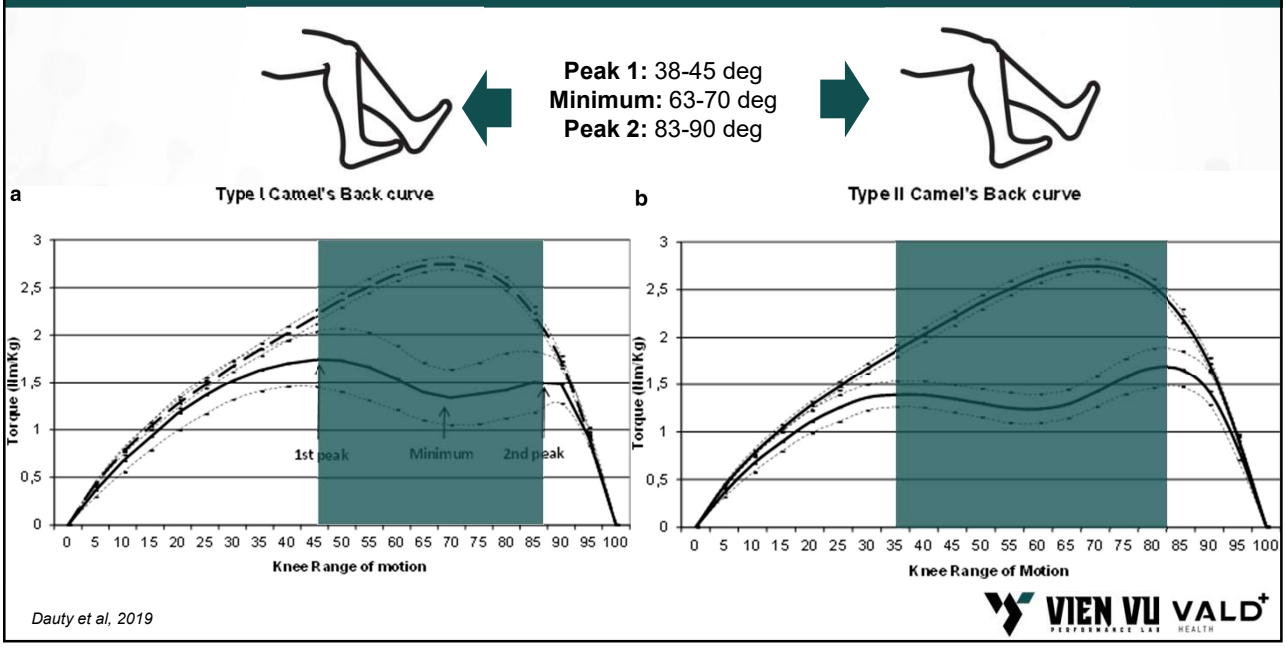
THOSE WITH TENDINOPATHY HAVE MAY EXHIBIT A "CAMEL BACK CURVE"

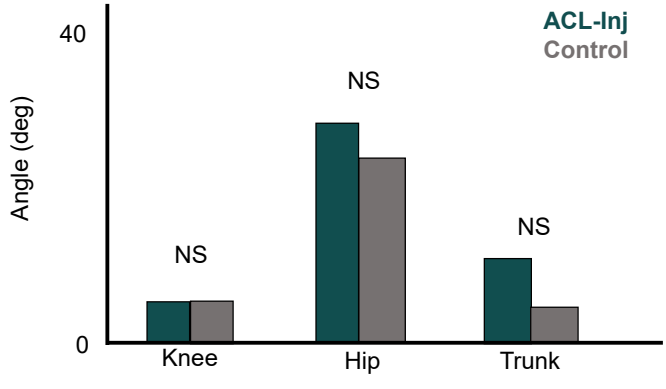


Dauty et al, 2019

63

FRONTAL PLANE MOTION MAY NOT EXPLAIN THE MECHANISMS FOR ACL INJURY

Lower Extremity Frontal Plane Angles (ACL-Inj vs. Control)



Boden et al, 2022

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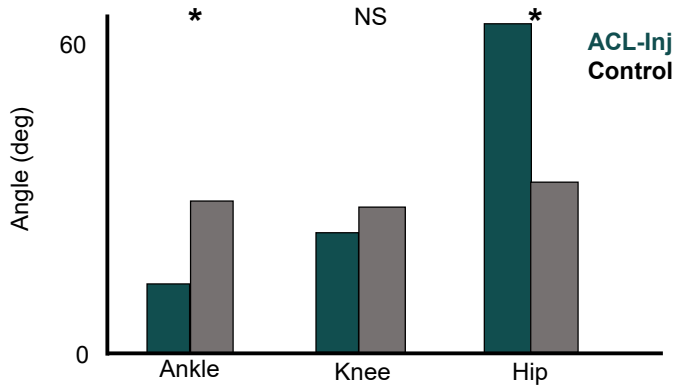
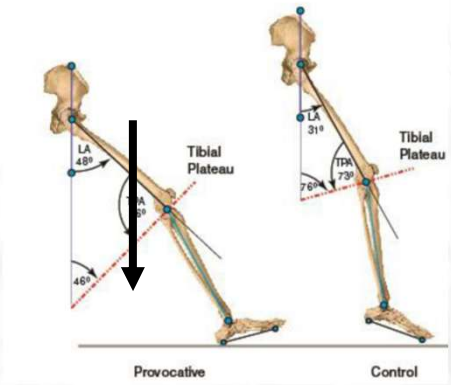
SAGITTAL PLANE KINETICS ARE MORE ASSOCIATED WITH ACL INJURIES

Lower Extremity Sagittal Plane Angles (ACL-Inj vs. Control)





Boden et al, 2022

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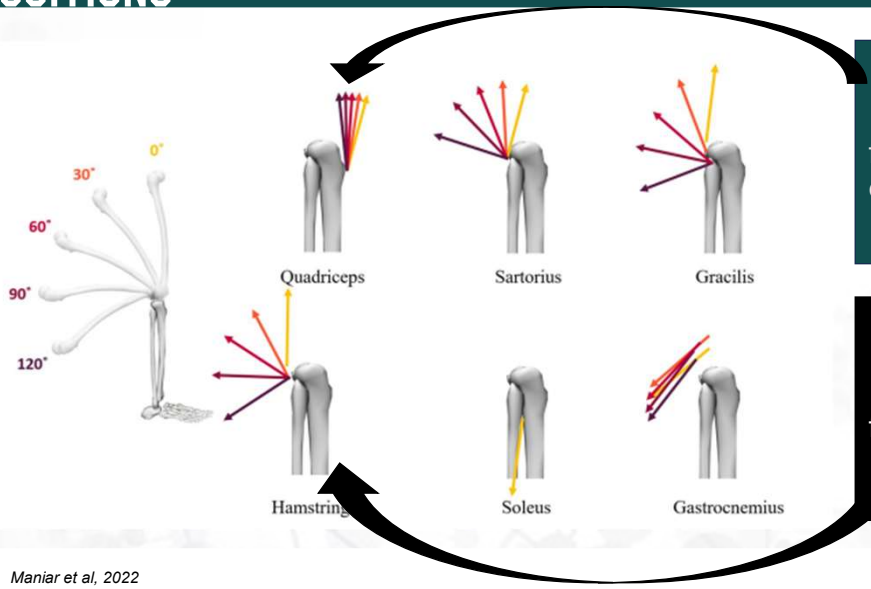
MUSCLE FORCES ARE ALSO NOT OUR FRIENDS IN EXTENDED LEG POSITIONS



Quadriceps exert the **MOST** anterior shear forces on the ACL at 50 degrees or less of knee flexion

Hamstrings exert the **LEAST** posterior shear forces on the ACL at 30 degrees or less

Maniar et al, 2022

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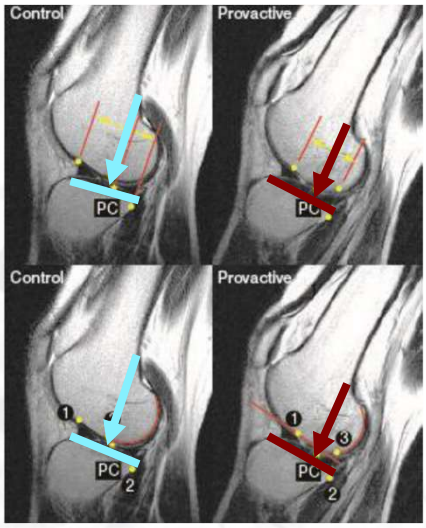
OUR QUADS ARE ONLY OUR FRIENDS IF WE FEEL STRONG ENOUGH TO LAND WITH GREATER KNEE FLEXION



Addition of quadriceps force in cadavers led to a 45% decrease in axial forces necessary to produce an ACL rupture

Boden et al, 2022

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THOSE WITH PATELLAR TENDINOPATHY MAY HAVE MECHANICAL DISADVANTAGES IN TORQUE PRODUCTION

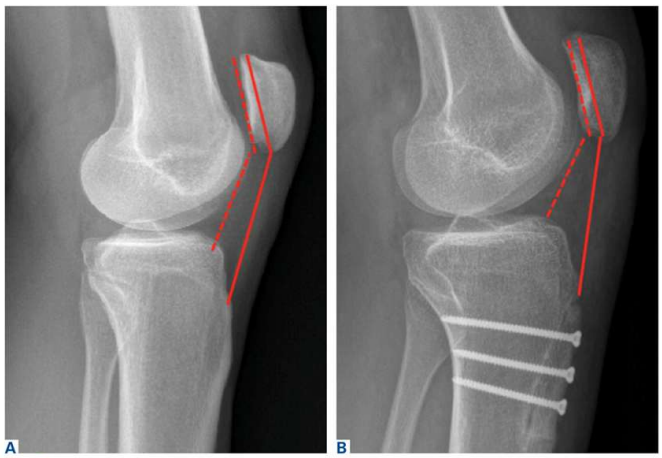

Figure 7. Patellar height (A) before and (B) after distalization of the tibial tubercle. Insall-Salvati index (solid line) does not change after distalization; Caton-Deschamps index (dotted line) documents correction.

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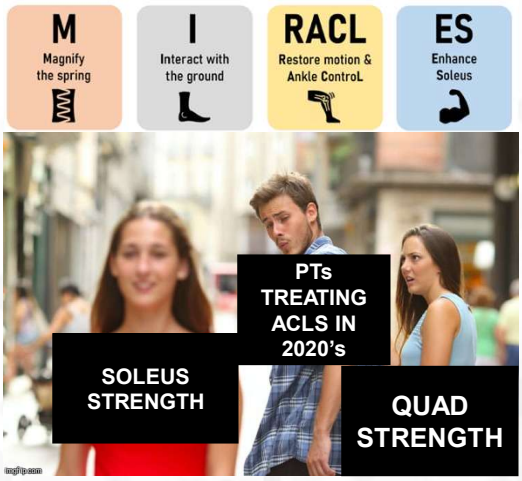
SOLEUS AND OTHER SURROUNDING MUSCLES ARE IMPORTANT, BUT QUADRICEPS STRENGTH SHOULD REMAIN THE PRIMARY FOCUS



Tourillon and Fourchet et al, 2023

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QUAD TESTING IS RELIABLE, BUT MAY BE UNDERESTIMATED WITH HHD

EXTENSION MAKE TEST
Interrater ICC = .88
Intrarater ICC = .94
r = .70 - .89
RTD250 r = .83

FLEXION MAKE TEST
Interrater ICC = .84-.96
Intrarater ICC = .89-.94
r = .53-.55

Lesnak et al, 2018; Sinacore et al, 2017; Whitley et al, 2012

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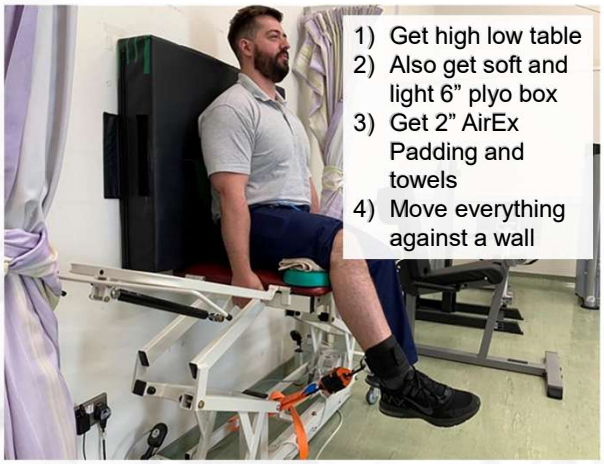
EXCELLENT RELIABILITY AND VALUES ARE POSSIBLE WITH THE RIGHT SET UP



1) Get high low table
2) Also get soft and light 6" plyo box
3) Get 2" AirEx Padding and towels
4) Move everything against a wall

Norris et al, 2023

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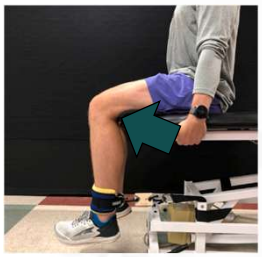
...AND QUICK SET UPS



	HUMAC Norm	MicroFET 2	Tindeq 150
Peak Torque Uninvolved Limb (Nm/kg)	2.98 ± 0.87	3.03 ± 0.71	3.30 ± 0.96
Peak Torque Involved Limb (Nm/kg)	2.64 ± 1.03	2.61 ± 0.86	2.81 ± 1.05
LSI (%)	0.88 ± 0.19	0.85 ± 0.16	0.85 ± 0.18

Center et al, 2024

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...AND QUICK SET UPS



Interclass Correlation coefficients vs. HUMAC Norm Cohen's Kappa k (95% CI); alpha = .05

	MicroFET 2	Tindeq 150
Peak Torque Uninvolved Limb (Nm/kg)	.84 (.69 - .92)	.91(.81-.95)
Peak Torque Involved Limb (Nm/kg)	.93 (.69 - .92)	.98 (.96-.99)
LSI (%)	.79 (.60-.90)	.89 (.78-.95)

Kappa k interpretation: ≤ 0: no agreement; 0.01–0.20: none to slight; 0.21–0.40: fair; 0.41– 0.60: moderate; 0.61–0.80: substantial; 0.81–1.00: almost perfect agreement.

Center et al, 2024

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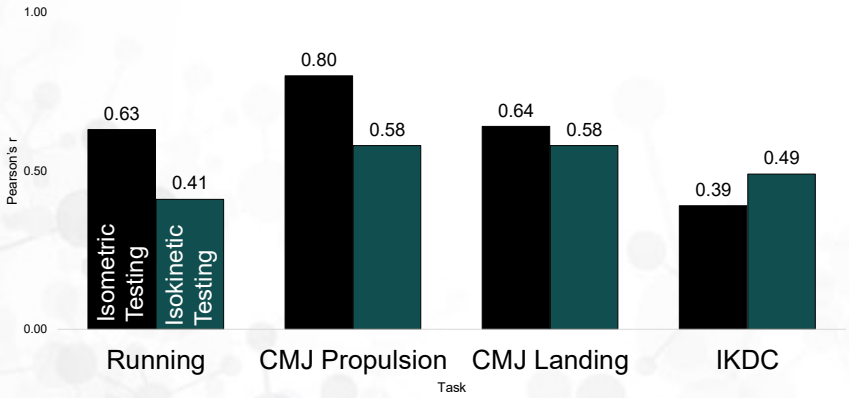
QUAD SYMMETRY ON ONE TASK DOES NOT MEAN SYMMETRY ON ANOTHER TASK

Correlation of Quad LSI on Functional LSI



Symmetry on force plates does not mean symmetry on isometric knee extension tests

Symmetry on isometric knee extension tests does not mean symmetry on force plates

Cobian et al, 2024

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BILATERAL METRICS HAVE THE MOST EVIDENCE IN SUPPORT OF RE-INJURY RISK AND OTHER PROBLEMS

1% decrease in Quad LSI
= 4% increase in risk of early onset symptomatic OA

Quad LSI 90% = 54% Risk
Quad LSI 87% = 66% Risk
Quad LSI 70% = 74% Risk
…

1% decrease in Quad LSI
= 3% increase in re-injury risk

Quad LSI 90% = 6% Risk
Quad LSI 87% = 18% Risk
Quad LSI 70% = 66% Risk
…

Arhos et al, 2020; Grindem et al, 2016

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BUT UNILATERAL METRICS MAY BE IMPORTANT IN LONG TERM PERFORMANCE

Isometric Peak Torque to Bodyweight Goal

$\geq 90\%$

Larson et al, 2021

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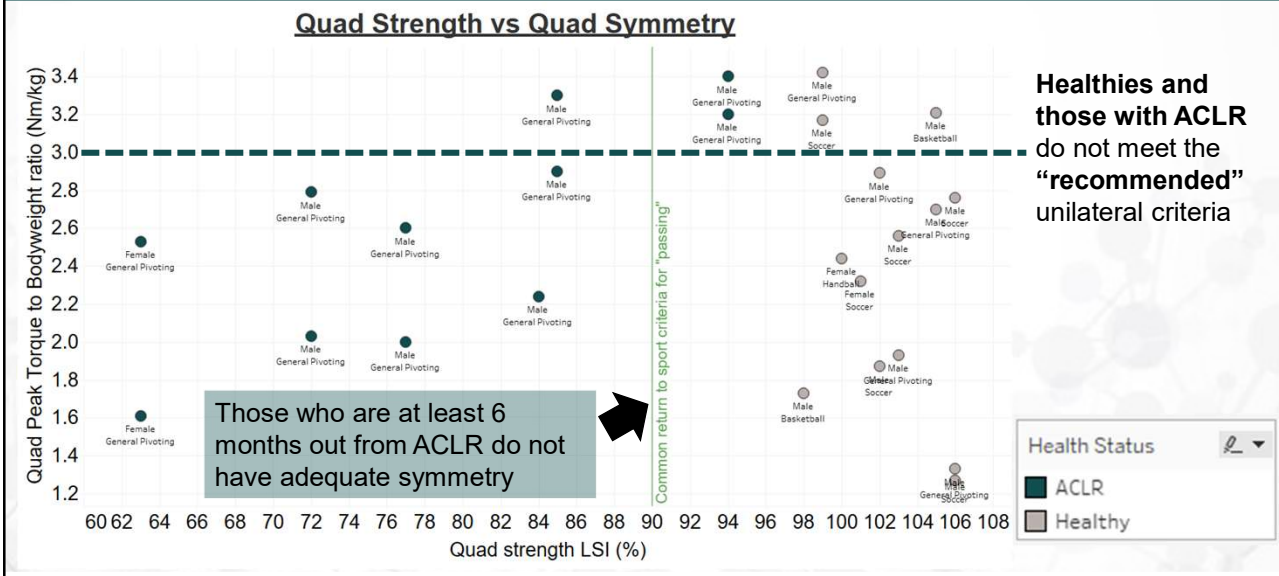
ACLR ATHLETES ARE RETURNING SYMMETRICAL, BUT NOT STRONG



Healthies and those with ACLR do not meet the **"recommended"** unilateral criteria

Van Melick et al, 2024

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RFD IS IMPORTANT, BUT TROUBLESOME

- Minimal evidence in support of re-injury
- Inconsistent set up and cueing
- Requires skill and familiarity
- High coefficient of variability

Rate of Torque Development Goal

≥90%

Knurr et al, 2021; Turpeinen et al, 2020; Cobian et al, 2017

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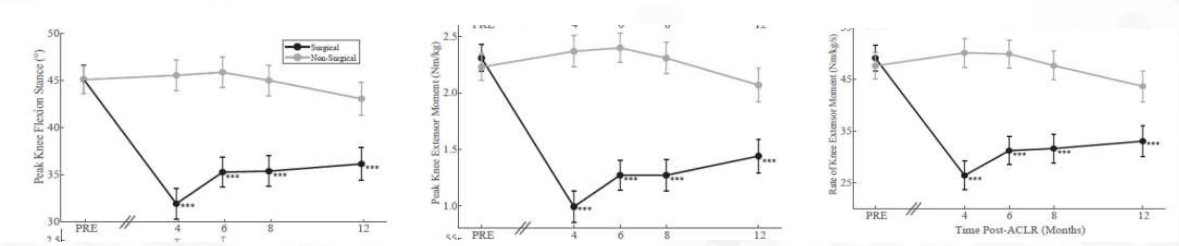
DESPITE IT'S NUANCE, IT HAS UTILITY

Those with decreased knee flexion also have decreased knee extension torque and RFD when running, although the RFD changes more resemble the knee flexion changes.



Knurr et al, 2021; Turpeinen et al, 2020; Cobian et al, 2017

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THERE IS LIMITED EVIDENCE IN UTILITY OF HAMSTRING TO QUAD RATIO

?

Hamstring to Quad Strength Ratio Goal

≥60%

Kellis et al, 2022; Weinhandl et al, 2014

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QUAD STRENGTH IS A PREDICTOR OF GOOD RUNNING MECHANICS AFTER KNEE INJURIES

In order to achieve >85% LSI on knee flexion angle at mid-stance:

1.72 Nm/kg (57%BW):
Sensitivity: 83%
Specificity: 66%

>=2.30 Nm/kg (77% BW): 100% of them were GREAT!
<=1.25 Nm/kg (41% BW): 100% of them SUCKED!

LSI is a poor predictor, however some say 66% is ideal, although 84% were the best of the best.

Megan Graham – unpublished data at CSM 2023

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ADEQUATE QUAD SYMMETRY CAN ALSO LEAD TO DECREASED RATES OF COMPLICATIONS DURING RUNNING – ISOKINETICS LAG BEHING ISOMETRICS

>60% Quad imb symmetry index at 60 degrees per second:

- 3x decrease in complaint of anterior knee pain
- 10x less rate of arthrofibrosis (chicken or the egg?)

OVERALL RECOMMENDATIONS FOR RUNNING:

- Full knee ROM
- 60% Quad Limb Symmetry Index
- 58% PT:BW
- 4 months after surgery

Grondin et al, 2022; Dauty et al, 2022; Iwame et al, 2021

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AIM FOR LSI OF 75 PERCENT IF USING HHD DUE TO OVERESTIMATION AND CONTRACTION SPEED

CASE	ISOMETRIC LSI (%)	ISOKINETIC 60 LSI (%)
ACLR + MMR, LET (Quad)	86	71
ACLR + MMR, LMR, LET (Quad)	74	62
Patellar tendon repair	92	32
ACLR + LET (BTB)	71	66
ACLR (Quad)	89	76
Average LSI difference between speeds	21	

Me - unpublished

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MY QUAD STRENGTH CRITERIA

- **Return to running:** >75% limb symmetry index in quadriceps
  - 57-77% BW or 1.72-2.30 Nm/kg
  - Ultimately, the higher the better
- **Full Return to Sport:** >90% limb symmetry index in quadriceps
- **Normative data (level 1 cutting sports; Larson et al, 2022)**
  - Knee Extension(Nm/kg): 1.5-2.2 (youth), 2.2 – 3.5 (adults)

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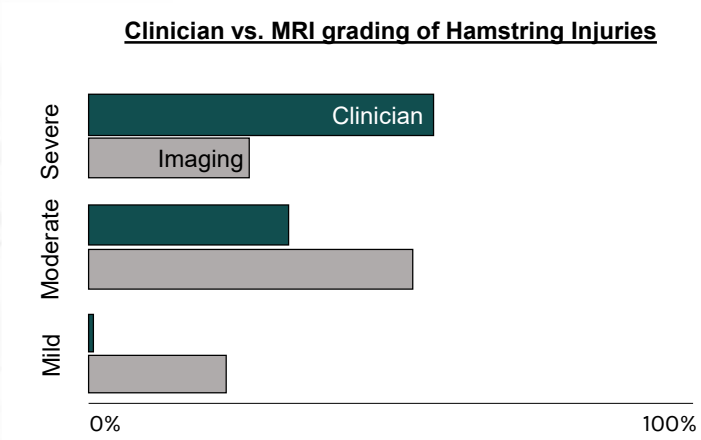
WE ARE NOT GOOD AT GRADING HAMSTRING INJURIES...

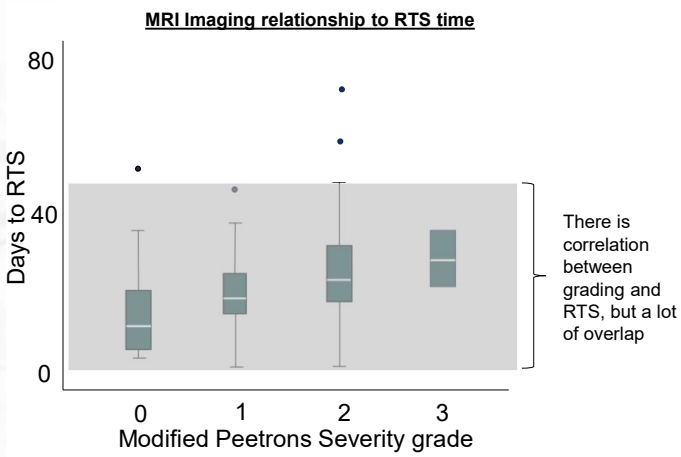


21% had no signs of Injury on MRI

Wangensteen et al, 2018; Schneider-Kolsky et al, 2006

85

IMAGING IS NOT THE GREATEST AT PROGNOSIS OF HAMSTRING INJURIES



Modified Peetrons Severity Grading

BAMIC

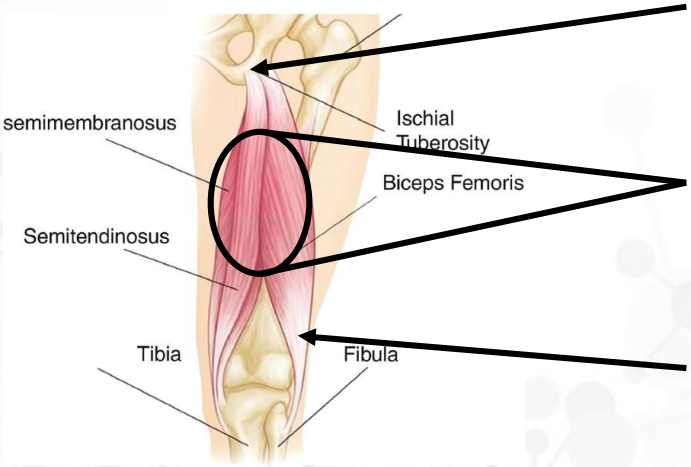
Chan Classification

Radiomics

Torres-Velazquez et al, 2024; Wille et al, 2024; Wangensteen et al, 2018

86

KIND OF...



There is contradictory evidence to suggest injury location is related to RTS time

Volume and cross-sectional area may be correlated with return to sports

There is contradictory evidence to suggest injury to specific muscle is related to RTS time

Wangensteen et al, 2018

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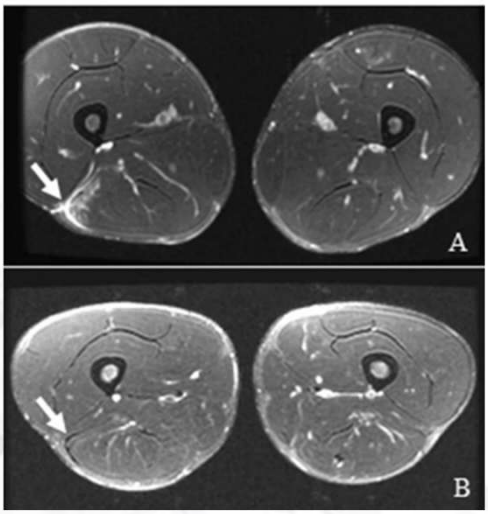
ATROPHY AND SCARRING REMAIN 6-MONTHS AFTER RTS DESPITE FUNCTION, STRENGTH, AND EDEMA RESTORING



Change in muscle qualities from RTS to 6-months after		
Biceps Femoris Long Head Volume	injured	-3%
	uninjured	-3.2%
Biceps Femoris Short Head Volume	injured	-7.5%
	uninjured	-4.7%
Semitendinosus Volume	injured	-3.3%
	uninjured	-4.9%
Peak Torque	injured	11.5%
	uninjured	0%
Angle of Peak Torque	injured	-11 deg
	uninjured	-10 deg
Work	injured	+22%
	uninjured	+6.4%

Sanfillippo et al, 2014

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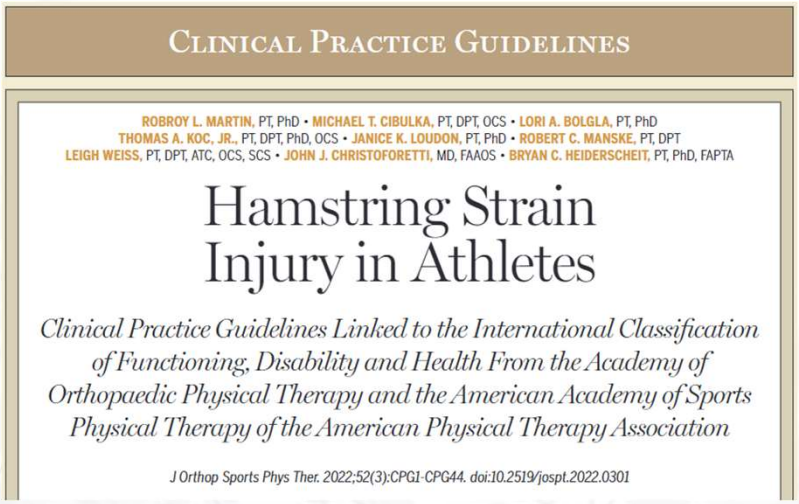
CLINICAL PRACTICE GUIDELINES ARE BEST EVIDENCE ON MANAGING AN INJURY


CLINICAL PRACTICE GUIDELINES

ROBROY L. MARTIN, PT, PhD • MICHAEL T. CIBULKA, PT, DPT, OCS • LORI A. BOLGLA, PT, PhD
THOMAS A. KOC, JR., PT, DPT, PhD, OCS • JANICE K. LOUDON, PT, PhD • ROBERT C. MANSKE, PT, DPT
LEIGH WEISS, PT, DPT, ATC, OCS, SCS • JOHN J. CHRISTOFORETTI, MD, FAAOS • BRYAN C. HEIDERSCHEIT, PT, PhD, FAPTA

Hamstring Strain Injury in Athletes

Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy of the American Physical Therapy Association

J Orthop Sports Phys Ther. 2022;52(3):CPG1-CPG44. doi:10.2519/jospt.2022.0301

Martin et al, 2022

89

CLINICAL PRACTICE GUIDELINES ARE BEST EVIDENCE ON MANAGING AN INJURY

RECOMMENDATIONS

- **A** **Strong Evidence** - Clinicians MUST or SHOULD perform this
- **B** **Moderate Evidence -** Clinicians SHOULD perform this
- **C** **Weak Evidence -** Clinicians MAY perform this
- **D** **Conflicting Evidence -** Clinicians MAY perform this
- **E** **Theoretical Evidence -** Clinicians MAY perform this
- **F** **Expert Opinion -** Clinicians MAY perform this

Martin et al, 2022

90

CLINICIANS SHOULD QUANTIFY RANGE OF MOTION, STRENGTH, AND USE IT TO GUIDE REHAB

RECOMMENDATIONS

A

Quantify knee flexor strength with dynamometer

Assess hamstring length in 90-deg hip flexion

B

Hx of injury

Impairment-based progression

Strength, walking, pain level, area of tenderness

FASH

Use FASH

Martin et al, 2022

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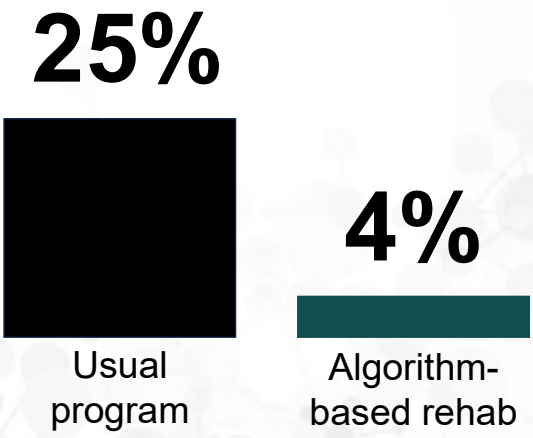
THOSE WHO USE ALGORITHM-BASED REHAB HAD A 6X DECREASE IN HAMSTRING RE-INJURY

Re-injury rate between standard care and impairment-based program



Martin et al, 2022; Mendiguchia et al, 2017

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OBJECTIVE MEASURES ARE A KEY PART OF ALGORITHM-BASED REHAB

Regeneration

Test	Criteria
Palpation	No pain
Strength	≥90% LSI
Slump test	Negative slump
AKE Test	≥90% LSI
Modified Thomas test	+5 symmetry below horizontal

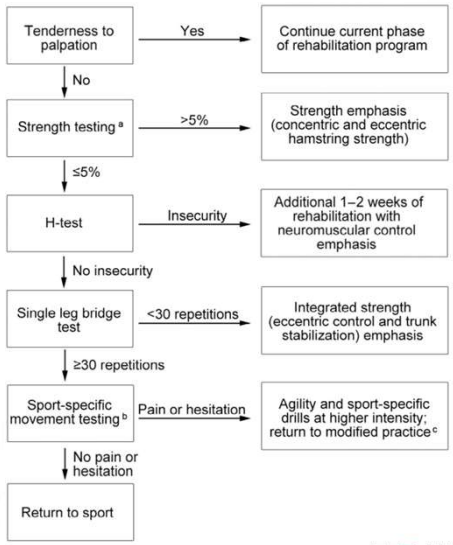
Functional

Test	Criteria
Palpation	No pain
Peak Torque LSI @ 60 d/sec	≥90% LSI
Ham:Quad	≥.45
Prone hip extension	≥90% LSI
Triple hop	≥90% LSI
SL Bridge	≥25 and ≥90% LSI
ASLR test	No compensations
Askling H-Test	No pain and insecurity

Martin et al, 2022; Mendiguchia et al, 2017

93

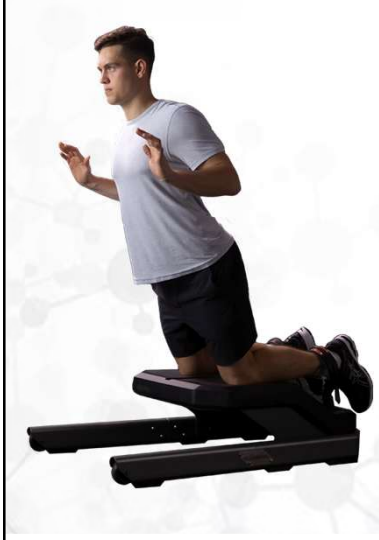
OBJECTIVE MEASURES ARE A KEY PART OF ALGORITHM-BASED REHAB



Martin et al, 2022; Erickson et al, 2017

94

EXPERIENCES TELL ME NORDIC HAMSTRING VARIATIONS MAY UNDERESTIMATE ASYMMETRIES

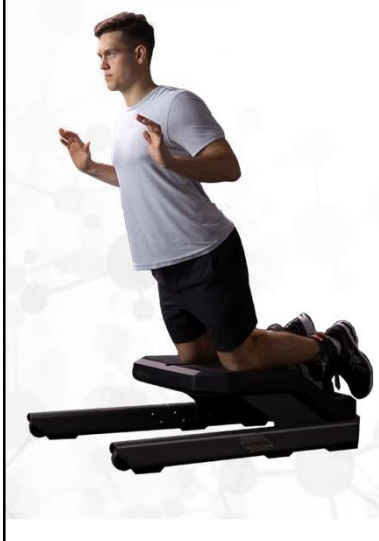


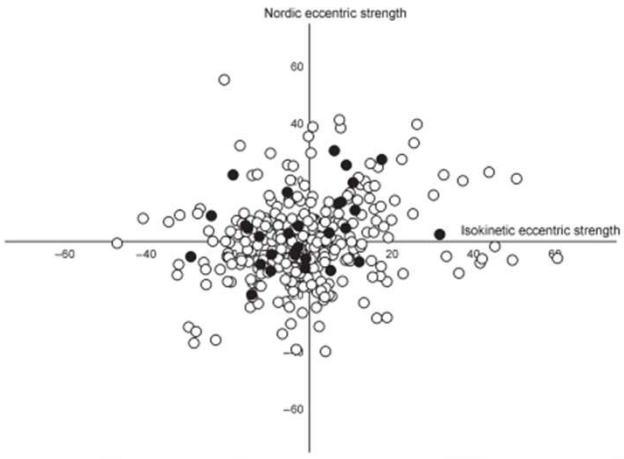
	Nordic Iso 30 R vs L LSI	HHD Break R vs L LSI
Athlete 1	97%	79%
Athlete 2	89%	100%
Athlete 3	109%	86%
Athlete 4	91%	83%

Me, Unpublished

95

...AND THEN RESEARCH CONFIRMED IT.



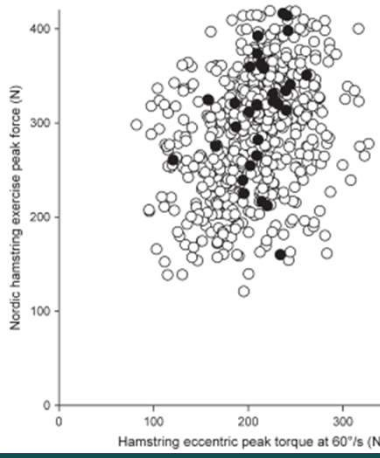


IMBALANCE: r = .037

Martin et al, 2022, van Dyk et al, 2018

96

PEAK FORCES ALSO DIFFER WHEN COMPARING NORDICS TO ISOKINETICS



PEAK FORCE: r = .35

Martin et al, 2022, van Dyk et al, 2018

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NORDICS ARE STILL USEFUL

98

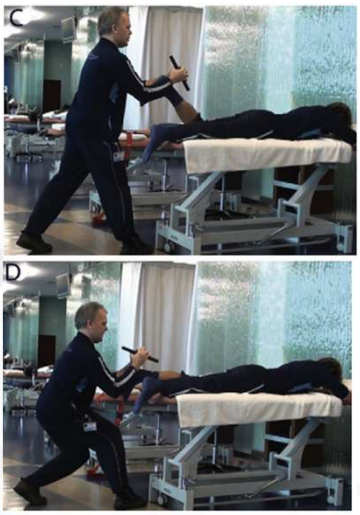
HHD "MAKE" TESTING FOR HAMSTRINGS IS RELIABLE

FLEXION MAKE TEST
Interrater ICC = .84-.96
Intrarater ICC = .89-.94
r = .53-.55

Larson et al, 2022; Martin et al, 2022

99

HHD BREAK TESTING IS ALSO RELIABLE



BREAK TEST INTRARATER RELIABILITY

ICC = .90

Martin et al, 2022; Whiteley et al, 2012

100

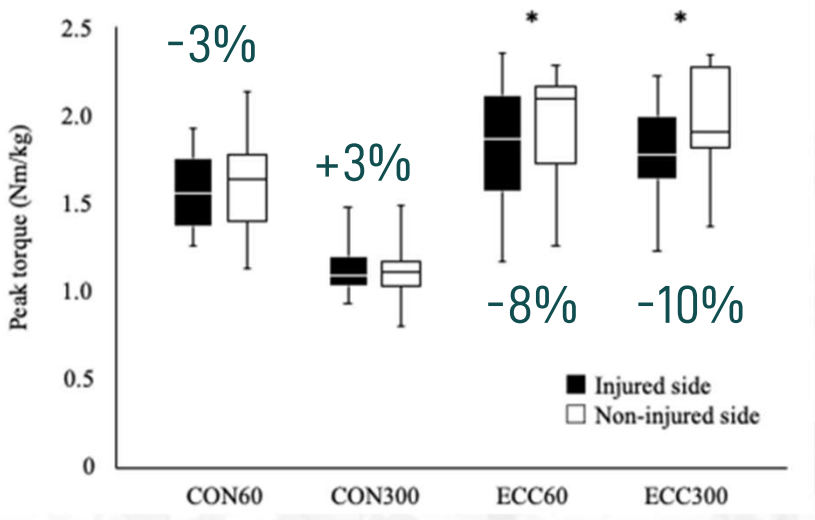
HHD BREAK TESTING IS ALSO RELIABLE

Martin et al, 2022; Whiteley et al, 2012

101

ASYMMETRIES ARE MORE LIKELY TO SHOW UP WITH ECCENTRICS

Between-limb differences with concentric vs. eccentric testing



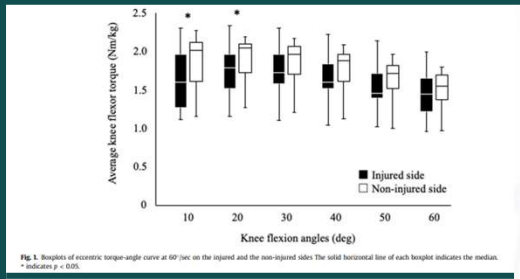
Martin et al, 2022; Mikami et al, 2022

102

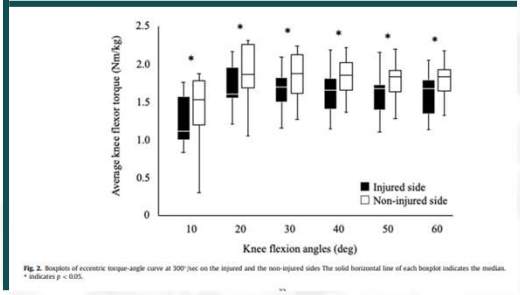
ASYMMETRIES ARE ALSO MORE APPARENT WHEN TESTED AT HIGHER SPEEDS

Asymmetries of hamstring eccentric strength when tested at 60 d/sec vs. 300 d/sec

60 d/sec eccentric



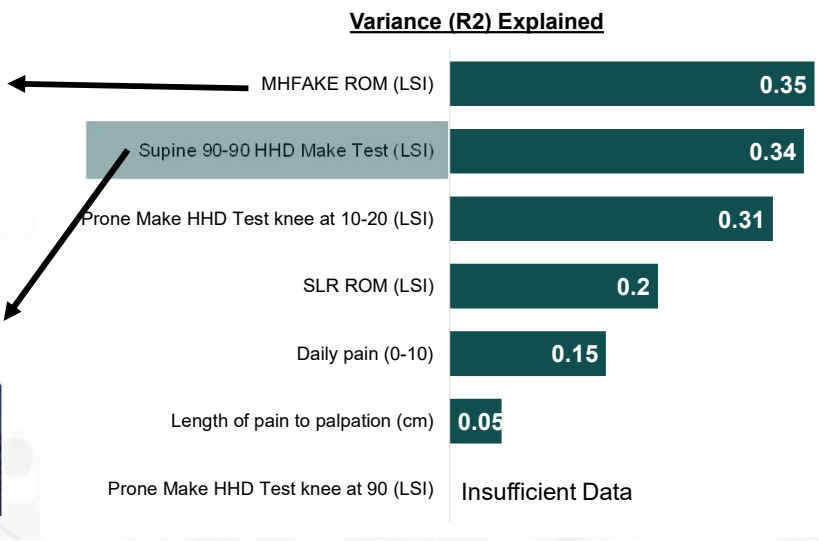
300 d/sec eccentric



Martin et al, 2022; Mikami et al, 2022

103

STRENGTH SEEMS TO BE THE LARGEST CONTRIBUTOR IN TELLING IF SOMEONE IS READY TO RUN



Whiteley et al, 2018

104

MY HAMSTRING STRENGTH CRITERIA

- **Return to running:** >75% limb symmetry index in hamstring
- **Full Return to Sport:** >90% limb symmetry index in hamstring
- **Normative data (level 1 cutting sports; Larson et al, 2022)**
  - Knee Flexion (Nm/kg): 1.0-1.7 (youth), 1.3 – 3.1 (adults)

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LAB ACTIVITY TWO
30 MIN

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LUNCH TIME

I'll be loitering here, so feel free to ask questions, or ask for help on personal initiatives

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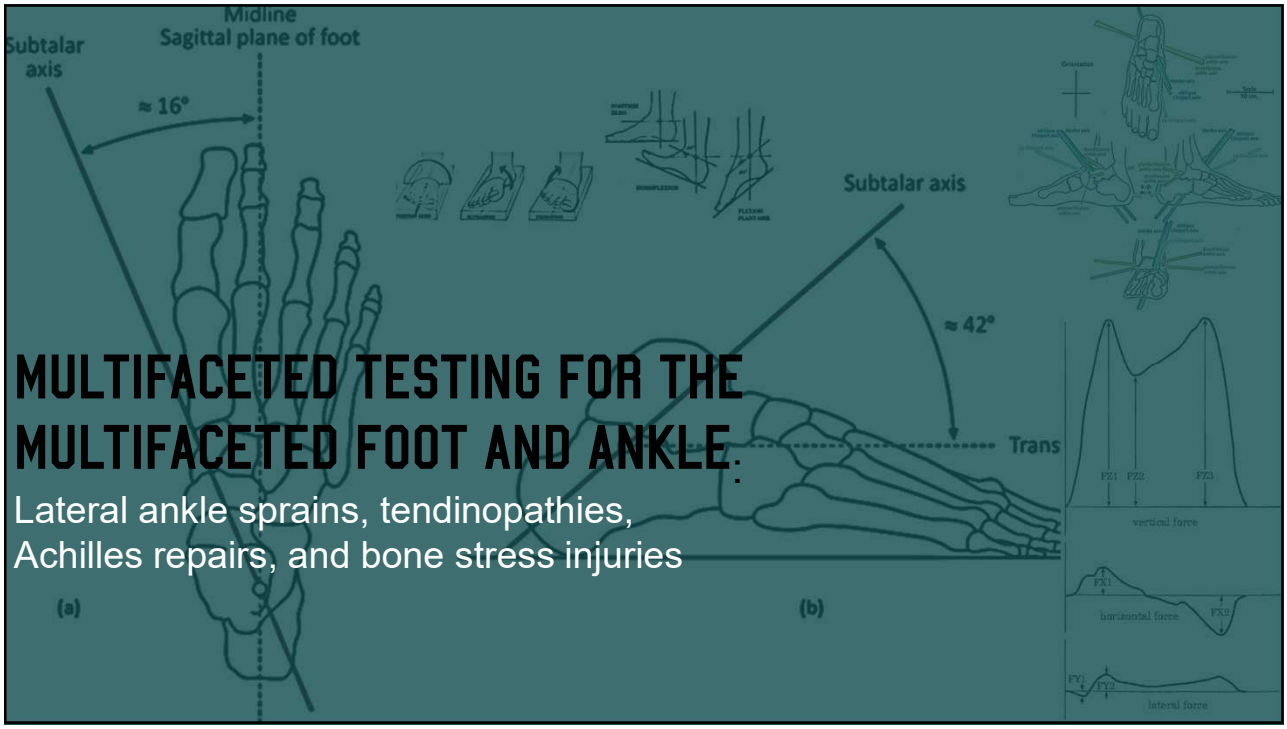

MULTIFACETED TESTING FOR THE MULTIFACETED FOOT AND ANKLE:

Lateral ankle sprains, tendinopathies, Achilles repairs, and bone stress injuries

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IT'S NOT JUST AN ANKLE SPRAIN...

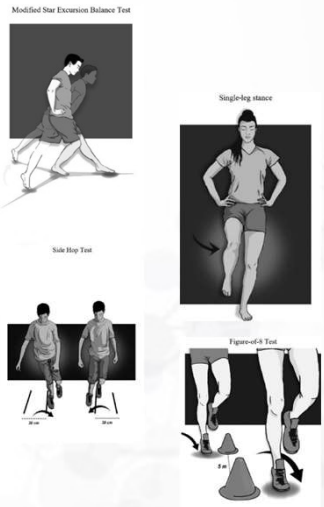
Picot et al, 2024; Karzon et al, 2022; Rhon et al, 2021

109

THERE IS A 9-FOLD INCREASE IN RE-INJURY OF AN ANKLE SPRAIN IN THOSE WHO SCORE LOW ON THE ANKLE-GO

Test	Raw Score	Equivalent Score
Single leg stance	>3 errors	0
	1-3 errors	1
	0 errors	2
	No apprehension	+1
Star excursion balance	<90%	0
	90-95%	2
	>95%	4
	Anterior >60%	+1
	Posteromedial >90%	+1
	No apprehension	+1
Side hop test	>13 sec	0
	10-13 sec	2
	<10 sec	4
	No apprehension	1
Figure 8 hop	>18 sec	0
	13-18 sec	1
	<13 sec	2
	No apprehension	+1
FAAM-ADL	<90%	0
	90-95%	1
	>95%	2
FAAM-Sport	<80%	0
	80-95%	1
	>95%	2
ALR-RSI	<55%	0
	55-63%	1
	63-76%	2
	>76%	3

- High reliability
  - ICC: .99
  - SEM: .41
  - MDC: 1.2
- Low redundancy
- No floor or ceiling effect
- Good predictive validity
  - Return to sport
  - Prior level of function



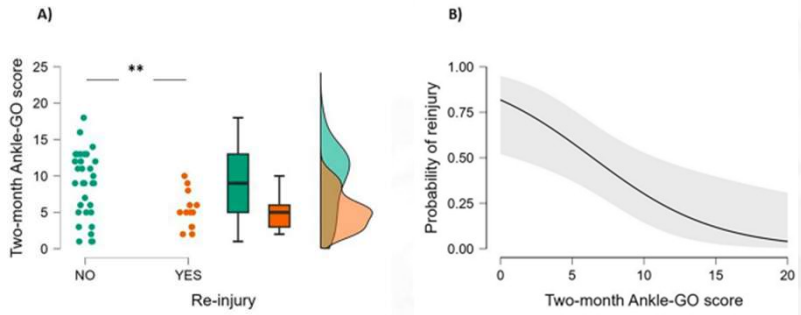
Picot et al, 2024; Picot et al 2024

110

THERE IS A 9-FOLD INCREASE IN RE-INJURY OF AN ANKLE SPRAIN IN THOSE WHO SCORE LOW ON THE ANKLE-GO

Test	Raw Score	Equivalent Score
Single leg stance	>3 errors	0
	1-3 errors	1
	0 errors	2
	No apprehension	+1
Star excursion balance	<90%	0
	90-95%	2
	>95%	4
	Anterior >60%	+1
	Posteromedial >90%	+1
	No apprehension	+1
Side hop test	>13 sec	0
	10-13 sec	2
	<10 sec	4
	No apprehension	1
Figure 8 hop	>18 sec	0
	13-18 sec	1
	<13 sec	2
	No apprehension	+1
FAAM-ADL	<90%	0
	90-95%	1
	>95%	2
FAAM-Sport	<80%	0
	80-95%	1
	>95%	2
ALR-RSI	<55%	0
	55-63%	1
	63-76%	2
	>76%	3

	Injured	Uninjured
FAAM-ADL	78.6 (14.4)	87.2 (14.8)
SEBT Composite	76.6 (8.2)	81.2 (6.8)
SEBT Anterior	57.7 (7.2)	61.7(6.2)



Picot et al, 2024; Picot et al 2024

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VARIABLES OF THE HEEL RAISE TEST MAY HELP SEE IF A PLAYER'S PERCEIVED FUNCTION IS TRUE

	Metric	LSI	Normative Data
Return to Sport	Peak Height LSI	≥78%	Peak Height/Reps
	Work LSI	≥76%	11 cm/ 34 reps
	Repetition LSI	≥95%	
Return to Running	Peak Height LSI	≥71%	Peak Height/Reps
	Work LSI	≥61%	10 cm/ 26 reps
	Repetition LSI	≥84%	

Silbernagel et al, 2010

112

VARIABLES OF THE HEEL RAISE TEST MAY HELP SEE IF A PLAYER'S PERCEIVED FUNCTION IS TRUE

- Validated against force plates and 3D motion capture
- Excellent reliability – sagittal preferred
- Be consistent!
  - Index finger on the wall
  - 10 degree incline
  - Clear criteria and instruction
  - 60 bpm

Fernandez et al, 2022

113

THE HEEL RAISE IS NOT A TRUE MEASURE OF STRENGTH

D1 Female Tennis Players, n = 22 legs

	Soleus Strength	heel raise peak height	heel raise work	heel raise reps
Soleus Strength				
heel raise peak height	0.05			
heel raise work	-0.05	0.49		
heel raise reps	-0.20	0.11	0.28	

Me, unpublished – never ending!!!!

114

SOLEUS STRENGTH CAN BE CHALLENGING TO TEST WITH MINIMAL RETURN-TO-SPORT UTILITY

"If there's many ways to do it, there's
way to do it – Niles

AS OF MARCH 2026 THE BEST WAY IS TO USE THE FORCEFRAME AND I PROMISE I GET NO PAYMENT FOR SAYING THAT

Credit: Rich W

Credit: Erik Meira, The Science PT

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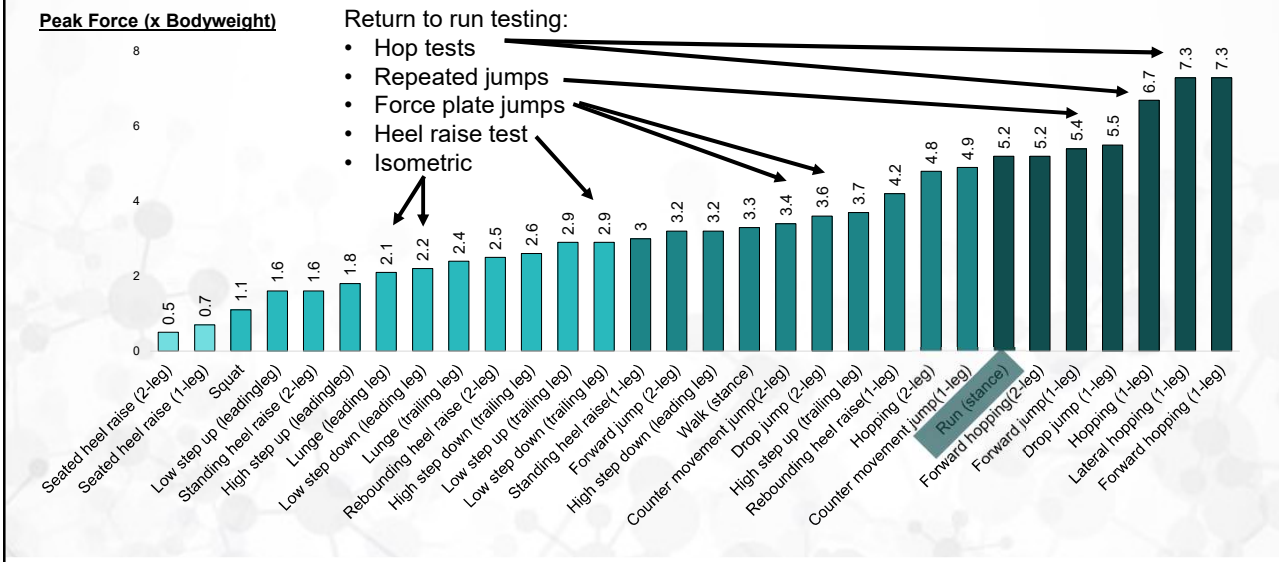
UNDERSTANDING LOAD AND IMPLICATED TISSUES IS LIKELY THE BEST WAY TO JUDGE READINESS



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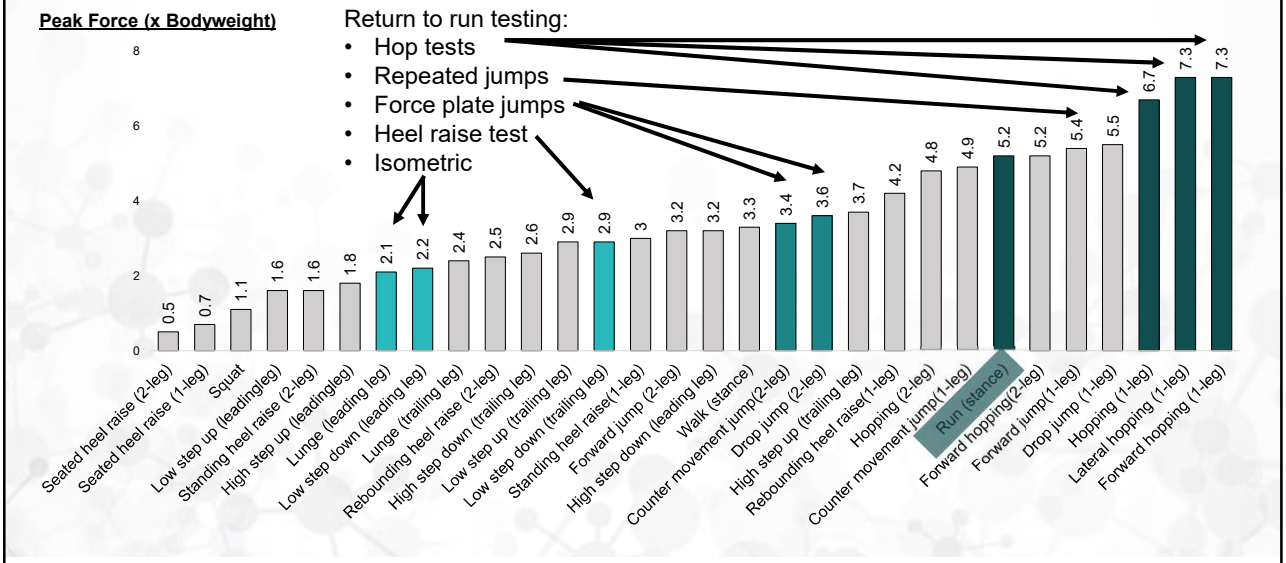
UNDERSTANDING LOAD AND IMPLICATED TISSUES IS LIKELY THE BEST WAY TO JUDGE READINESS



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SELECTED METRICS ARE DEPENDENT ON PURPOSE

PERFORMANCE PROFILING

Purpose: to assess associations with other measures of performance

Metric	What it Assesses
Jump height [cm]	Vertical displacement of the athlete's center of mass
Peak power [W]	Highest rate of doing work during the jump
Mean propulsive force [N]	Mean force produced during ascent
Propulsive impulse [Ns]*	Product of force and time during ascent

Output metrics, including the metrics above, correspond with physical capacities that benefit sport performance, including strength, linear speed, and change-of-direction ability.

NEUROMUSCULAR FATIGUE

Purpose: to detect when neuromuscular fatigue is present

Metric	What it Assesses
Reactive Strength Index (RSI) Modified*	Ratio of output (jump height) to time spent to produce the output (contraction time)
Time to take-off [s]	Total duration from initiation of movement to take-off
Propulsive phase duration [s]	Time spent during ascent (prior to take-off)
Time to peak power [s]*	Amount of time it takes before the greatest amount of power is produced

Time-based metrics, including the metrics above, correspond with acute neuromuscular fatigue (induced by intense physical activity).

RETURN FROM INJURY

Purpose: to assess post-injury progress and preparedness for return to sport

Metric	What it Assesses
Peak propulsive force [N]	Greatest amount of force produced during ascent
Peak landing force [N]	Greatest amount of force produced upon landing from the jump
Landing impulse [Ns]*	Product of force and time during landing from the jump
Asymmetry [%]	Differences in metric outcomes between limbs

Deceleration, landing, and inter-limb asymmetry metrics can differentiate between athletes with and without injuries.

Bishop et al, 2023

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PROPULSIVE METRICS MAY BE BEST FOR PERFORMANCE

PERFORMANCE PROFILING

Purpose: to assess associations with other measures of performance

Metric	What it Assesses
Jump height [cm]	Vertical displacement of the athlete's center of mass
Peak power [W]	Highest rate of doing work during the jump
Mean propulsive force [N]	Mean force produced during ascent
Propulsive impulse [Ns]*	Product of force and time during ascent

Output metrics, including the metrics above, correspond with physical capacities that benefit sport performance, including strength, linear speed, and change-of-direction ability.

- **Jump height:** Correlated with strength and sprint speed
- **Peak power:** Indicates how explosive individual is
- **Mean Propulsive Force:** Tells you about average force produced with leg drive
- **Propulsive Impulse:** Shows ability to produce force over time throughout leg drive

Bishop et al, 2023

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RATE OR TIME-BASED METRICS ARE USEFUL FOR FATIGUE

RSImod: May indicate someone is getting "stuck in the mud"

Time to take-off: May indicate eccentric and concentric movement is sluggish and slow

NEUROMUSCULAR FATIGUE

Purpose: to detect when neuromuscular fatigue is present

Metric	What it Assesses
Reactive Strength Index (RSI) Modified*	Ratio of output (jump height) to time spent to produce the output (contraction time)
Time to take-off [s]	Total duration from initiation of movement to take-off
Propulsive phase duration [s]	Time spent during ascent (prior to take-off)
Time to peak power [s]*	Amount of time it takes before the greatest amount of power is produced

Time-based metrics, including the metrics above, correspond with acute neuromuscular fatigue (induced by intense physical activity).

Propulsive phase duration: May indicate sluggish and slow concentric movement

Time to peak power: May indicate decreased ability to generate force quickly

Bishop et al, 2023

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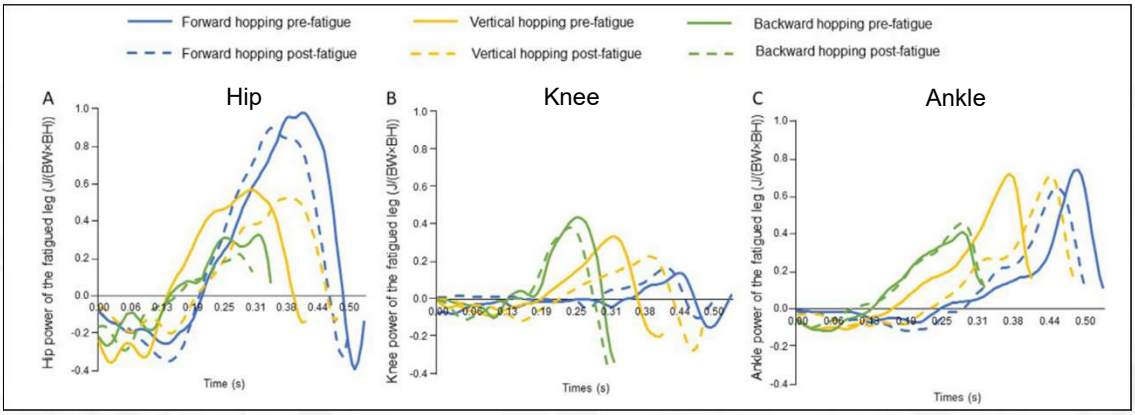
FATIGUE DOES NOT AFFECT POWER, IT AFFECTS TIME

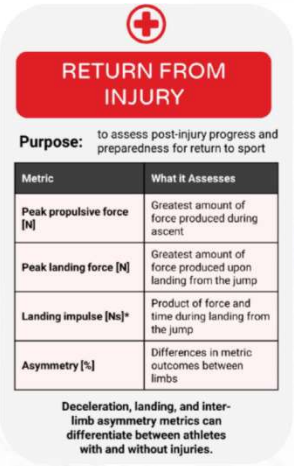


Song et al, 2024

122

ASYMMETRIES ARE USEFUL FOR INJURIES AND REHAB

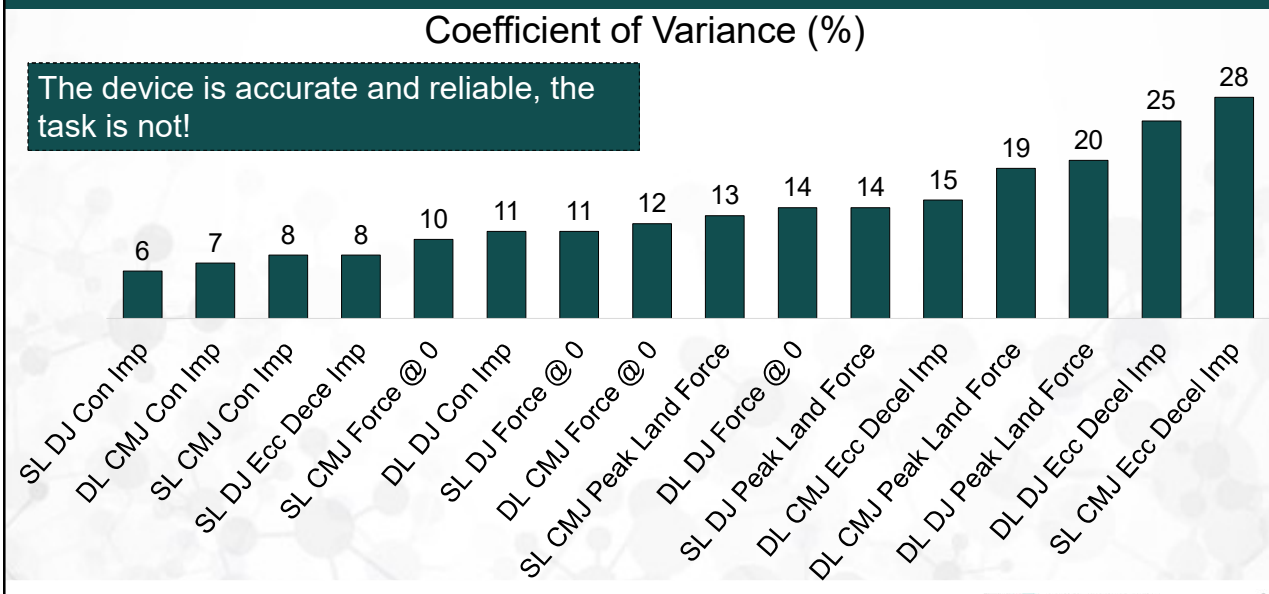
- **Peak propulsive force:** May indicate recovery to baseline leg drive force generation
- **Peak landing force:** May indicate inability to accept large forces during landing
- **Landing Impulse:** May indicate inability to accept large forces during entire landing phase
- **Asymmetries:** May indicate injured limbs inability to equally produce leg drive or load acceptance during key phases.



Bishop et al, 2023

123

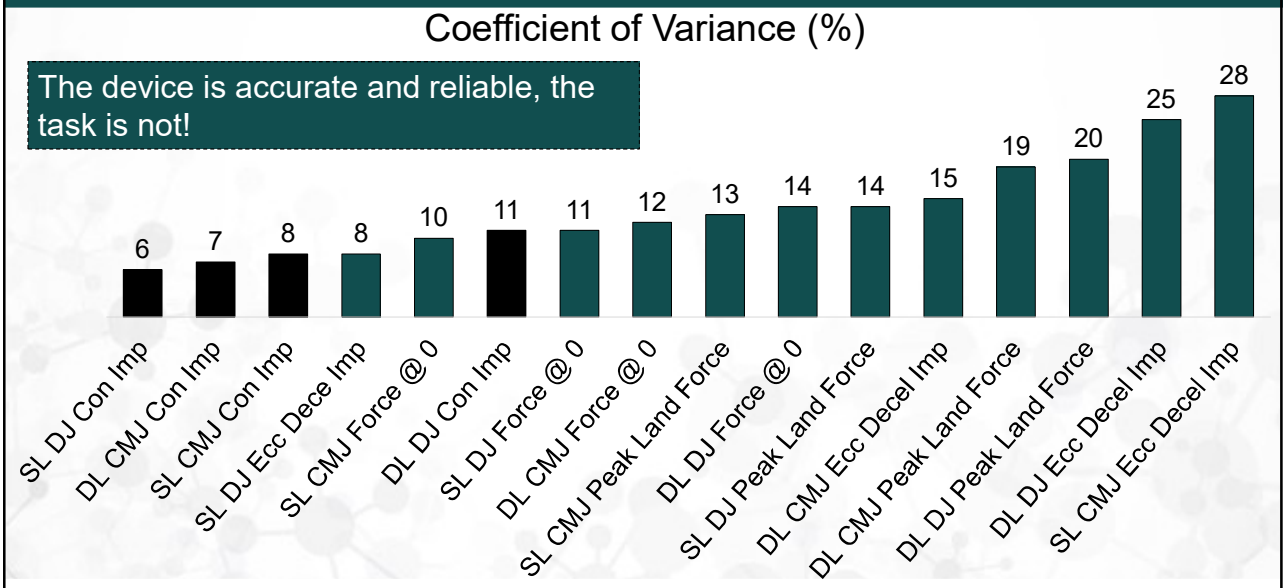
POWER-BASED MOVEMENTS HAVE HIGH VARIABILITY



Kotsafaki et al, 2023

124

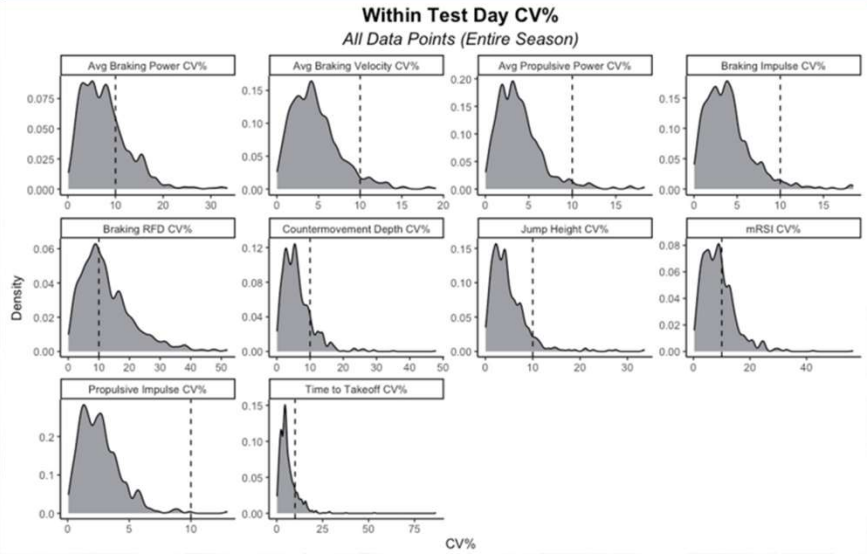
POWER-BASED MOVEMENTS HAVE HIGH VARIABILITY



Kotsafaki et al, 2023

125

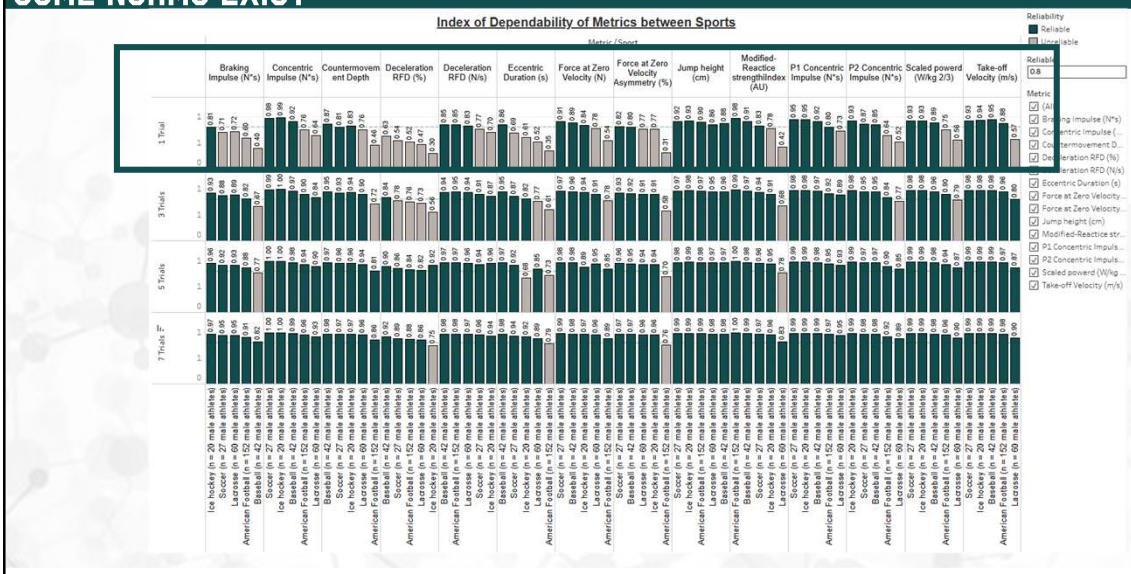
SYMMETRY-BASED METRICS SEEM TO BE THE CULPRIT FOR HIGH COEFFICIENT OF VARIABILITY



Philipp et al, 2023

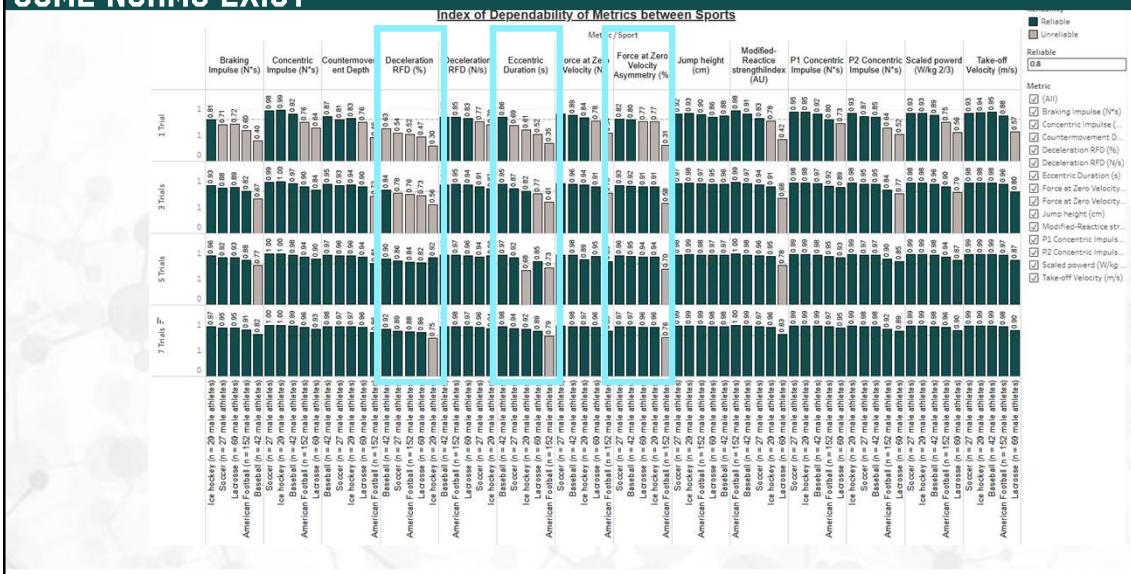
126

ACCESSING YOUR COHORT DATA IS IMPORTANT IN DETERMINING RELIABILITY, BUT SOME NORMS EXIST



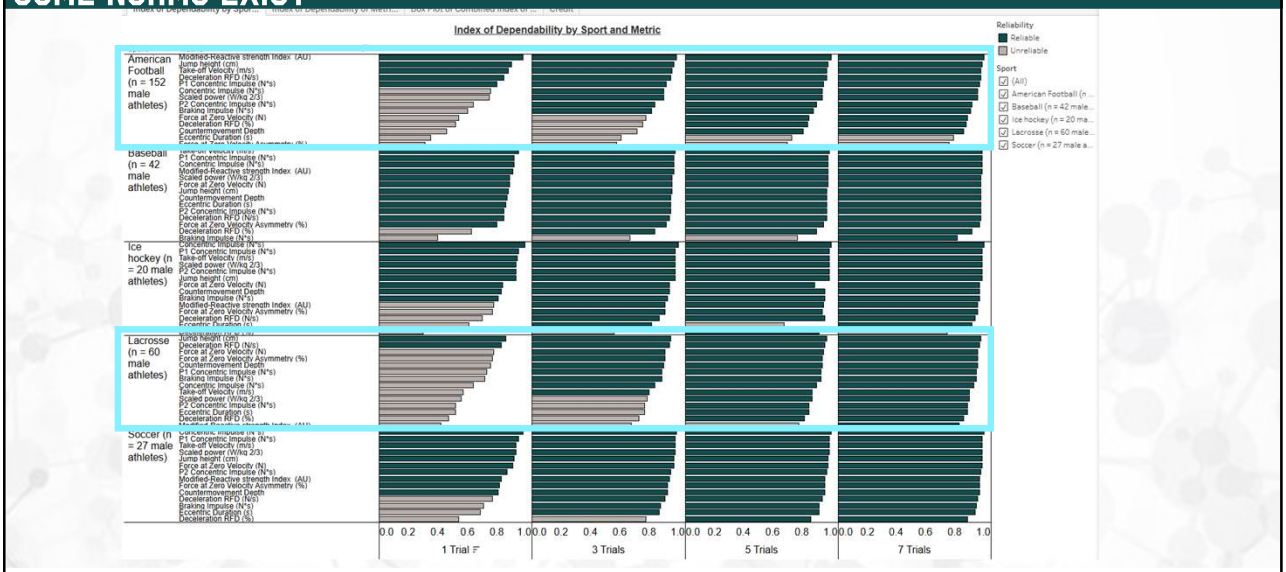
Huebner et al, 2025

ACCESSING YOUR COHORT DATA IS IMPORTANT IN DETERMINING RELIABILITY, BUT SOME NORMS EXIST



Huebner et al, 2025

ACCESSING YOUR COHORT DATA IS IMPORTANT IN DETERMINING RELIABILITY, BUT SOME NORMS EXIST



Huebner et al, 2025

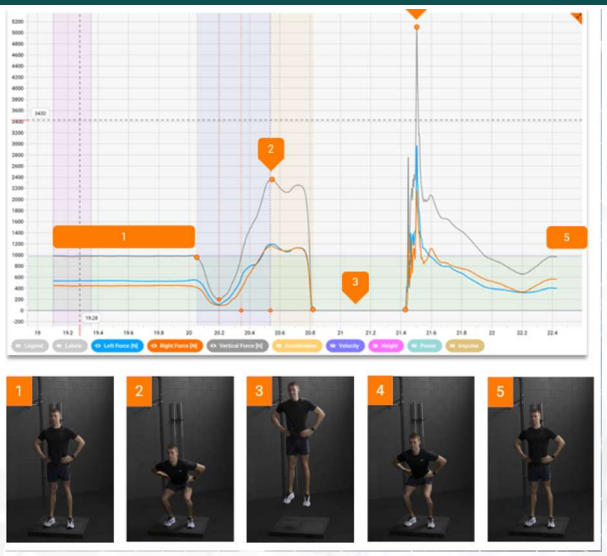
MULTIPLE STUDIES TEND TO RECOMMEND 3 METRICS

Eccentric deceleration impulse or RFD asymmetry:

Concentric impulse asymmetry:

Peak landing asymmetry:

*Eccentric peak velocity or peak power/BW:



Kotsafaki et al, 2023; Bishop et al, 2023, Read et al, 2020

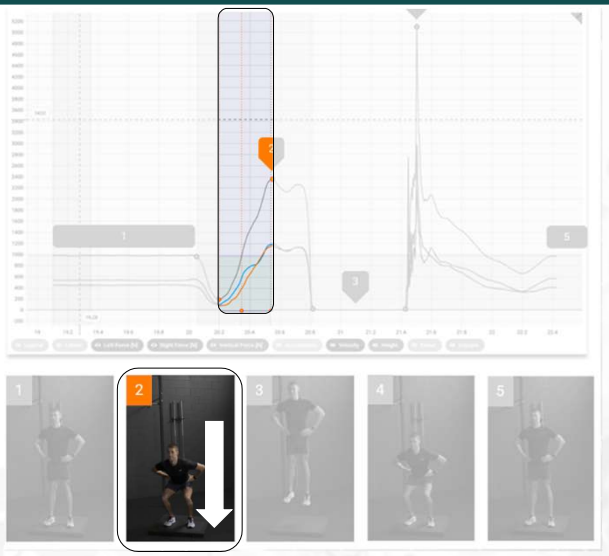
BRAKING ASYMMETRY MAY INDICATE POOR MOTOR PATTERN

Eccentric deceleration impulse:

Concentric impulse asymmetry:

Peak landing impulse asymmetry:

*Eccentric peak velocity or peak power/BW:



Kotsafaki et al, 2023; Bishop et al, 2023, Read et al, 2020

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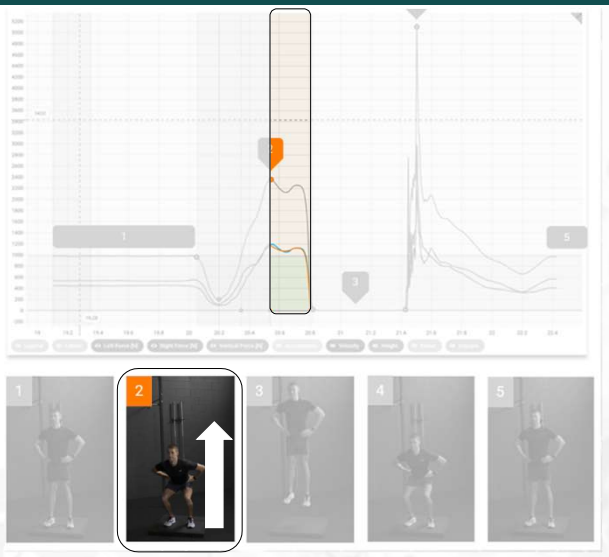
CONCENTRIC IMPULSE WAS DEFICIENT IN THOSE REHABBING OR HAD A HISTORY OF ACLR

Eccentric deceleration impulse asymmetry:

Concentric impulse asymmetry:

Peak landing impulse asymmetry:

*Eccentric peak velocity or peak power/BW:



Kotsafaki et al, 2023; Bishop et al, 2023, Read et al, 2020

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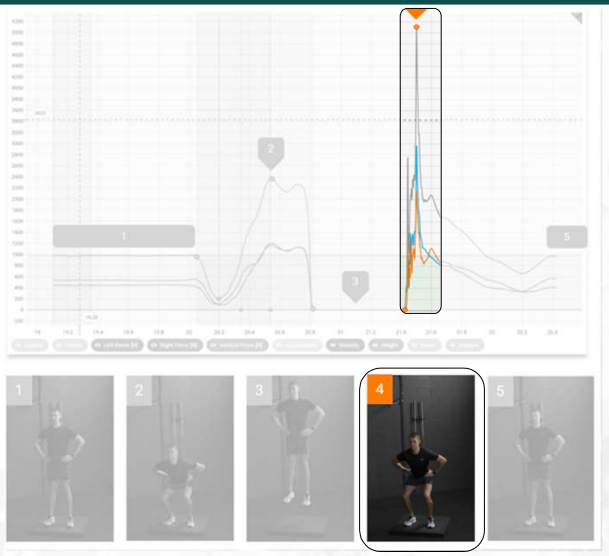
LANDING IMPULSE HAD SIGNIFICANT ASYMMETRIES MONTHS AFTER ACLR AND BETWEEN HEALTHY CONTROLS

Eccentric deceleration impulse asymmetry:

Concentric impulse asymmetry:

Peak landing impulse asymmetry:

*Eccentric peak velocity or peak power/BW:



Kotsafaki et al, 2023; Bishop et al, 2023, Read et al, 2020

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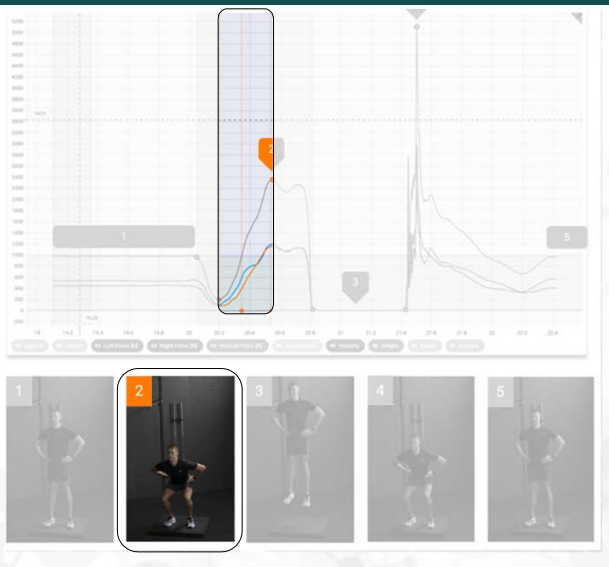
OBSERVING HOW FAST A PERSON ACCEPTS WEIGHT

Eccentric deceleration impulse or RFD asymmetry:

Concentric impulse asymmetry:

Peak landing asymmetry:

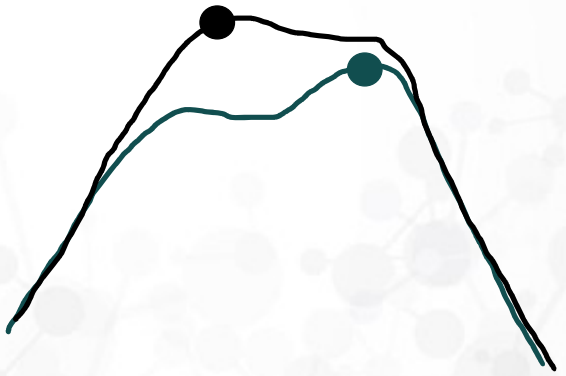
***Eccentric peak velocity or peak power/BW:**



Kotsafaki et al, 2023; Bishop et al, 2023, Read et al, 2020

134

PEAK FORCE
OR
MEAN FORCE



Lake et al, 2020

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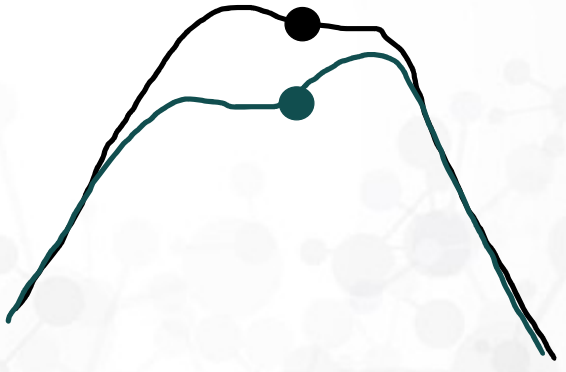
135

PEAK FORCE
OR
MEAN FORCE



Lake et al, 2020

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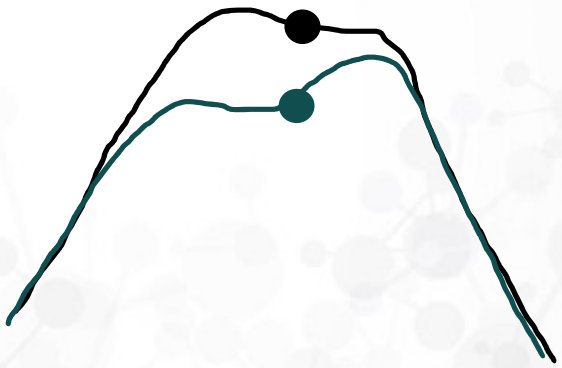
PEAK FORCE OR MEAN FORCE



Eccentric Braking κ = 67% (substantial)
Concentric κ = 72% (substantial)

Lake et al, 2020

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Double Leg Countermovement Jump	Metric	LSI
Return to Sport	Concentric Impulse LSI	≥95%
	Eccentric Deceleration Impulse LSI	≥90%
	Peak Landing Impulse LSI	≥90%
	Peak Eccentric Velocity	≤-1.2 (m/s)
Return to Running	Concentric Impulse LSI	≥85%
	Eccentric Deceleration Impulse LSI	≥70%
	Peak Landing Impulse LSI	≥70%
	Peak Eccentric Velocity	≤-1.2 (m/s)

Read et al, 2020

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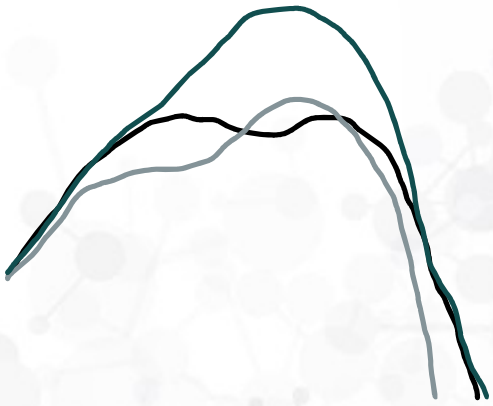
FORCE-TIME WAVEFORM MAY INDICATE MOVEMENT PROFICIENCY

Cluster 1

Cluster 2

Cluster 3



Guess et al, 2020

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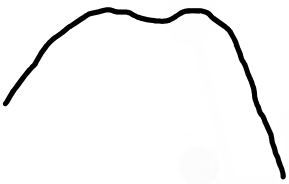
SEAMLESS CURVES INDICATE POWERFUL ATHLETES

Cluster 1	Cluster 2	Cluster 3
		
Low jump height, low RFD, and low power; inefficient jumper	Great jump height, good RFD, good power, and good at decel; Strong athlete that can likely improve on power	Great jump height, great RFD, great power, great decel; Explosive and powerful athletes

Guess et al, 2020

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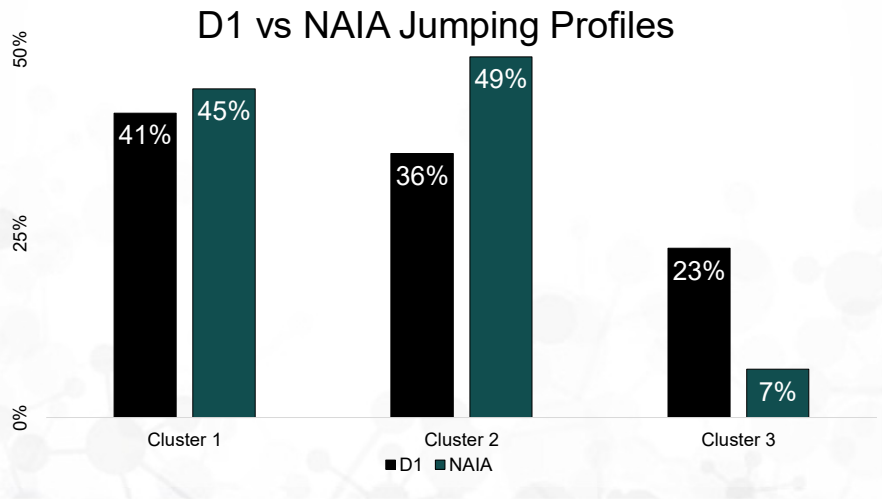
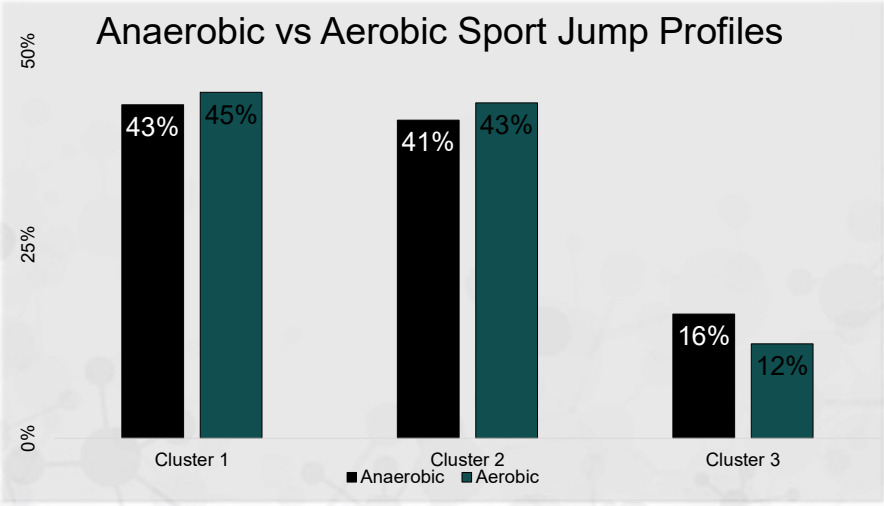
A HIGHER PROPORTION OF D1 ATHLETES FIT CLUSTER 3



Guess et al, 2020

141

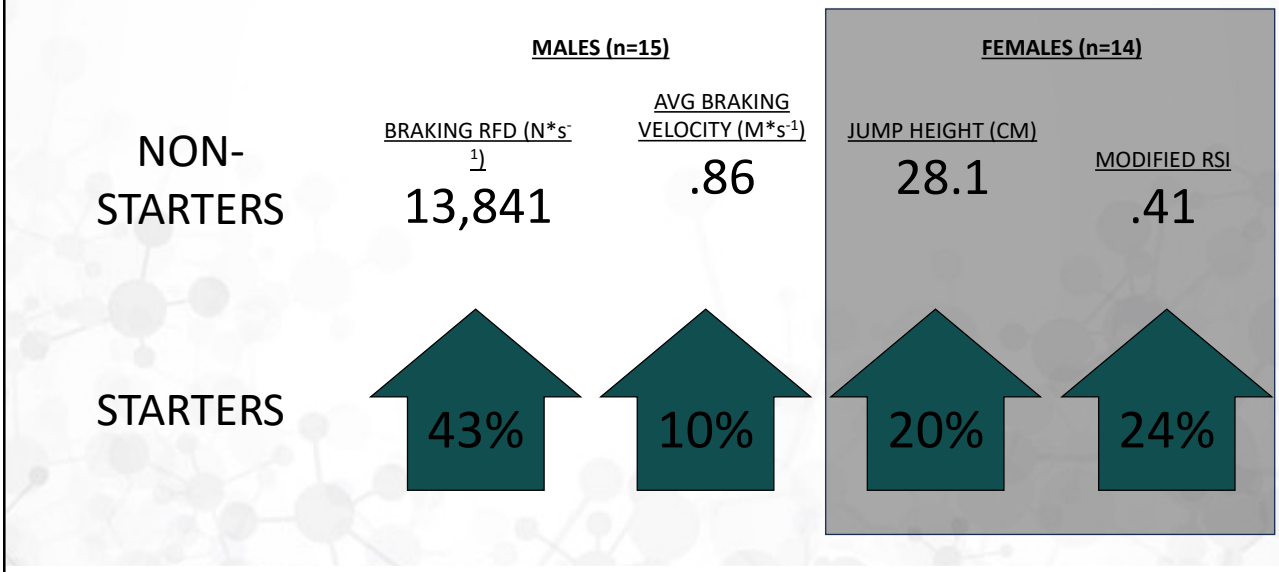
PROFICIENCY IS GOOD ACROSS ALL SPORTS



Guess et al, 2020

142

JUMP METRICS MAY DISCRIMINATE STARTERS VS. NON-STARTERS



Guess et al, 2020

143

JUMP METRICS MAY DISCRIMINATE STARTERS VS. NON-STARTERS

CUT-OFF VALUES

MALES (n=15)

BRAKING RFD (N*s-1)
19,778
SP: .71
SN: .75

AVG BRAKING VELOCITY (M*s-1)
.87
SP: .86
SN: .75

FEMALES (n=14)

JUMP HEIGHT (CM)
29.0
SP: .67
SN: .85

MODIFIED RSI
.46
SP: .67
SN: .75

Phillipp et al, 22023

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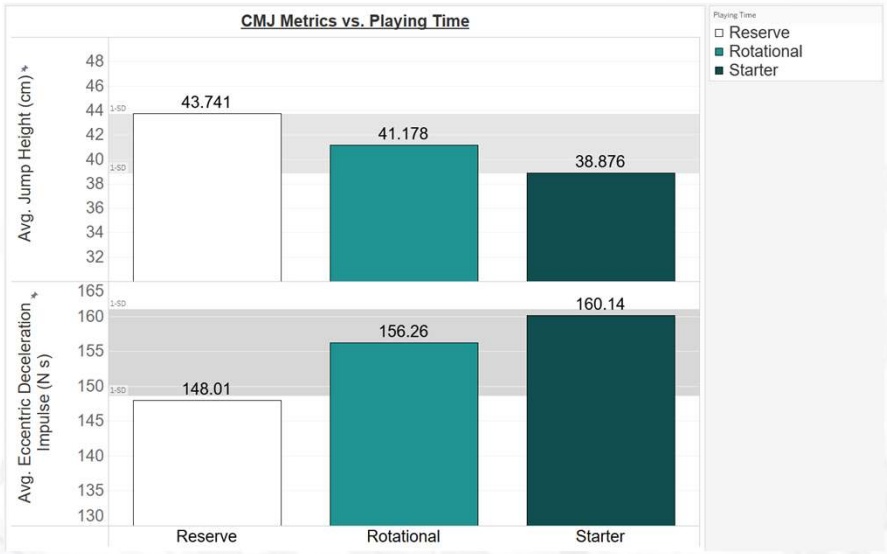
JUMP METRICS MAY DISCRIMINATE STARTERS VS. NON-STARTERS

What THEY care about:

What WE care about:



Unpublished, Me

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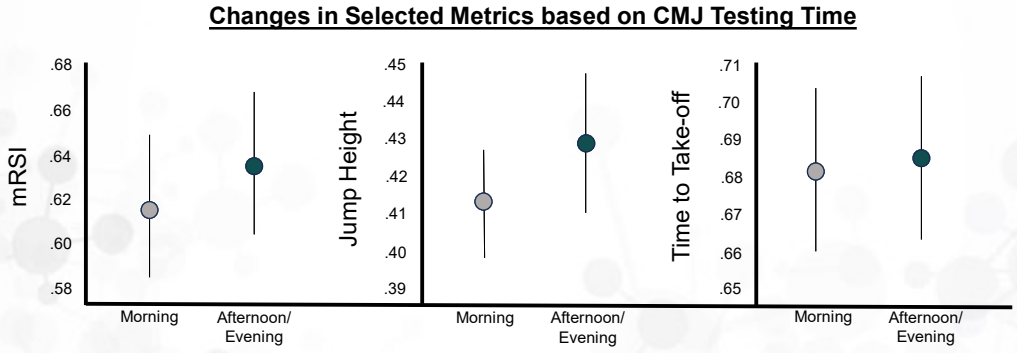
WHEN SHOULD THEY BE TESTED



Mornings: 8:13 AM to 11:37 AM

Afternoon: 12:30 pm to 14:26 PM

mRSI: p-value = .39 and effect size = .18

Berberet et al, 2024

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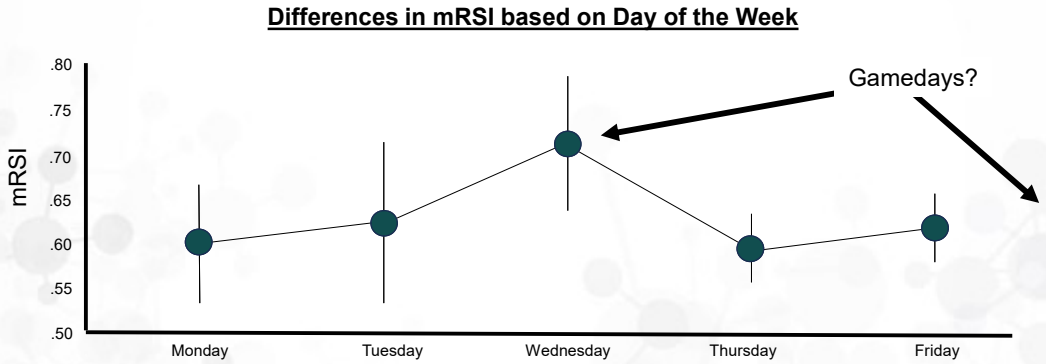
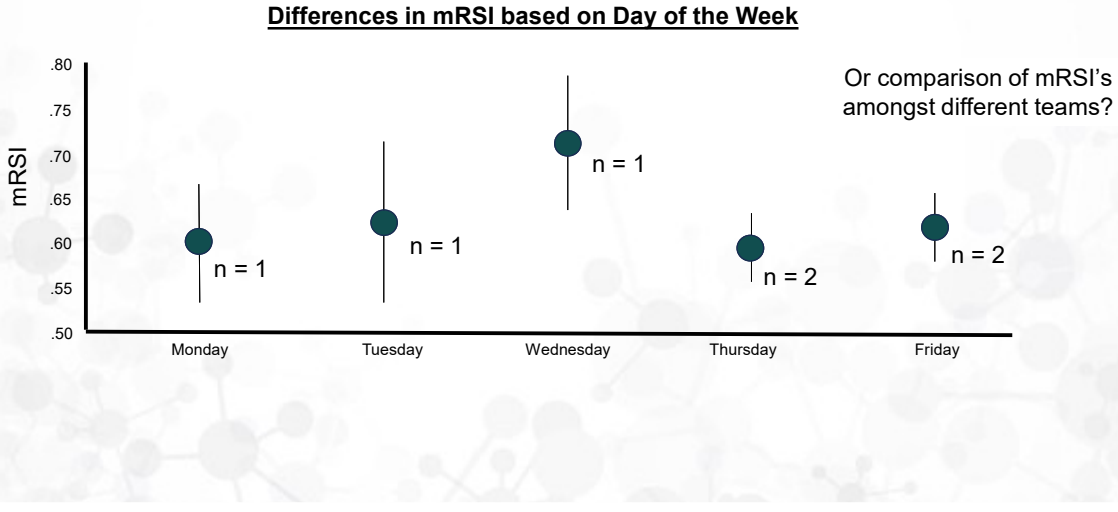
WHEN SHOULD THEY BE TESTED



Berberet et al, 2024

147

WHEN SHOULD THEY BE TESTED



Berberet et al, 2024

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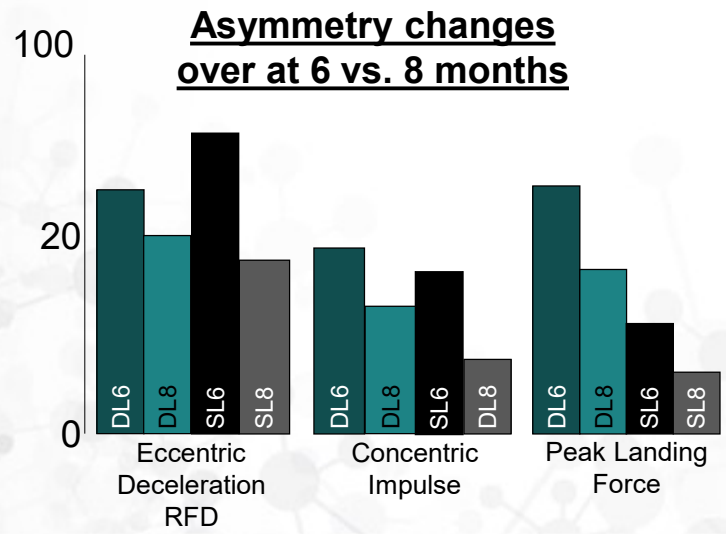
SINGLE LEG OR DOUBLE LEG JUMPS



- Double leg CMJ asymmetries were correlated with PROs, and single leg CMJ asymmetries were not
- Single leg asymmetries equalize faster than double leg

Cohen et al, 2020

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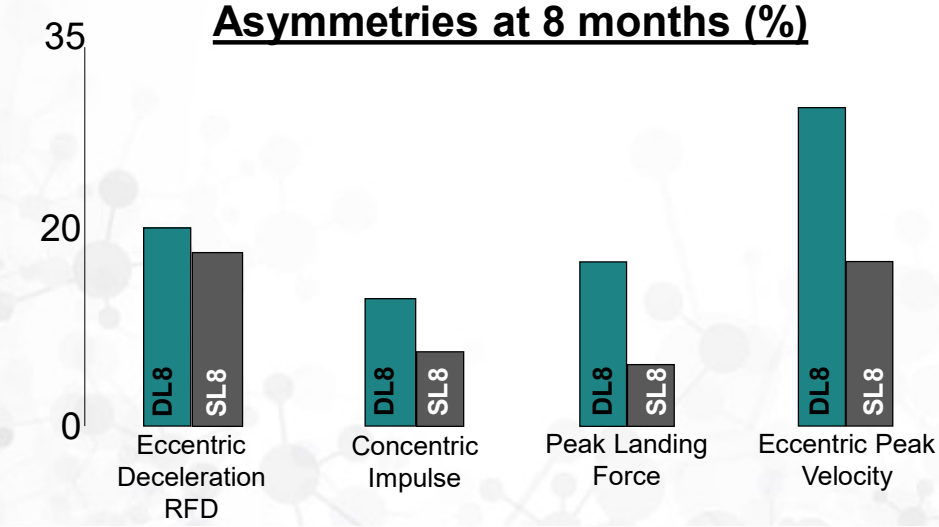
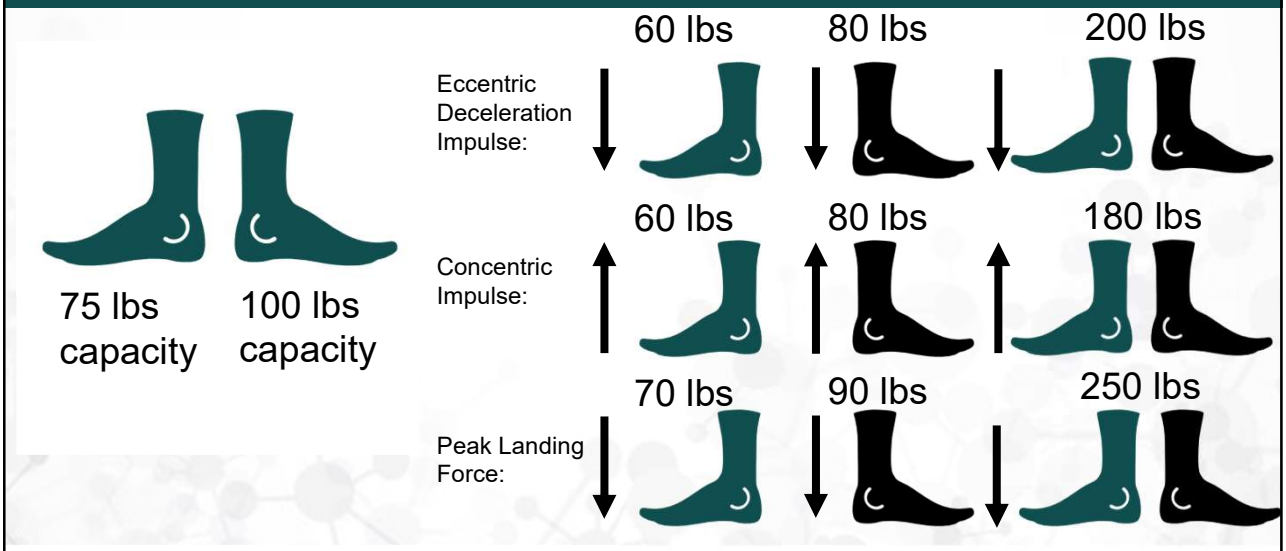
SINGLE LEG ASYMMETRIES NORMALIZE FASTER BECAUSE THE DEMANDS ARE LOW



Cohen et al, 2020

150

SINGLE LEG ASYMMETRIES NORMALIZE FASTER BECAUSE THE DEMANDS ARE LOW



Cohen et al, 2020

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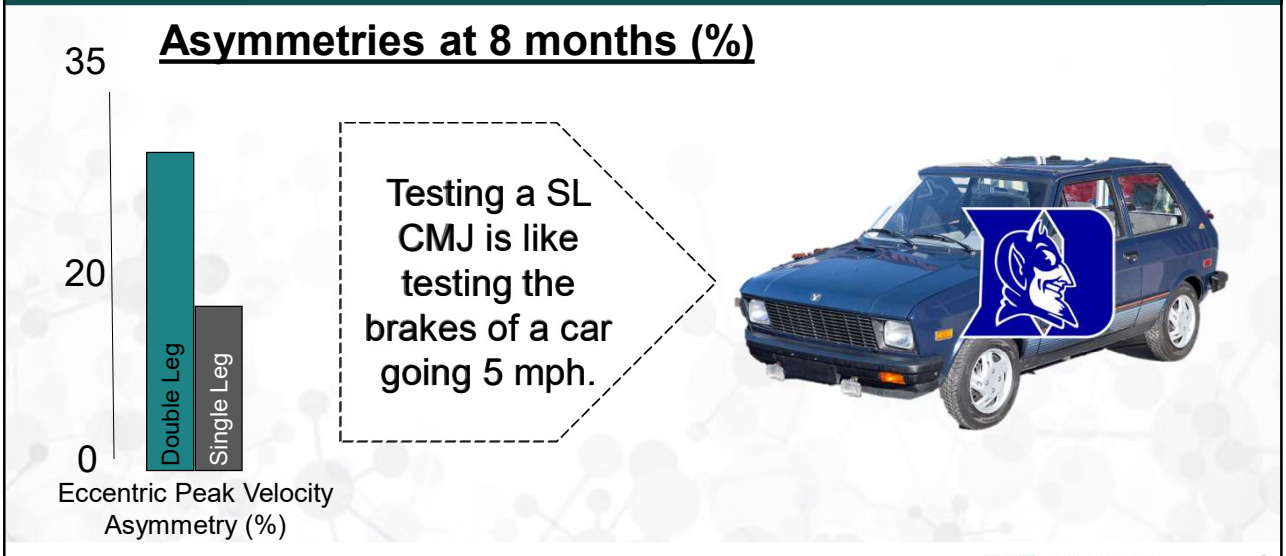
SINGLE LEG ASYMMETRIES NORMALIZE FASTER BECAUSE THE DEMANDS ARE LOW



Cohen et al, 2020

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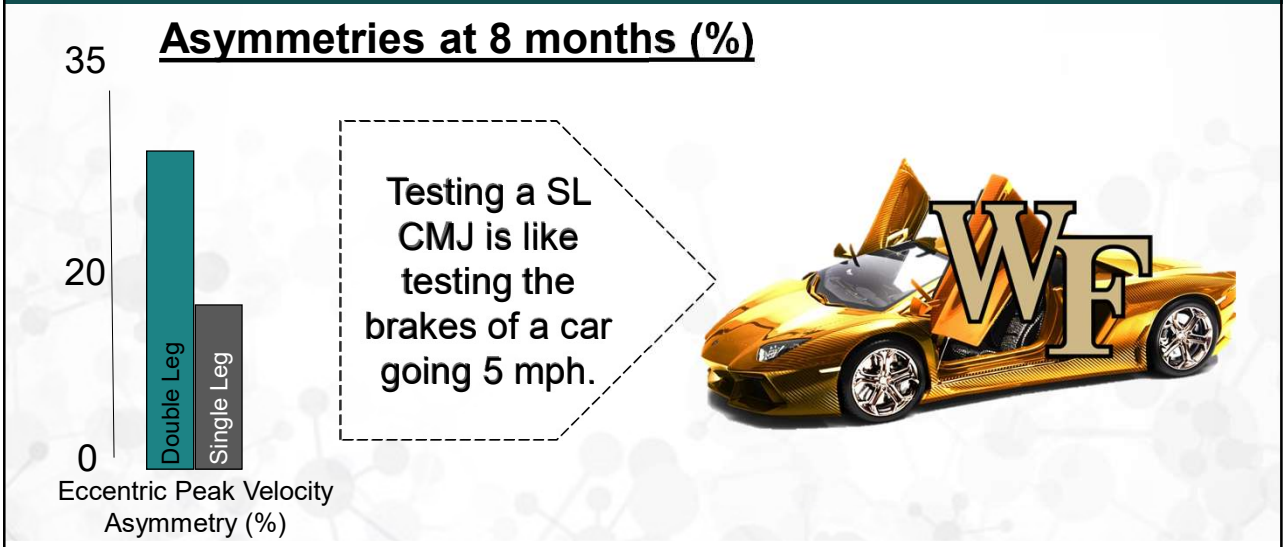
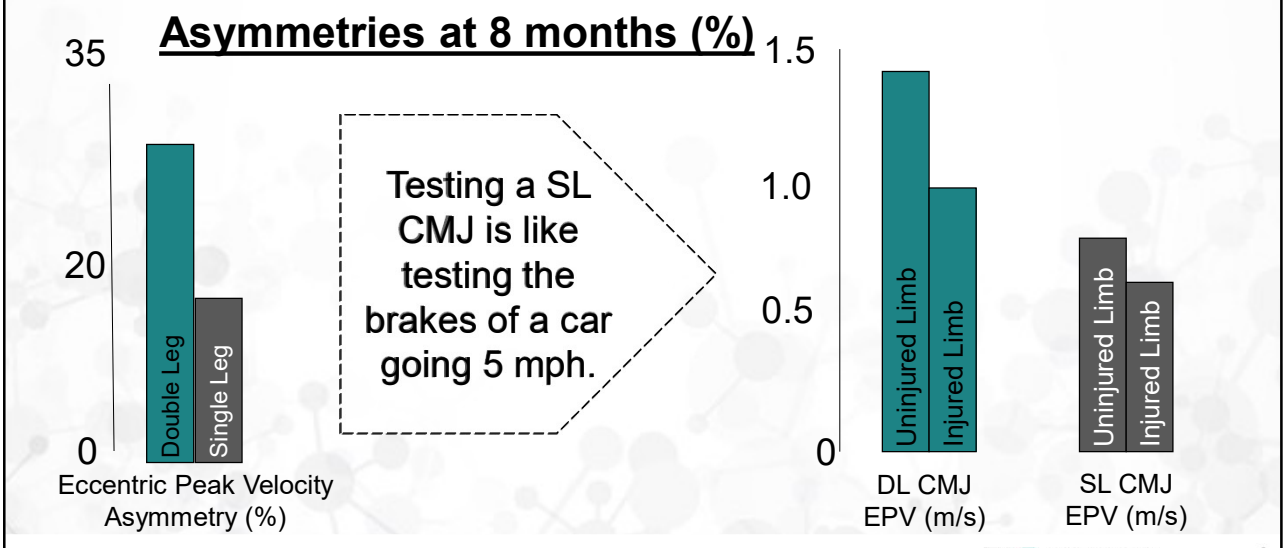
SINGLE LEG ASYMMETRIES NORMALIZE FASTER BECAUSE THE DEMANDS ARE LOW



Cohen et al, 2020

153

SINGLE LEG ASYMMETRIES NORMALIZE FASTER BECAUSE THE DEMANDS ARE LOW



Cohen et al, 2020

154

SL COUNTERMOVEMENT JUMP METRICS WERE MOST SENSITIVE TO CHANGE OVER TIME, AND REALLY ONLY 5 ARE NEEDED

Force/power/impulse (51%)	Concentric impulse
Contraction time (9%)	Braking phase duration
Concentric velocity/Jump height (3%)	Jump height (velocity)
Contact time/Depth (2%)	Countermovement jump depth
Contact time/Depth (1%)	Eccentric peak velocity

Dutaillis et al, 2026

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SL COUNTERMOVEMENT JUMP METRICS WERE MOST SENSITIVE TO CHANGE OVER TIME, AND REALLY ONLY 5 ARE NEEDED

Force/power/impulse (51%)	Concentric impulse
Contraction time (9%)	Braking phase duration
Concentric velocity/Jump height (3%)	Jump height (velocity)
Contact time/Depth (2%)	Countermovement jump depth
Contact time/Depth (1%)	Eccentric peak velocity

Dutaillis et al, 2026

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Group 1	Group 2	Group 3		Group 4	Group 5	Group 6	Group 7	Group 8	Group 9
Avg. Propulsive Velocity	Avg. Braking Power	Avg. Braking Force	Peak Propulsive Force	Avg. Landing Force	L|R Avg. Braking Force	Avg. Rel. Braking Force	L Force at Peak Landing Force	Braking Net Impulse	Braking Phase %
Avg. Rel. Propulsive Force	Avg. Braking Velocity	Avg. Propulsive Force	Positive Net Impulse	Avg. Propulsive Power	L|R Avg. Braking RFD	Braking RFD	Peak Landing Force	Propulsive Phase	Countermovement Depth
Avg. Rel. Propulsive Power	Avg. Rel. Braking Power	Force at Minimum Displacement	Propulsive Net Impulse	Braking Impulse	L|R Avg. Landing Force	L Avg. Braking RFD	Rel. Peak Landing Force	Rel. Braking Impulse	mRSI
Flight Time	Braking Phase	Jump Momentum	R Avg. Braking Force	L Avg. Landing Force	L|R Avg. Propulsive Force	Peak Rel. Braking Force	R Force at Peak Landing Force	Rel. Braking Net Impulse	Propulsive Phase %
Jump Height	Impulse Ratio	L Avg. Braking Force	R Avg. Propulsive Force	Peak Propulsive Power	L|R Braking Impulse Index	R Avg. Braking RFD	Unweighting Phase	Rel. Propulsive Impulse	RSI
Peak Rel. Propulsive Force	Peak Braking Power	L Avg. Propulsive Force	R Force at Peak Braking Force	Positive Impulse	L|R Peak Braking Force		Unweighting Phase %	Stiffness	
Peak Rel. Propulsive Power	Peak Rel. Braking Power	L Force at Peak Braking Force	R Force at Peak Propulsive Force	Propulsive Impulse	L|R Peak Landing Force			Time to Takeoff	
Peak Velocity		L Force at Peak Propulsive Force		R Avg. Landing Force	L|R Peak Propulsive Force				
Rel. Propulsive Net Impulse		Peak Braking Force			L|R Propulsive Impulse Index				
Takeoff Velocity		System Weight							

Table 1. Countermovement Metric Groupings

Tenan - unpublished

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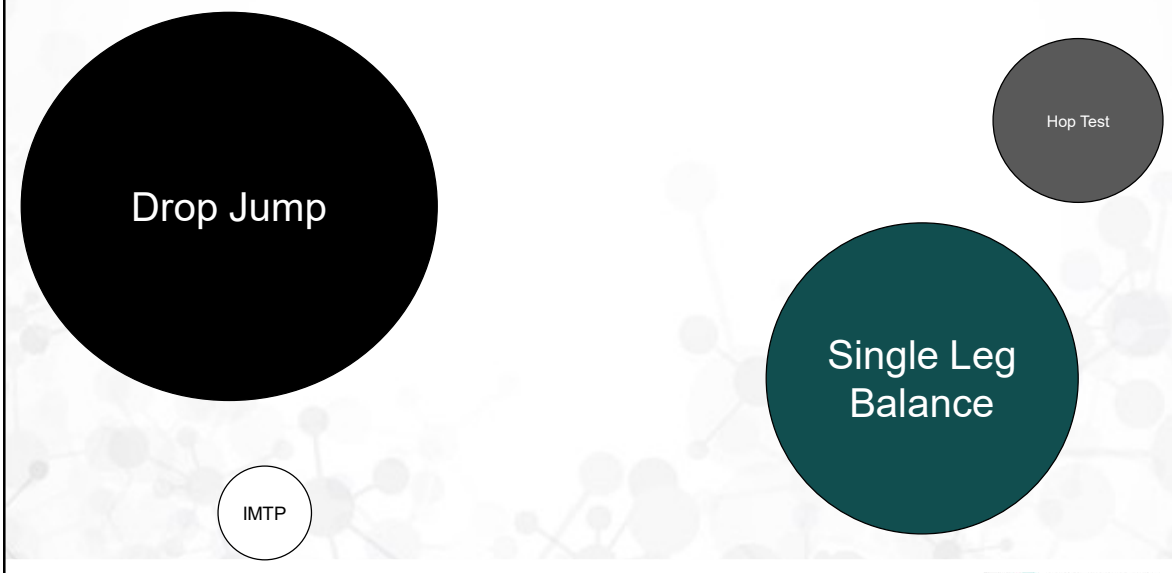
OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW



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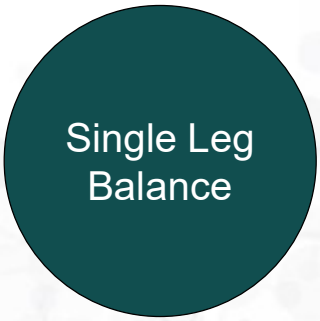
OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW

- Able to get RSI
- Able to see eccentric and concentric asymmetries under higher stresses



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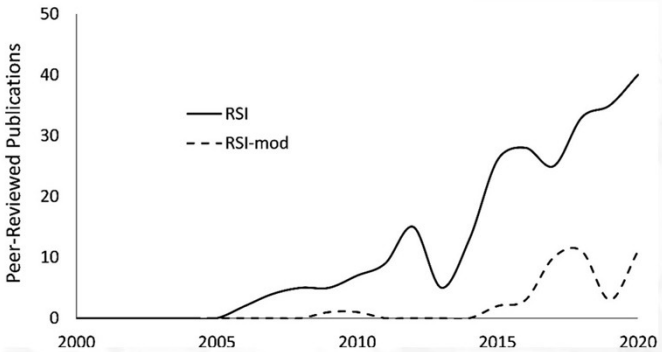
RSI HAS BEEN WELL-STUDIED, AND MRSI IS GROWING

RSI

- Flight time(FT)/**Ground Contact time (GCT)**
- Jump Height (JH)/**Ground Contact Time (GCT)**
- Drop Jump or Repeated Jumps

mRSI

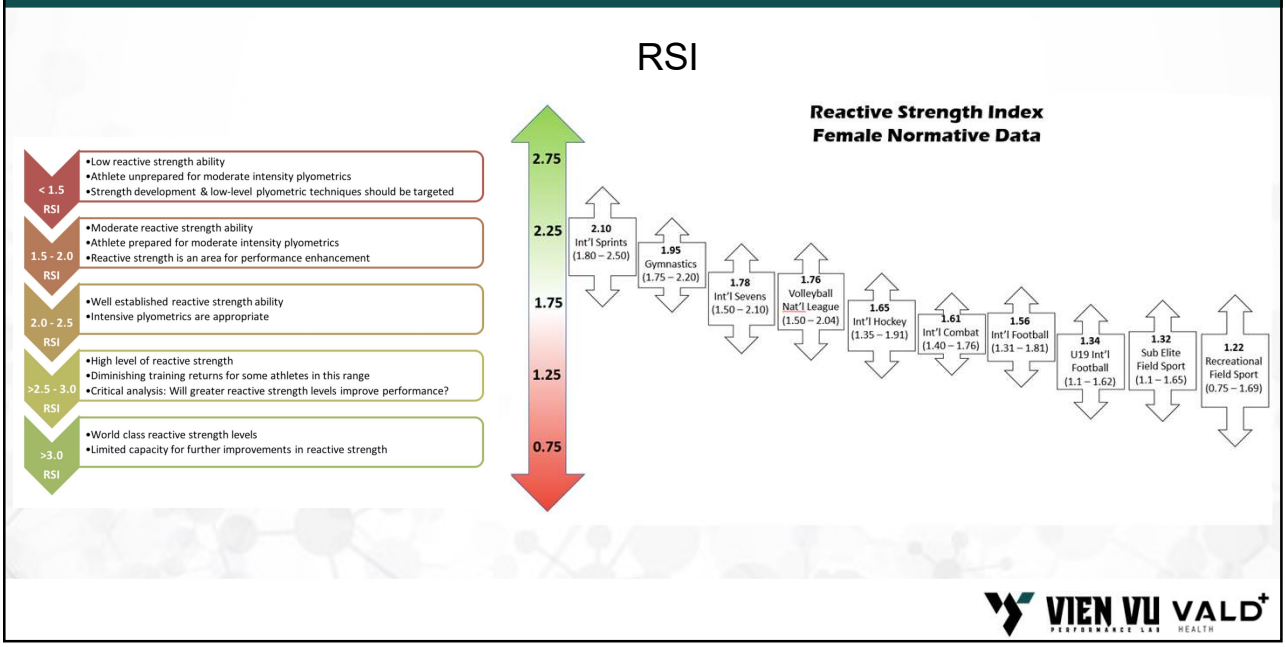
- Jump Height (JH)/**Time to Take-Off (TTT)**
- Countermovement Jump



McMahon et al, 2018

160

THERE ARE GENERAL RSI RECOMMENDATIONS AS WELL AS SPORT SPECIFIC



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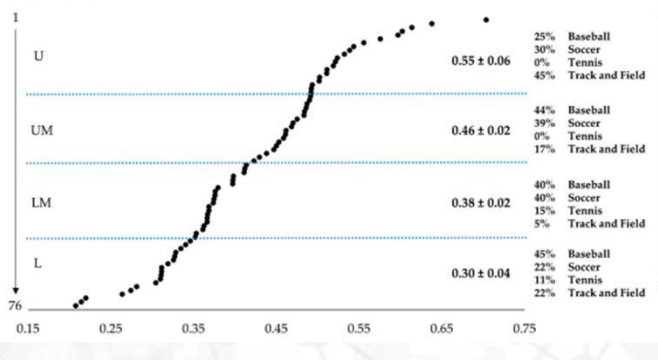
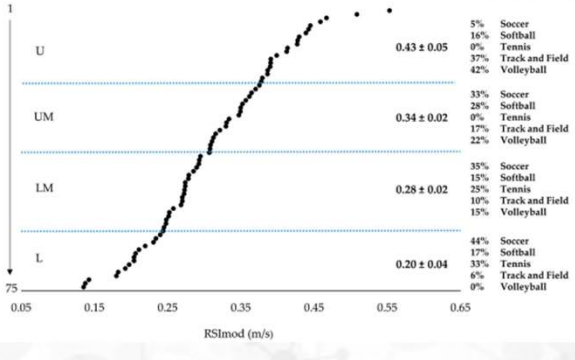
DIFFERENT SPORTS WILL HAVE DIFFERENT MRSI

RSI-Modified Norms of College Athletes

Males



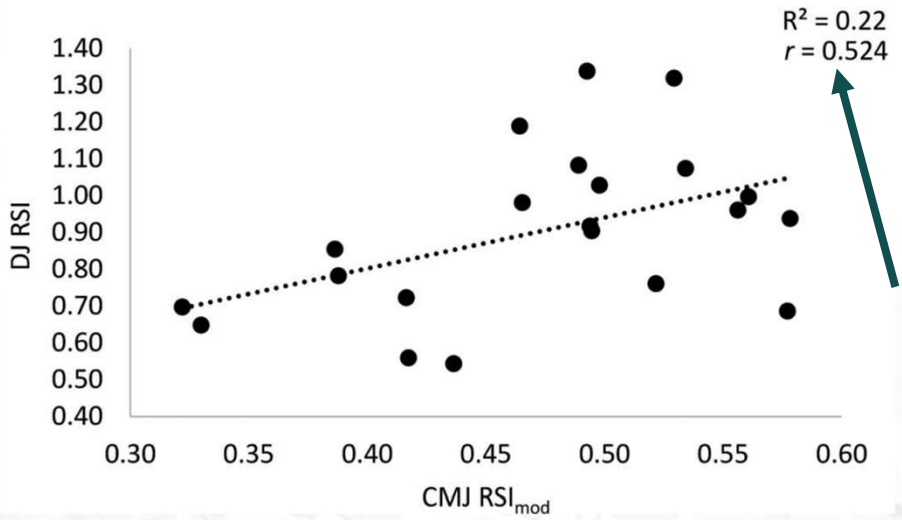
Females



Sole et al, 2018

162

DOES MRSI CORRELATE TO RSI



mRSI only contributes 22% of what makes RSI; these two are distinctly different

There is a moderate correlation between the two

Louder et al, 2021; McMahon et al, 2018

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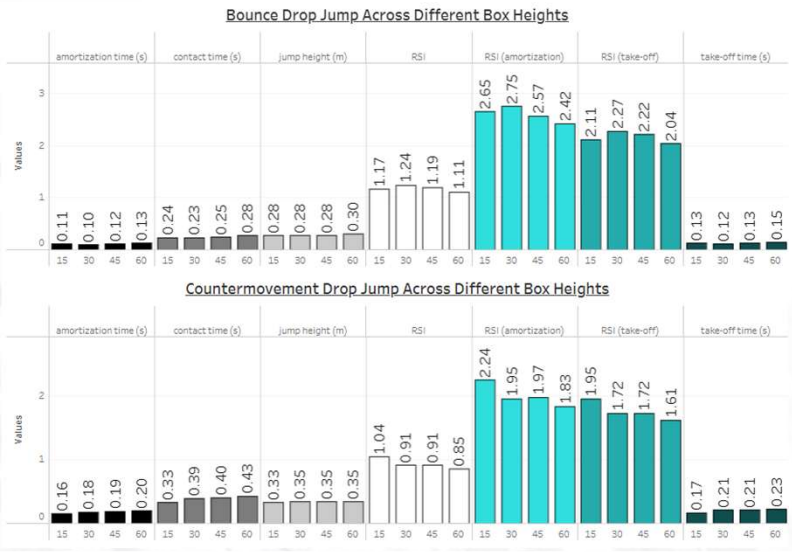
STAY CONSISTENT WITH CUEING AS KINEMATIC DIFFERENCES RESULT IN PERFORMANCE DIFFERENCES



"Jump as fast as you can" produced different performance metrics than "jump as high as you can."

Struzik et al, 2016

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STAY CONSISTENT WITH CUEING AS KINEMATIC DIFFERENCES RESULT IN PERFORMANCE DIFFERENCES

Struzik et al, 2016

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IT DOESN'T MATTER WHICH ONE YOU CHOOSE, JUST REFER TO NORMS AND BE CONSISTENT

You have an athlete with a calf strain and want to know if they have the same "explosive" ability on each leg, and if they are as strong as healthy athletes:

Symmetry is a comparison of one leg to the other leg, not one metric to the other metric.

Because each metric will have different absolute values, stick with one of them to observe trends over time.

You will have to look up studies to identify norms. Depending on what metric the study chose, choose to track that one for your athlete.

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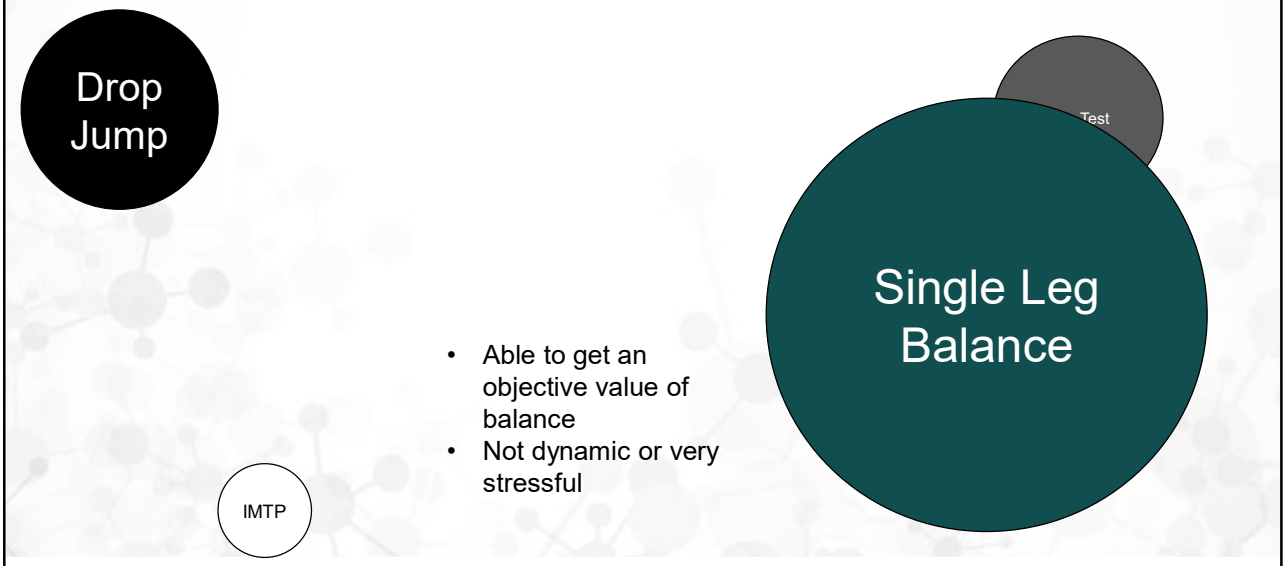
166

OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW



- Able to get an objective value of balance
- Not dynamic or very stressful

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OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW

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OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW

Drop Jump

Isometric Mid-Thigh Pull

Single Leg Balance

- Troublesome set up
- Inconsistent data
- Low transfer to dynamic tasks

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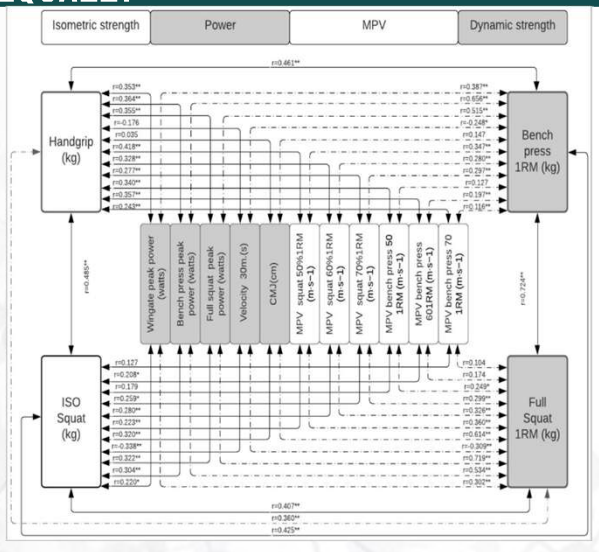
STRENGTH CHANGES DO NOT AFFECT ISOMETRIC AND DYNAMICS TESTS EQUALLY



- Dynamic values correlate
- Isometrics correlate
- Isometrics correlate to dynamics
- Strong means strong, but not at the same rate

James et al, 2024

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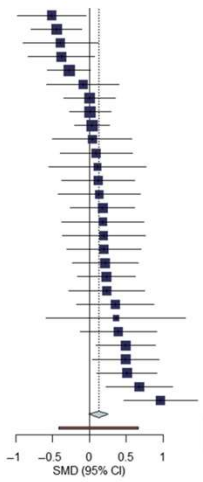
STRENGTH CHANGES DO NOT AFFECT ISOMETRIC AND DYNAMICS TESTS EQUALLY

Source	SMD (95% CI)
Suchomel et al, 2020, (IMTP-PC-PULL)	−0.51 [−0.97; −0.05]
Painter et al, 2012, (IMTP-BS-DUP)	−0.45 [−0.79; −0.10]
James et al, 2018, (ISQU-BS-STRONG)	−0.39 [−0.90; 0.12]
Suchomel et al, 2020, (IMTP-PC-OLOAD)	−0.38 [−0.83; 0.07]
Painter et al, 2012, (IMTP-BS-BLOCK)	−0.28 [−0.57; 0.02]
Travis et al, 2021, (ISQU-DL-STEP)	−0.09 [−0.58; 0.41]
Toohey et al, 2020, (IMTP-DL-SUPP_0)	0.00 [−0.34; 0.35]
Comfort et al, 2018, (IMTP-PC-CATCH)	0.01 [−0.27; 0.29]
Comfort et al, 2018, (IMTP-PC-PULL)	0.04 [−0.21; 0.28]
Bazyler et al, 2014, (ISQU-BS-PROM)	0.04 [−0.50; 0.58]
Banaszek et al, 2019, (IMTP-DL-SUPP_P)	0.09 [−0.40; 0.58]
James et al, 2018, (ISQU-BS-WEAK)	0.11 [−0.55; 0.77]
Banaszek et al, 2019, (IMTP-BS-SUPP_P)	0.12 [−0.37; 0.61]
Banaszek et al, 2019, (IMTP-BS-SUPP_W)	0.13 [−0.43; 0.70]
Suchomel et al, 2020, (IMTP-PC-CATCH)	0.18 [−0.26; 0.62]
Cormie et al, 2007, (ISQU-BS-COM)	0.18 [−0.37; 0.74]
Banaszek et al, 2019, (IMTP-DL-SUPP_W)	0.20 [−0.37; 0.76]
Travis et al, 2021, (ISQU-BS-STEP)	0.20 [−0.31; 0.71]
Bazyler et al, 2014, (ISQU-BS-FROM)	0.21 [−0.23; 0.66]
Cormie et al, 2007, (ISQU-BS-VEL)	0.24 [−0.16; 0.63]
Travis et al, 2021, (ISQU-DL-EXP)	0.24 [−0.27; 0.75]
Travis et al, 2021, (ISQU-BS-EXP)	0.35 [−0.17; 0.88]
Cormie et al, 2010, (ISQU-BS-STRENGTH)	0.36 [−0.59; 1.31]
Cormie et al, 2010, (ISQU-BS-VEL)	0.40 [−0.13; 0.92]
Toohey et al, 2020, (IMTP-BS-SUPP_0)	0.49 [0.09; 0.90]
Bartolomei et al, 2021, (ISQU-BS-FB)	0.49 [0.04; 0.95]
Bartolomei et al, 2021, (ISQU-BS-SB)	0.51 [0.10; 0.92]
Toohey et al, 2020, (IMTP-DL-SUPP_1)	0.68 [0.23; 1.13]
Toohey et al, 2020, (IMTP-BS-SUPP_1)	0.97 [0.47; 1.47]
Total	0.13 [−0.00; 0.25]
Prediction interval	[-0.42; 0.67]

Heterogeneity: $\chi^2_{28} = 64.07$ ($P < .001$), $I^2 = 56\%$



- Dynamic values correlate
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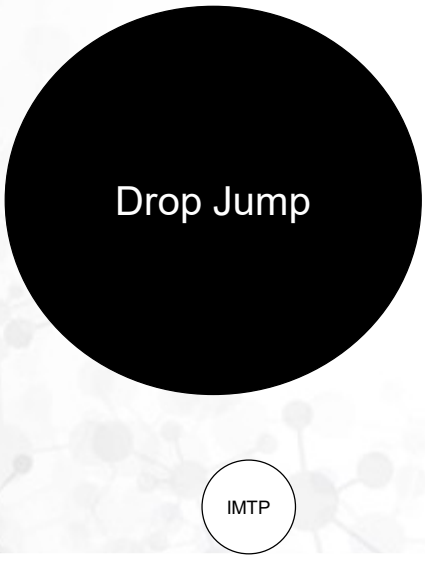
- Strong means strong, but not at the same rate

Ortega et al, 2022

171

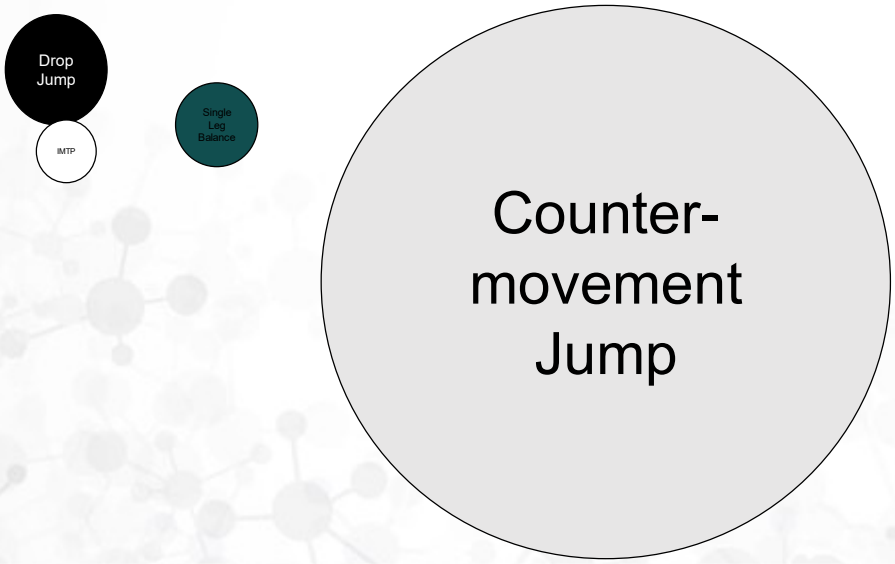
OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW



- Able to see fatigue factor
- Requires intentional cueing
- Minimal influence on RTS decision

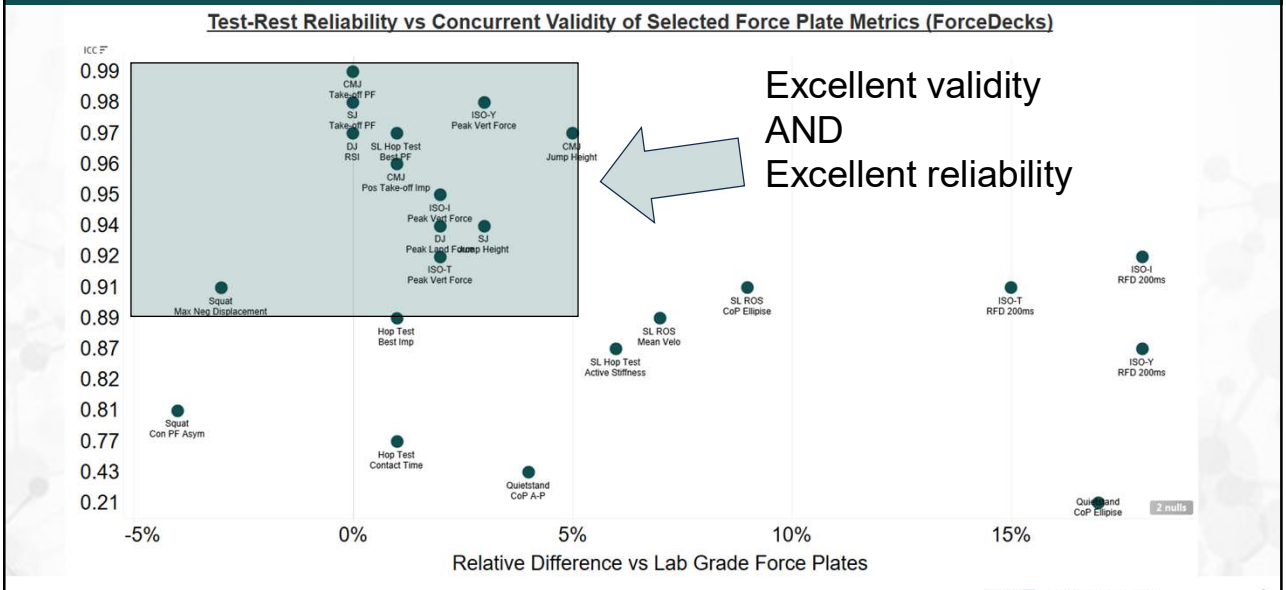
172

OTHER TESTS MAY BE USEFUL, BUT NOT ESSENTIAL FOR NOW



173

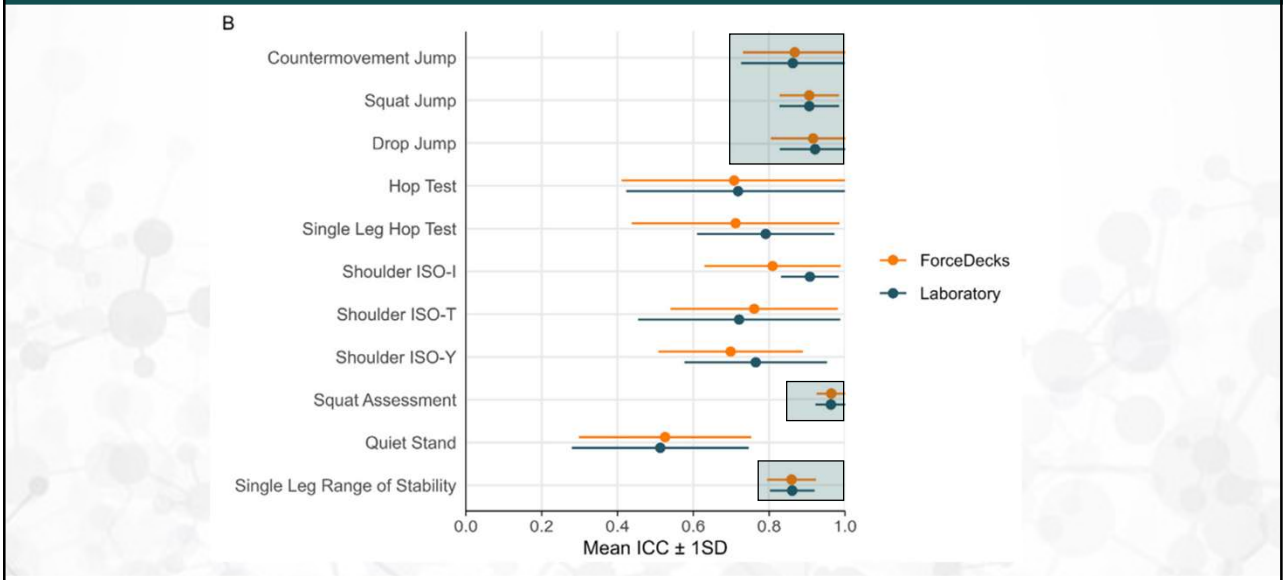
REMEMBER, THERE IS ALWAYS PROS AND CONS



Collings et al, 2024

174

REMEMBER, THERE IS ALWAYS PROS AND CONS



Collings et al, 2024

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THERE SHOULD BE NO ASYMMETRIES UNLESS BASELINE INDICATES OTHERWISE, EXCEPT FOR ACLR

Injury History	Result vs healthies
Hamstring injury	No significant differences in kinetics or asymmetries
Hip/groin injury	No significant differences in kinetics or asymmetries
ACL Reconstruction	Significant differences in landing asymmetries

Collings et al, 2021

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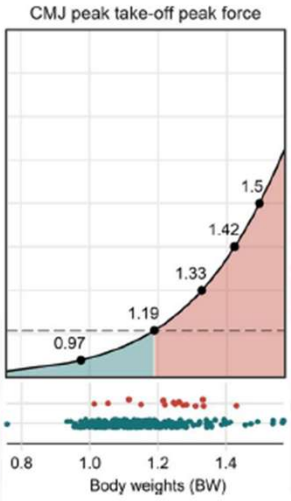
CMJ ASYMMETRIES DID NOT PREDICT INJURY, BUT PEAK-TAKE OFF FORCE

Making people weaker is not a practical ways to decrease injury.



Collings et al, 2023

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LOWER EXTREMITY SUMMARY

- *"Test don't guess!" – George Davies"* – Vien Vu
- HHD is reliable and can help keep athletes safe and high-functioning
- Force plate data can guide treatment and can make movement qualities objective
- Data is overwhelming, so just start small
- You're doing just fine

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LAB
ACTIVITY THREE
30 MIN

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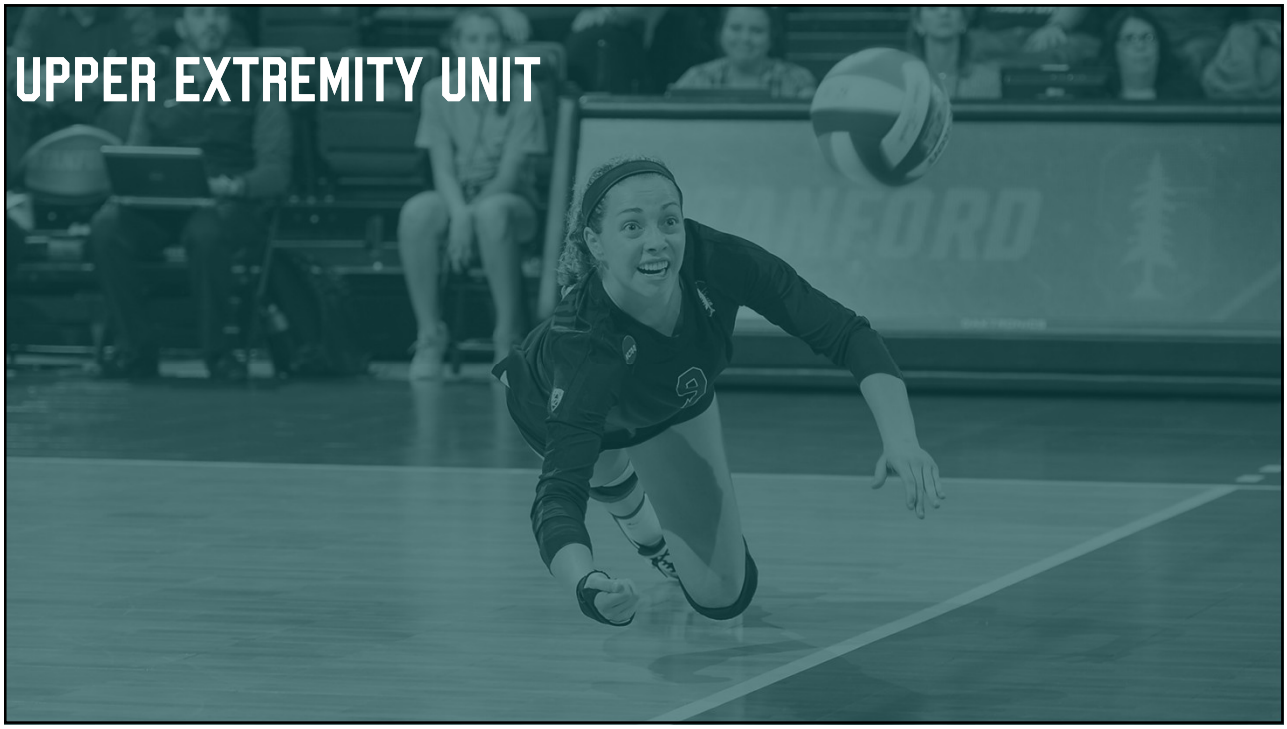

180

MAYBE THAT'S WHY THESE NUMBERS ARE OH SO FAMILIAR…

UE RTS Outcomes

- **Shoulder**
  - Partial and full RC repair
    - **41%** RPL
  - Transtendon partial repair
    - **45-72%** RTS
    - **51%** RPL
  - Type II SLAP repair
    - **31.8%** RPL
    - **45%** retired due to inability to RTP
- Tenodesis
  - **60%** returned to prior level
- SLAP vs. Tenodesis:
  - **20%** vs 87% RTS
- Labral debridement
  - **67%** returned to prior level of play
- Internal Impingement
  - **52%** returned to prior level

Peduzzi et al, 2019; Keller et al, 2018; Thorsness et al, 2016

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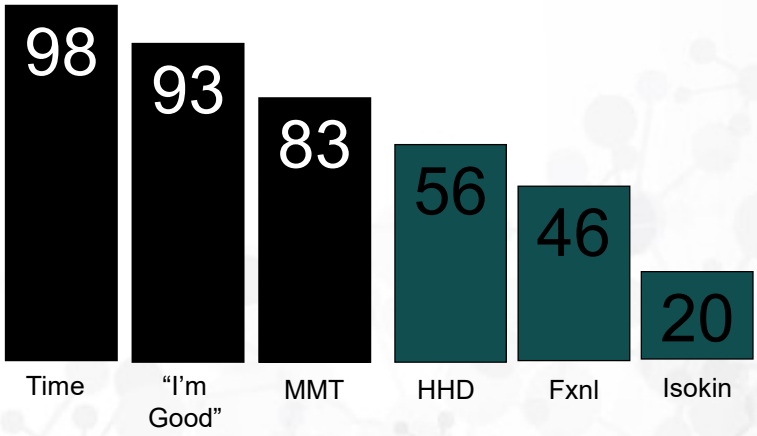
UPPER EXTREMITY TESTING TRENDS ARE SIMILAR TO LOWER EXTREMITY TRENDS

498 physical therapists

Percentage of PTs who use selected methods for RTS decision



Gauthier et al, 2023

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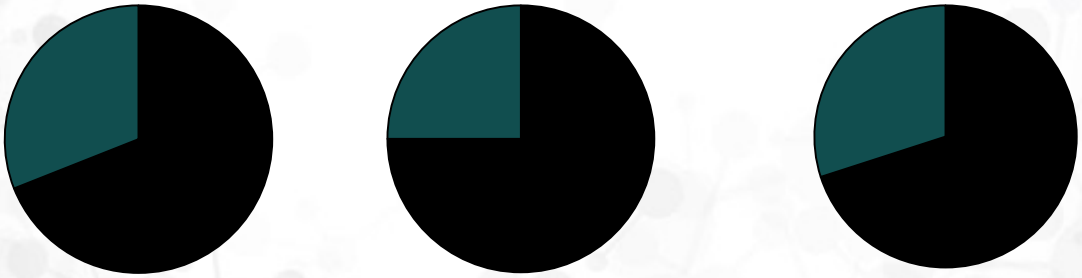
MMT UNDERESTIMATES SHOULDER MUSCLE WEAKNESS

Of patients who were deemed symmetrical in shoulder strength by Manual Muscle Test…

External Rotation | Abduction | Internal Rotation



"Correctly Judged"
>30% Muscle Weakness

Nagatomi et al, 2017

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"I'M THE PROBLEM IT'S ME" – TAYLOR SWIFT

Reported Barriers

"I have no time"

"We don't have the equipment"

"I don't understand the research"

"There's not enough research"

"My patient's ~~don't~~ care"

"My referral sources ~~don't~~ care"

Gauthier et al, 2023

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WE CAN INFLUENCE THOSE RE-INJURY RATES

TEST	CLEARANCE CRITERIA
Isokinetic ER/IR strength at 60 and 180 degrees per second	90% symmetrical
Isometric ER/IR strength	90% symmetrical
Closed Kinetic Chain Upper Extremity Stability Test	>21 reps
Unilateral Seated Shotput Test	90% symmetrical, 110% for dominant side

Drummond et al, 2021

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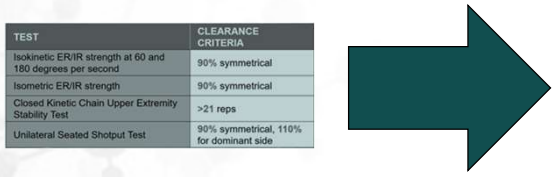
RETURN TO SPORTS TESTING THE RISK OF RE-INJURY...AGAIN



5% reinjury rate
(criteria)

vs.

22% reinjury rate
(control)

Drummond et al, 2021

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RETURN TO SPORTS TESTING THE RISK OF RE-INJURY...AGAIN

TEST	CLEARANCE CRITERIA
Isokinetic ER/IR strength at 60 and 180 degrees per second	90% symmetrical
Isometric ER/IR strength	90% symmetrical
Closed Kinetic Chain Upper Extremity Stability Test	>21 reps
Unilateral Seated Shotput Test	90% symmetrical, 110% for dominant side

4.85x higher risk of reinjury
if they do not pass criteria

Drummond et al, 2021

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"BUT MY PATIENT'S SAY THEY'RE FINE!"

	Grip Strength Loss	Abduction Strength Loss	ER Strength Loss
VAS	No correlation	No correlation	No correlation
SANE	No correlation	No correlation	No correlation
QuickDASH	No correlation	No correlation	No correlation
ASES Index Score	No correlation	No correlation	No correlation
ASES Function Score	No correlation	Significant low negative correlation	Significant low negative correlation
Simple Shoulder Test	No correlation	No correlation	No correlation
VR-12 Mental Health	No correlation	No correlation	No correlation
VR-12 Physical Health	No correlation	No correlation	No correlation

Manske et al, 2020

188

"BUT MY PATIENT'S SAY THEY'RE FINE!"

	Grip Strength	Abduction Strength	ER Strength
VAS	No correlation	No correlation	No correlation
SANE	No correlation	No correlation	No correlation
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Simple Shoulder Test	No correlation	Significant low positive correlation	Significant low positive correlation
VR-12 Mental Health	Significant low positive correlation	No correlation	No correlation
VR-12 Physical Health	No correlation	No correlation	No correlation

Manske et al, 2020

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THEY'RE FINE...IF YOU DON'T ASK THE RIGHT QUESTIONS

These are the only 3 PRO's that asked about throwing a ball, lifting weight, or if they've returned to their prior self

	Grip Strength	Abduction Strength	ER Strength
ASES Function Score	No correlation	Significant low negative correlation	No correlation
Simple Shoulder Test	No correlation	Significant low positive correlation	Significant low positive correlation
VR-12 Mental Health	Significant low positive correlation	No correlation	No correlation

Manske et al, 2020

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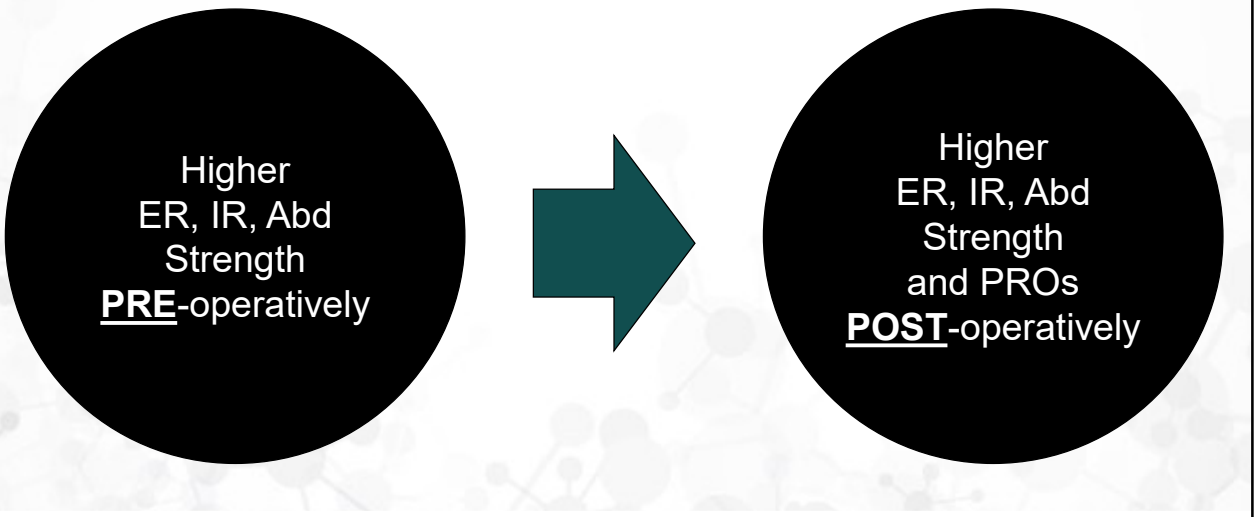
AT THE WORST, PRE-OPERATIVE MEASURES HELP PREDICT POST-SURGICAL OUTCOMES



Hao et al, 2022

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AT THE WORST, PRE-OPERATIVE MEASURES HELP PREDICT POST-SURGICAL OUTCOMES

Abduction Score Grading
0 = unable to perform 90 deg abduction **1**= 0 - 4.9 lbs. produced **2** = 5 - 9.9 lbs. produced **3** = 10 – 14.9 lbs. produced **4** = 15 - 19.9 lbs. produced **5** = 20.0 – 24.9 lbs. produced

Hao et al, 2022

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ABDUCTION SCORE WAS THE BIGGEST PREDICTOR OF ROM AND FUNCTION

For every 1 point increase in abduction score, there was a:

ROM:
- 24.4 deg improvement in Abduction AROM
- 19.3 deg improvement in Flexion AROM
- 4.81 deg improvement in ER AROM

PRO:
- 8.35 point improvement on Constant Score (MCID:6.1)
- 3.88 point improvement on SPADI (MCID:15.4)
- .52 point improvement in SST (MCID: 2.4)
- 1.03 point improvement on UCLA score (MCID: 3.5)

Hao et al, 2022

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BUT WHAT SHOULD WE DO TO HELP OUR PATIENTS



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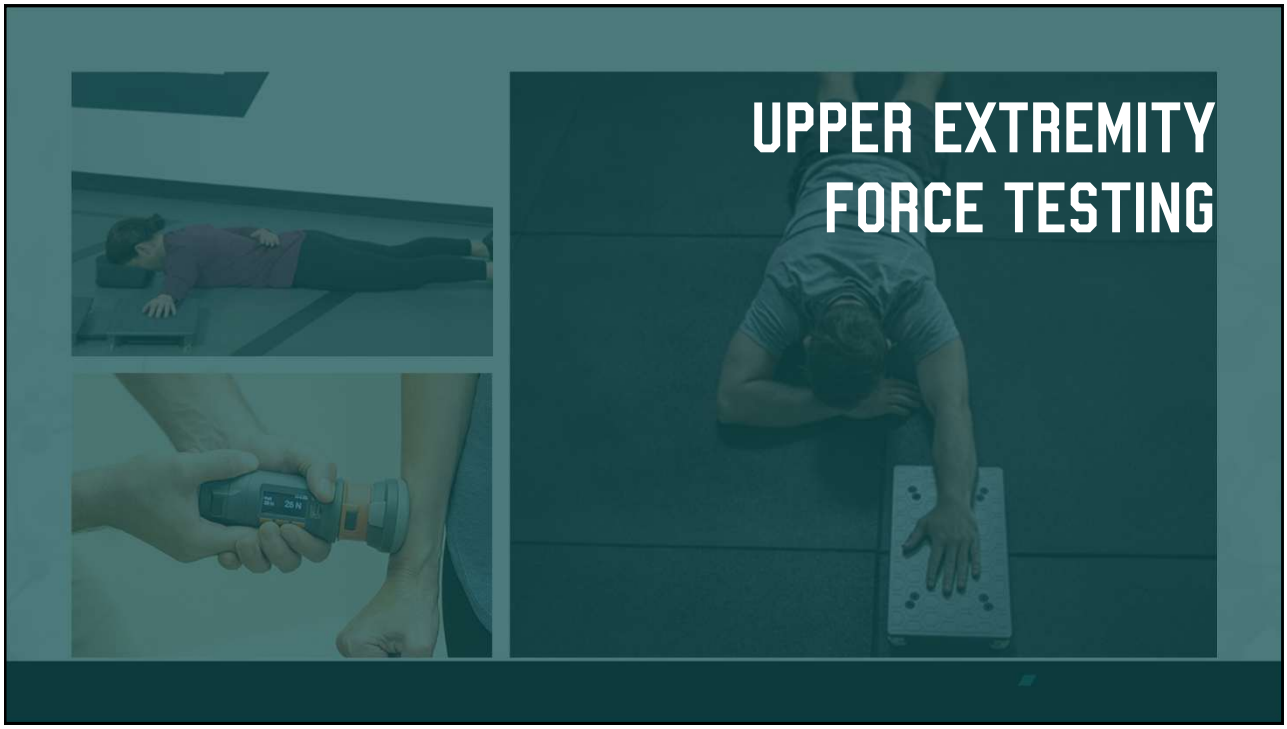

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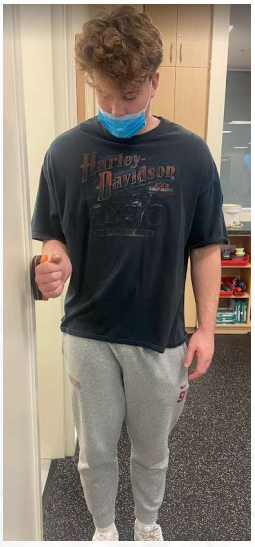
MAKE VS. BREAK TEST IN THE SHOULDER ARE RELIABLE



ER MAKE TEST
SEM = 3.5%
Intrarater ICC = .93-.96
Interrater ICC = .89

IR MAKE TEST
SEM = 3.4%
Intrarater ICC = .96
Interrater ICC = .92

BREAK TEST (ER)
SEM = 6.8% - 12%
Intrarater ICC = .86-.88
Interrater ICC = .71
r = .70-.78

Johansson et al, 2015

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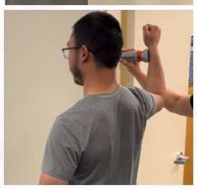
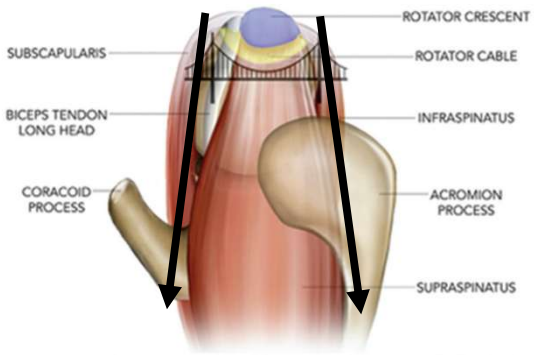
SUBSCAPULARIS AND INFRASPINATUS ARE STABILIZERS BASED ON FORCE VECTORS



ER MAKE TEST
SEM = 3.5%
Intrarater ICC = .93-.96
Interrater ICC = .89

IR MAKE TEST
SEM = 3.4%
Intrarater ICC = .96
Interrater ICC = .92

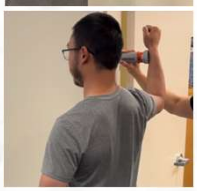
Scaption
SEM = 5.6%
Intrarater ICC = .95



Decleve et al, 2020; Edwards et al, 2017; Stratford et al, 1994

197

THERE IS HIGH EMG ACTIVITY IN BOTH INFRASPINATUS AND SUPRASPINATUS DURING ABDUCTION



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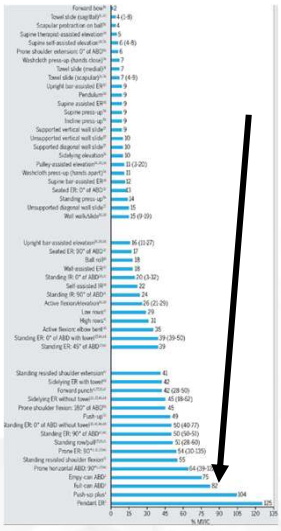

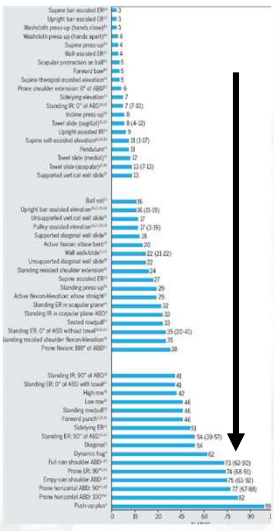

Decleve et al, 2020; Edwards et al, 2017; Stratford et al, 1994

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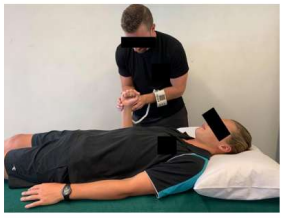
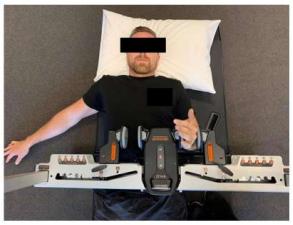
THERE IS GOOD INTRARATER RELIABILITY FOR MANUAL FIXATION AND FIXED-FRAME



External Rotators
ICC: .87
SEM: 11.5

Internal Rotators
ICC: .92
SEM: 10.9

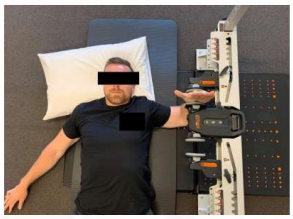


External Rotators
ICC: .92
SEM: 11.4

Internal Rotators
ICC: .89
SEM: 11.4

External Rotators
ICC: .91
SEM: 11.4

Internal Rotators
ICC: .85
SEM: 15.1



External Rotators
ICC: .91
SEM: 11.4

Internal Rotators
ICC: .85
SEM: 12.9

**Couch et al, 2021*

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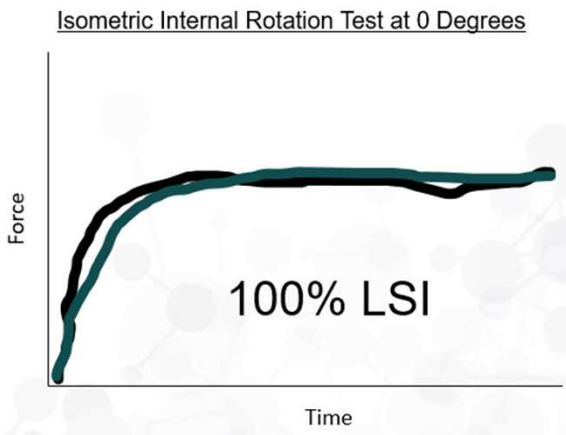
SHOULDERS SHOULD BE TESTED AT 90-90 POSITION FOR FULL RETURN

Shoulder Strength Testing of College Male Volleyball Player with Chronic Instability

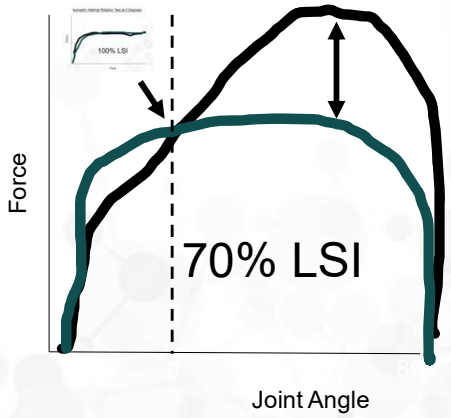


200

SHOULDERS SHOULD BE TESTED AT 90-90 POSITION FOR FULL RETURN

Shoulder Strength Testing of College Male Volleyball Player with Chronic Instability

Isokinetic Internal Rotation Test at 60 d/sec



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SHOULDER STRENGTH HAS NOT RETURNED TO NORMS OF HEALTHY CONTROLS 6 MONTHS AFTER UCLR

	UCLR (n=43)	Controls (n=43)
External Rotation LSI (Throwing vs Non-Throwing)	100%	106%
Internal Rotation LSI (Throwing vs Non-Throwing)	96%	135%

202

EVEN IF THEY DID, THEY ARE EQUALLY WEAK, AND NOT EQUALLY STRONG

	UCLR (n=43)	Controls (n=43)
External Rotation LSI (Throwing vs Non-Throwing)	92%	100%
Internal Rotation LSI (Throwing vs Non-Throwing)	97%	101%
External Rotation Strength in kg (Throwing)	8.8*	12.4
Internal Rotation Strength in kg (Throwing)	13.4*	17.7

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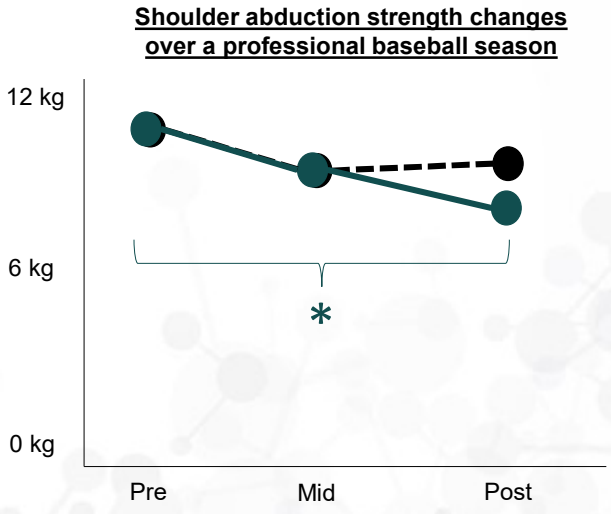
EVEN IF THEY DID, THEY ARE EQUALLY WEAK, AND NOT EQUALLY STRONG



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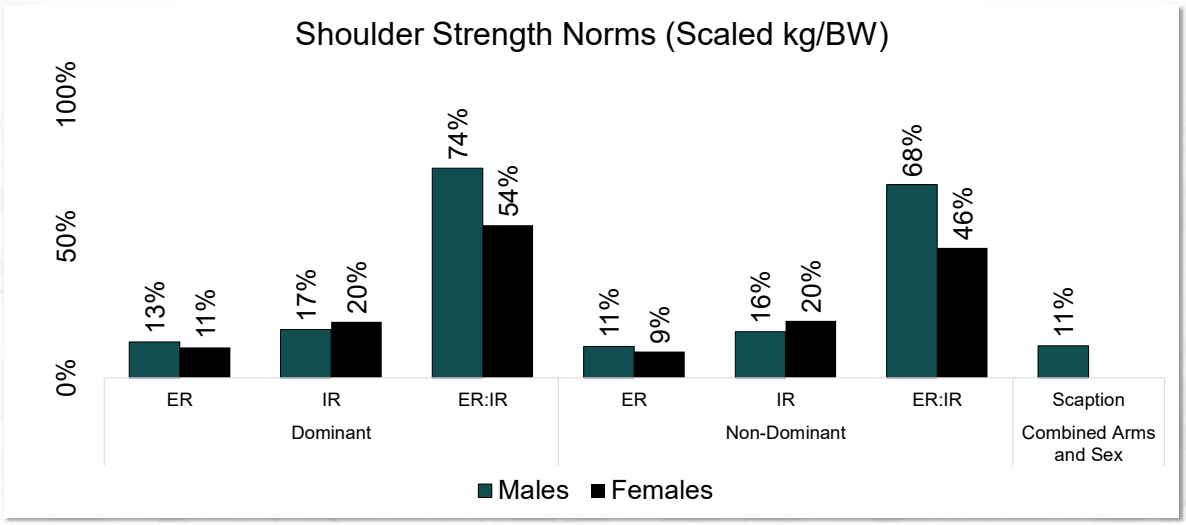
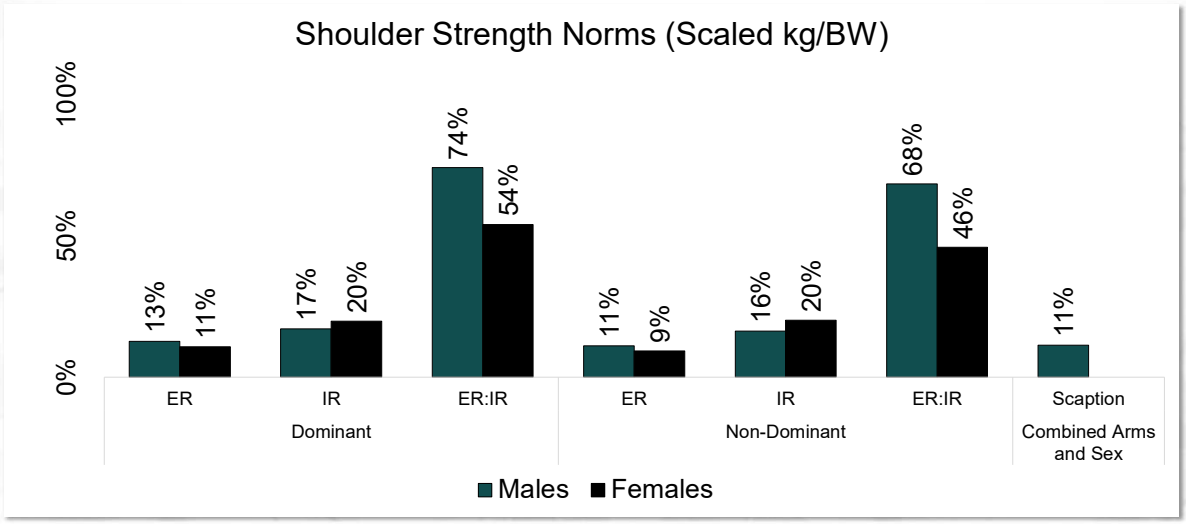
ALLOMETRIC SCALING IS ALSO POPULAR WITH THE SHOULDER



Decleve et al, 2020; Collins et al, 2018

205

THERE SEEMS TO BE NO SIGNIFICANT DIFFERENCES IN DOMINANT AND NON-DOMINANT ARM STRENGTH



Decleve et al, 2020; Collins et al, 2018

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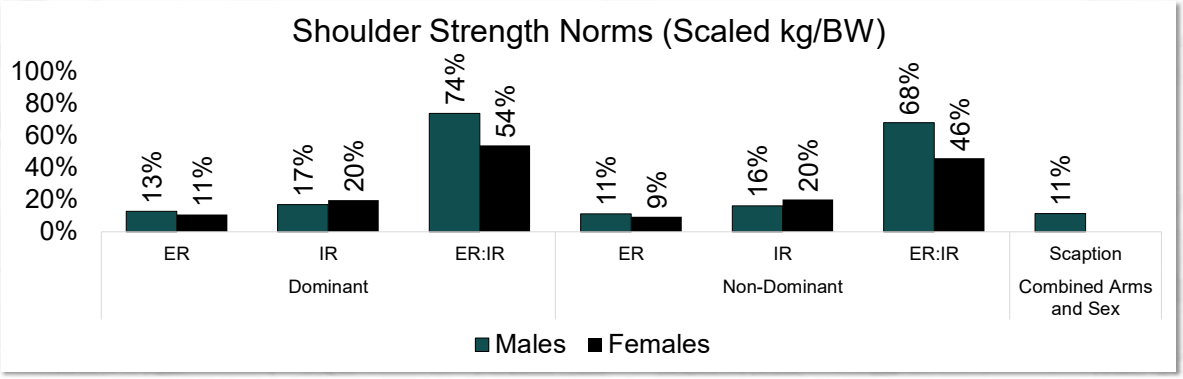
MY CRITERIA

Key metrics:

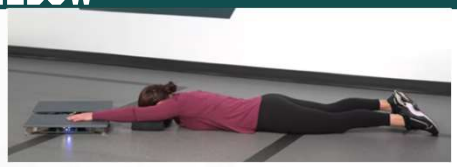
- >75% limb symmetry index in all muscle groups for UE plyometrics clearance
- >90% limb symmetry index in all muscle groups for full clearance and beginning of interval throwing
- >65% ER to IR ratio
  - IR limb symmetry index must be >90% before this is considered



VIEN VU PERFORMANCE LAB VALD+ HEALTH

207

ASH TEST IS A STRESSFUL AND RELIABLE TEST FOR THE SHOULDER AND ELBOW



ICC: .94-.98

Ashworth et al, 2018

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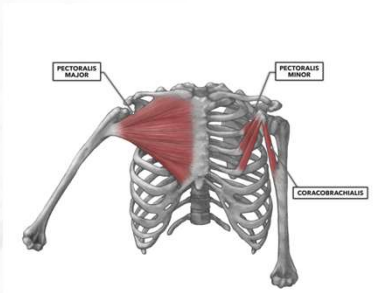
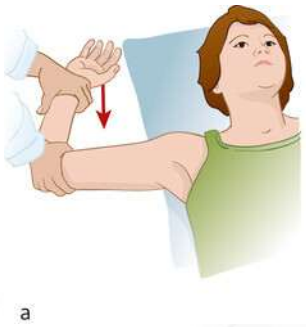
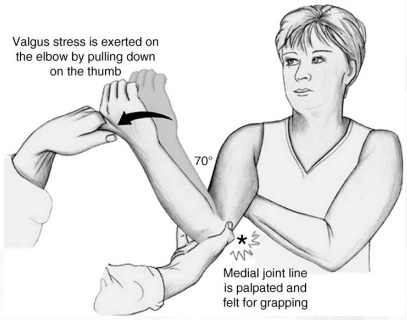
208

ASH TEST IS A STRESSFUL AND RELIABLE TEST FOR THE SHOULDER AND ELBOW







209

ASH TEST IS RELIABLE USING HANDHELD DYNAMOMETERS

	Intrarater Reliability	Interrater Reliability
Force Plates	.90-.98	.94-.99
Handheld Dynameter	.86-.96	.95-.98

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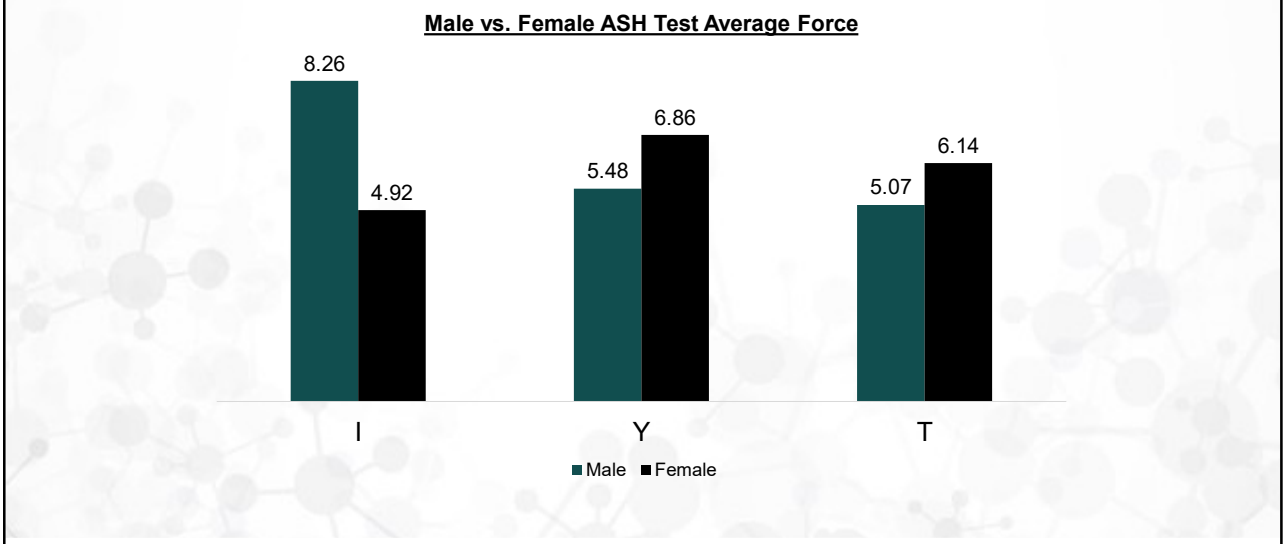
Krolikowska et al, 2022

210

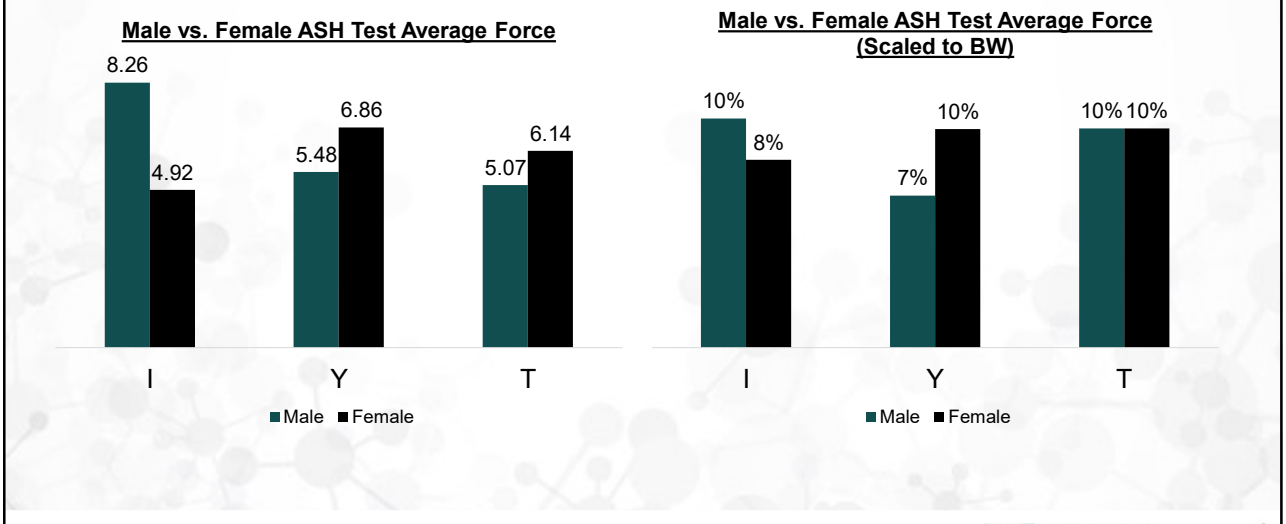
ABSOLUTE STRENGTH DATA SHOULD BE SCALED



Krolikowska et al, 2022

211

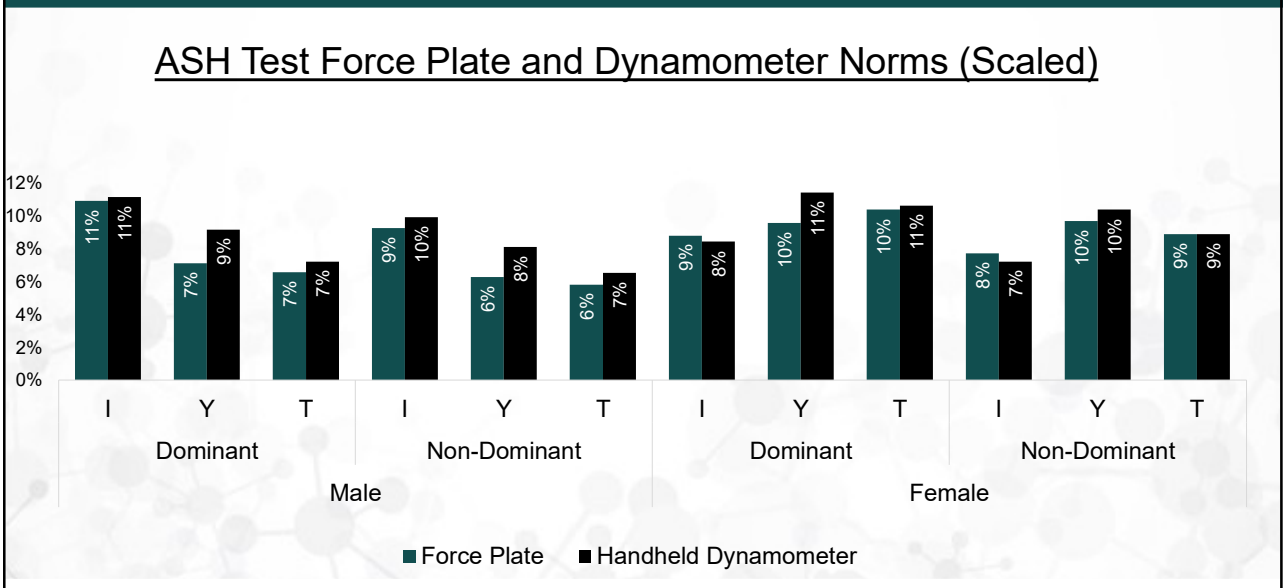
FEMALES ARE STRONGER... EVEN WHEN FFM IS NOT FACTORED



Krolikowska et al, 2022

212

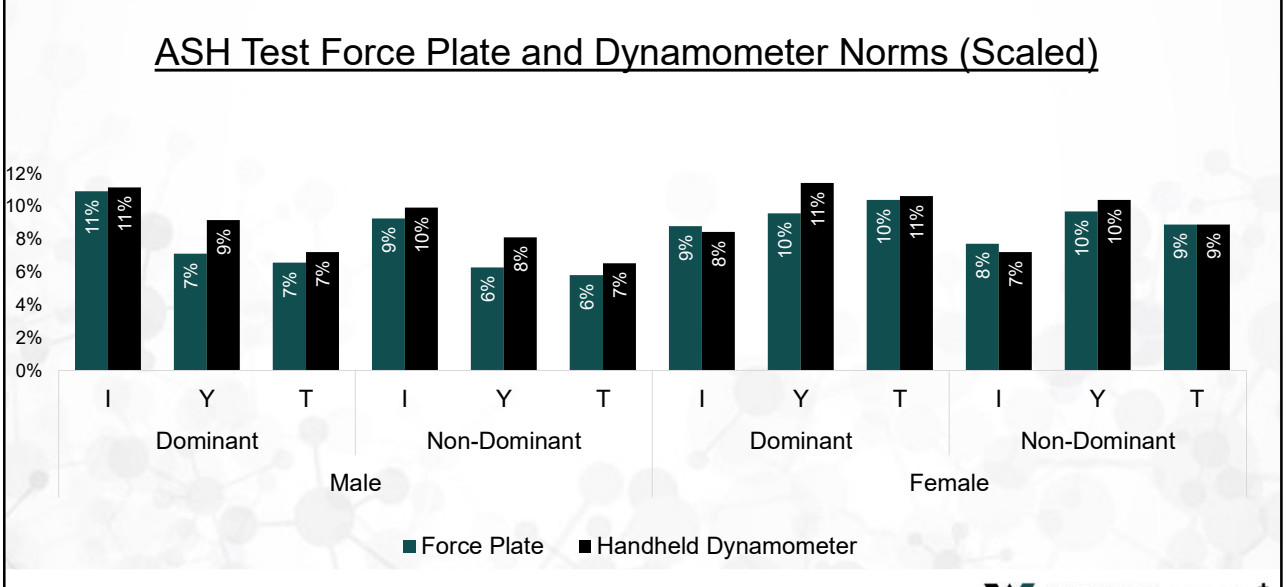
FORCE PLATE AND HHD DATA MAY NOT BE USED INTERCHANGEABLY



Krolikowska et al, 2022

213

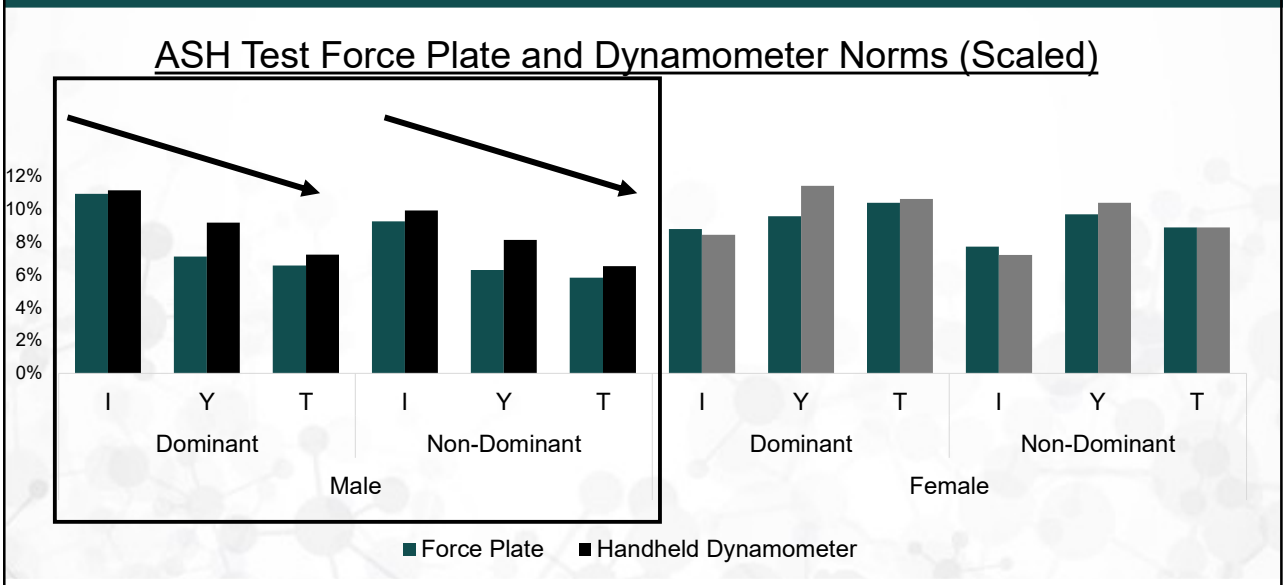
ASYMMETRIES BETWEEN ND AND D ARMS IS BETWEEN -1 AND 15 PERCENT, WITH AND AVERAGE OF 11 PERCENT AMONGST ALL POSITIONS.



Krolikowska et al, 2022

214

MALES PRODUCE LESS FORCE AT LOWER ANGLES



Krolikowska et al, 2022

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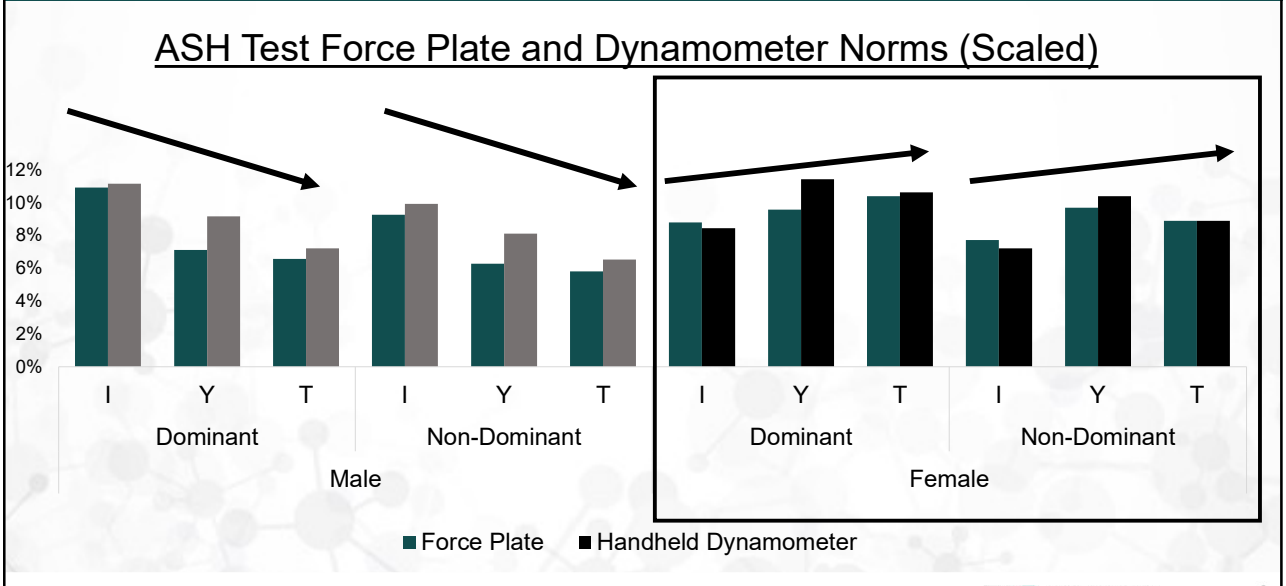
FEMALES ARE OPPOSITE



Krolikowska et al, 2022

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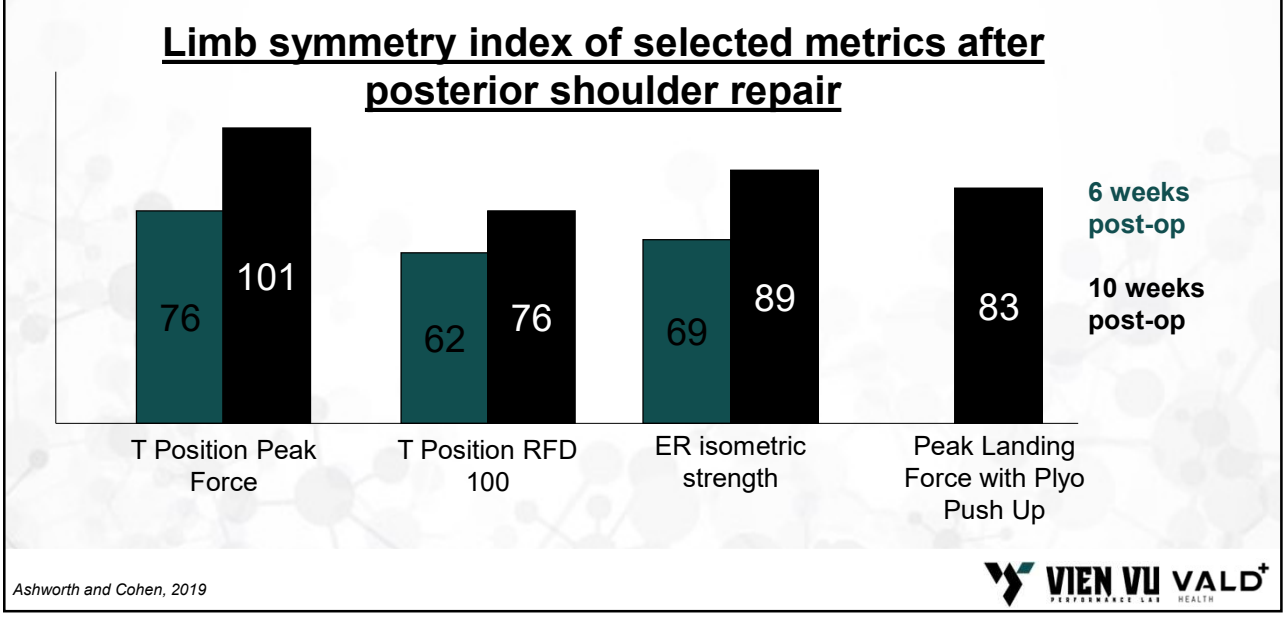
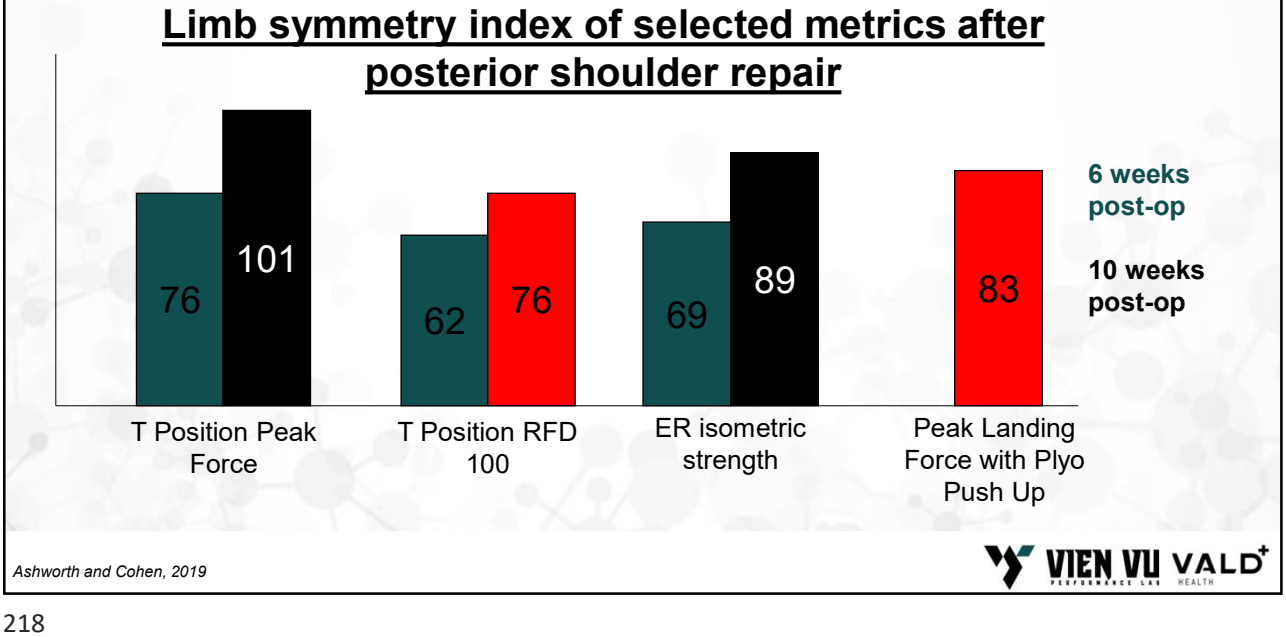
RFD100 MAY BE SUGGESTIVE, HOWEVER EVIDENCE IS NOT STRONG



Ashworth and Cohen, 2019

217

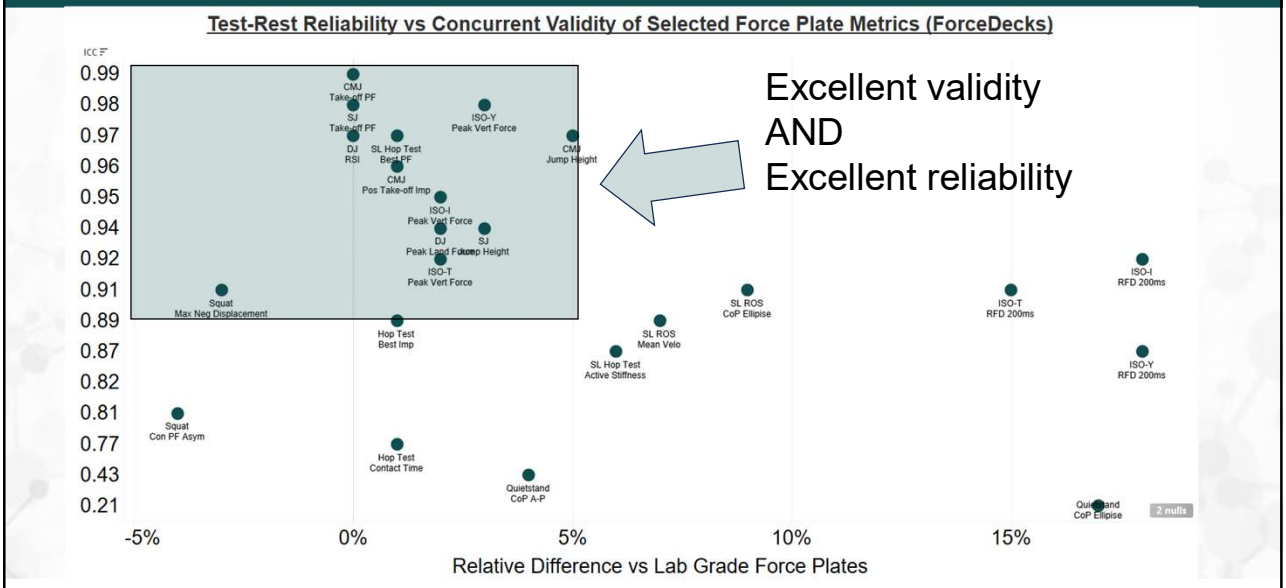
RFD100 MAY BE SUGGESTIVE, HOWEVER EVIDENCE IS NOT STRONG



Ashworth and Cohen, 2019

218

REMEMBER, THERE IS ALWAYS PROS AND CONS

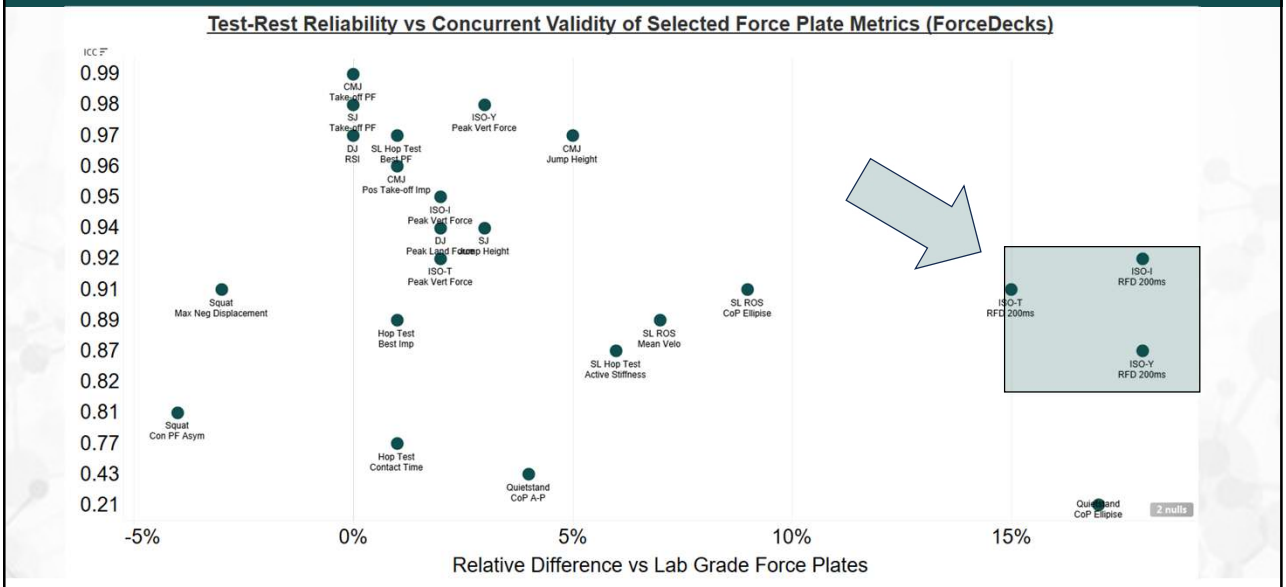


Excellent validity
AND
Excellent reliability

Collings et al, 2024

219

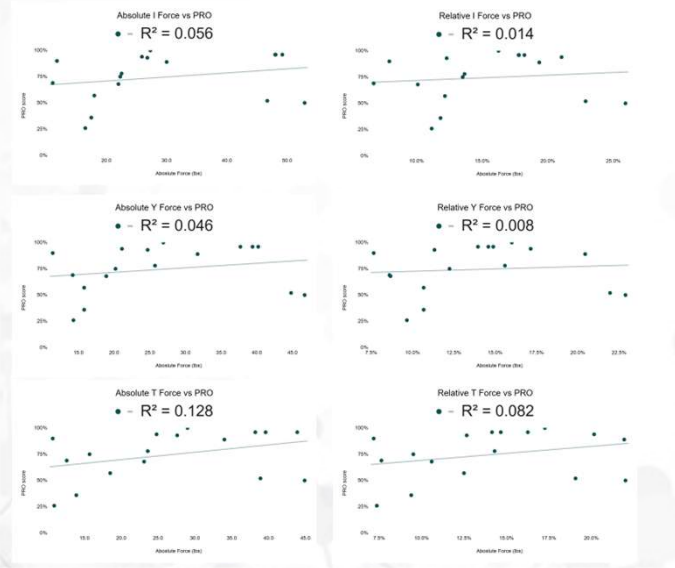
REMEMBER, THERE IS ALWAYS PROS AND CONS



Collings et al, 2024

220

ASH TEST MAY NOT BE VERY USEFUL IN ASSESSING FUNCTION, BUT SYMMETRY IS BETTER THAN ABSOLUTE FORCE WHICH IS BETTER THAN RELATIVE FORCE



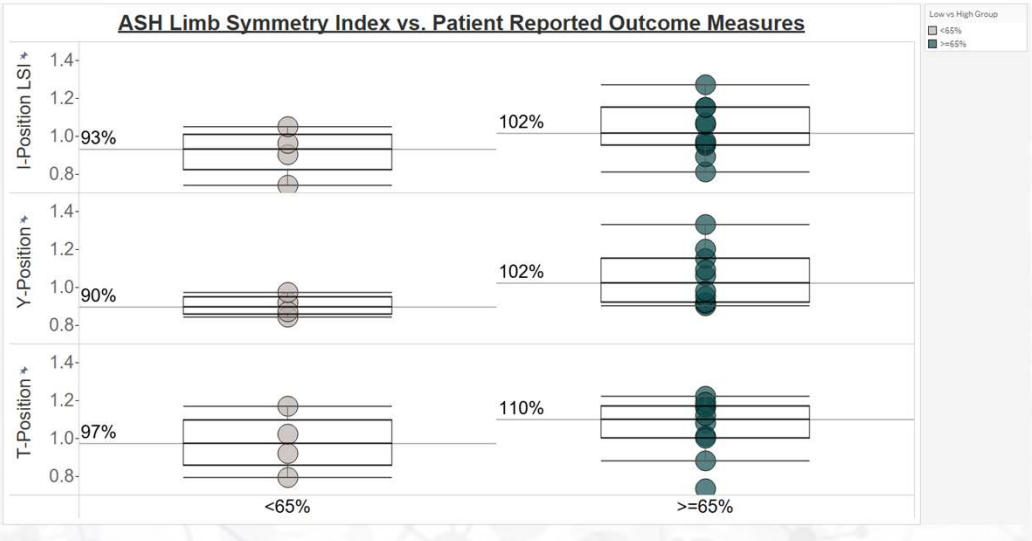
	Pearson's r	Interpretation
I Absolute	0.24	Weak
Y Absolute	0.22	Weak
T Absolute	0.36	Weak
I Relative	0.12	Very Weak
Y Relative	0.09	Very Weak
T Relative	0.29	Weak

	Pearson's R	Interpretation
I-Position	0.38	Weak
Y-Position	0.44	Moderate
T-Position	0.48	Moderate
	R2	Interpretation
I-Position	14%	Low impact
Y-Position	20%	Quite strong
T-Position	23%	Quite strong

Me et al, Unpublished

221

ASH TEST MAY NOT BE VERY USEFUL IN ASSESSING FUNCTION, BUT SYMMETRY IS BETTER THAN ABSOLUTE FORCE WHICH IS BETTER THAN RELATIVE FORCE

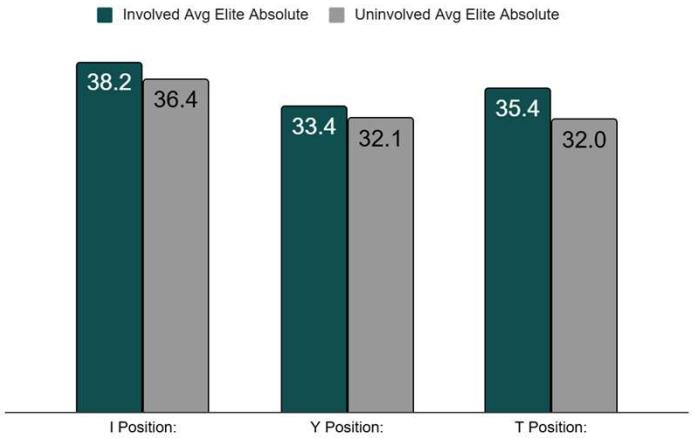


Me et al, Unpublished

222

HERE ARE NORMS REGARDLESS...

Average Absolute Force (lbs) of D1 Athletes
(Those with prior hx of shoulder injury with 80%+ patient reported outcome measures; n = 6)

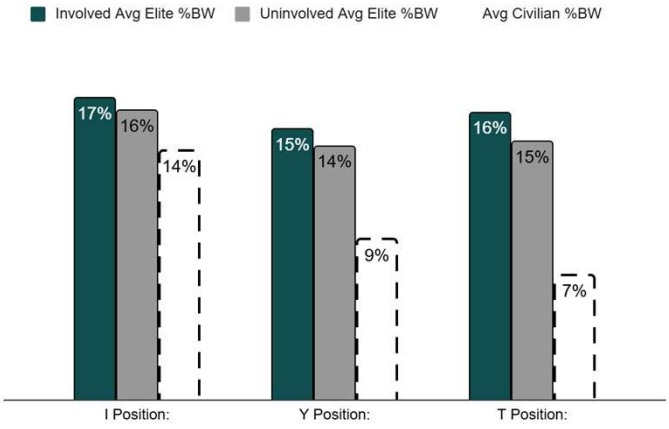


Me et al, Unpublished

223

HERE ARE NORMS REGARDLESS...

Average Relative Force (%BW) of D1 Athletes vs. Civilian Athletes



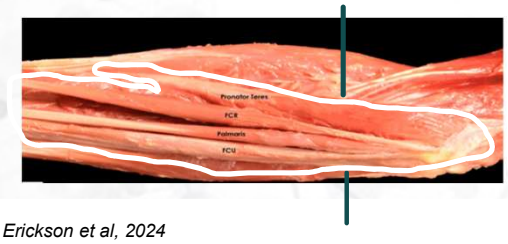
Me et al, Unpublished; Krolikowska et al, 2022

224

GRIP TESTING HAS BEEN RESEARCHED IN SHOULDER AND ELBOW INJURIES

Flexor pronator mass

- Pronator Teres
- Flexor carpi radialis (FCR)
  - Base of 2nd and 3rd metacarpal
- Palmaris Longus (PL)
- Flexor Digitorum Superficialis (FDS)
  - Middle phalanges of the 2nd to 5th digits
- Flexor Carpi Ulnaris (FCU)
  - Pisiform, hook of hamate, base of the 6th metacarpal



Erickson et al, 2024

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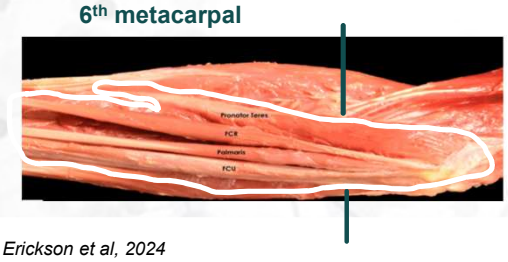
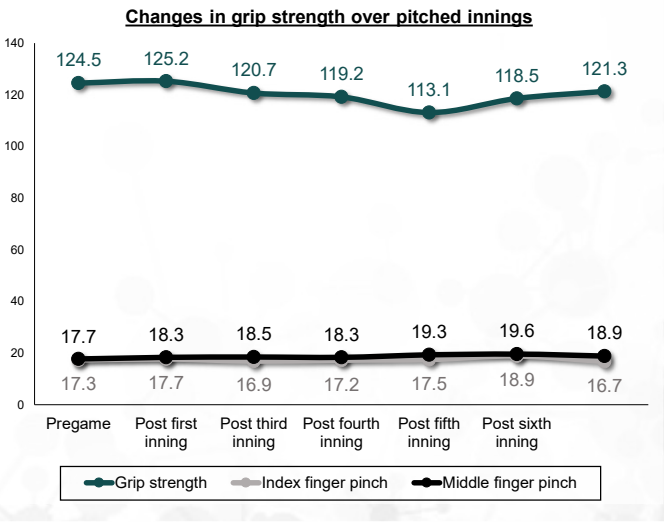
225

THERE SEEMS TO BE NO RELATIONSHIP TO ACUTE FATIGUE

Flexor pronator mass

- Pronator Teres
- **Flexor carpi radialis (FCR)**
  - **Base of 2nd and 3rd metacarpal**
- Palmaris Longus (PL)
- **Flexor Digitorum Superficialis (FDS)**
  - **Middle phalanges of the 2nd to 5th digits**
- **Flexor Carpi Ulnaris (FCU)**
  - **Pisiform, hook of hamate, base of the 6th metacarpal**





Erickson et al, 2024

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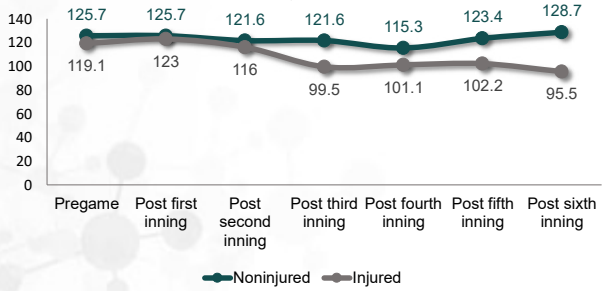
226

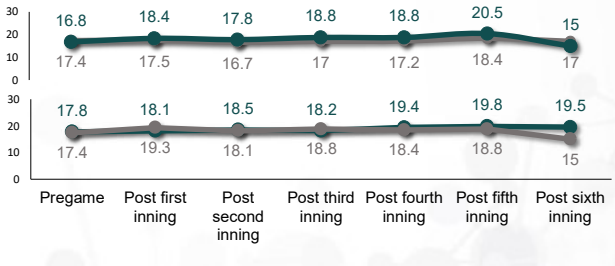
THERE SEEMS TO BE NO RELATIONSHIP TO INJURY FOR ANY GRIPS

Grip Strength over Pitched Innings (Injured vs. Non-injured)



	Pregame	Post first inning	Post second inning	Post third inning	Post fourth inning	Post fifth inning	Post sixth inning
Noninjured	125.7	125.7	121.6	121.6	115.3	123.4	128.7
Injured	119.1	123	116	99.5	101.1	102.2	95.5
difference	-6.6	-2.7	-5.6	-22.1	-14.2	-21.2	-33.2
% difference	-5.3%	-2.1%	-4.6%	-18.2%	-12.3%	-17.2%	-25.8%
p-value	0.45	0.76	0.51	0.18	0.37	0.28	N/A

Index (above) and Middle (below) Finger Pincer Strength over Pitched Innings (Injured vs. Non-Injured)



		Pregame	Post first inning	Post second inning	Post third inning	Post fourth inning	Post fifth inning	Post sixth inning
Index Finger Pincer Strength	Noninjured	17.4	17.5	16.7	17	17.2	18.4	17
	Injured	16.8	18.4	17.8	18.8	18.8	20.5	15
	difference	-0.6	+0.9	+1.1	+1.8	+1.6	+2.1	-2.0
	% difference	-3.4%	+5.1%	+6.6%	+10.6%	+9.3%	+11.4%	-11.8%
	p-value	0.5	0.27	0.37	0.78	0.73	0.78	N/A
Middle Finger Pincer Strength	Noninjured	17.8	18.1	18.5	18.2	19.4	19.8	19.5
	Injured	17.4	19.3	18.1	18.8	18.4	18.8	15
	difference	-0.4	+1.2	-0.4	+0.6	-1.0	-1.0	-4.5
	% difference	-2.2%	+6.6%	-2.2%	+3.3%	-5.2%	-5.1%	-23.1%
	p-value	0.5	0.27	0.37	0.78	0.73	0.78	N/A

Erickson et al, 2024

227

THERE WAS A STATISTICALLY SIGNFICANT ASSOCIATION IN ONE GROUP, BUT IT DOESN'T TELL US MUCH

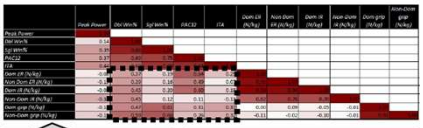
	Elbow Only		Shoulder or Elbow	
Timepoints	Injured (n = 29)	Not injured (n = 184)	Injured (n = 53)	Not injured (n = 160)
Season mean	144.7	143.9	148.2	142.6
Initial mean	144.8	140.6	145.9	139.5
Final mean	150.1	143.9	152.6	142
% change	+3.7%	+2.3%	+4.6%	+1.8%

Erickson et al, 2024

228

I THINK IT TELLS US ABOUT INVOLVEMENT AND PHYSICAL ACTIVITY

Methods: Team data was collected using a combination of VALD force plates for countermovement jump (CMJ) peak power, Kinvent K-Force plates for soleus strength, Calf Raise app for gastroc strength and endurance, and VALD Dynamo Plus for shoulder and grip strength. Shoulder strength, grip strength, and CMJ peak power were all scaled to bodyweight for data analysis. Pearson's correlation was run to observe relationships between metrics of historical win percentage and All-PAC12 or All-ITA status. Because these metrics were not collected annually, win percentage was calculated based off of average win percentage each year. Freshmen were not included in the analysis, and only individual seasons with more than 5 matches were included. Linear regression was then performed on any metric that had strong correlation with statistical significance ($p<.05$). Purpose was to find what metrics correlated to performance, and which of those metrics predicted having a history of high win percentage.

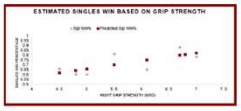


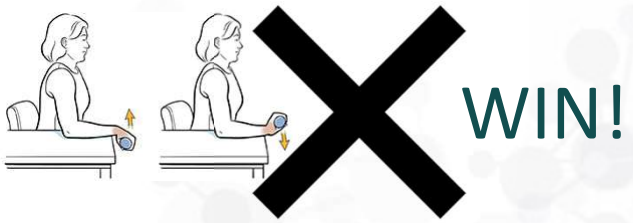
Performance Correlation

When looking at which metrics correlate with performance, shoulder strength has moderate to strong positive correlations with All-PAC12 status. Additionally, grip strength has moderate to strong positive correlation with doubles and singles win percentage. Interestingly, this correlation increases when not accounting for dominant arm. R hand grip is more correlated to doubles ($r = .57$) and singles ($r = .71$) win percentage than dominant arm grip ($r = .47$ and $r = .61$ respectively). There could be many reasons for this, but this data suggests staff should look to keep shoulder and grip strength of both arms strong throughout the season and motivate athletes by educating them on it's relationship to winning. Proper arm care routine should be developed.

Performance Prediction

Because there was no significance and less correlation between singles win percentage and dominant arm grip strength ($r = .61$, $p = .08$), linear regression was performed on singles win percentage and right hand grip strength ($r = .71$, $p = .012$). The results show that for every .56 N/kg of R hand grip strength predicted a 100 increase in annual singles win percentage. Limitations are a small sample group. Future analysis can be enhanced with more data collection in pre or post-season.





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LAB ACTIVITY FOUR 30 MIN

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