



Jumpers Knee: Maintaining Performance in the Presence of Pain Utilizing Tendon Loading Principles

Seth Jackson, PT, DPT, CSCS

Objectives

Upon completion of this session, the attendee will be able to:

- Describe the current epidemiology of patellar tendinopathy in the athletic population
- Construct an appropriate tendon loading program with appropriate progressions of intensity for a patient with patellar tendinopathy
- Apply biomechanical principles into exercise selection to alter treatment for a patient with patellar tendinopathy

Disclosures: None



Pathophysiology and Risk Factors of Patellar Tendinopathy

- Patellar tendinopathy is the clinical presentation of pain and associated dysfunction in people with underlying tendon pathology¹
- Results from repetitive, excessive overload injury to the extensor mechanism of the knee and occurs frequently in sports with explosive jumping²
- Risk factors include² :
 - Reduced Quad strength
 - Inappropriately progressed training load
 - Reduced LE flexibility
 - Reduced skill in a sport
 - Inferiorly displaced patella

Epidemiology of Patellar Tendinopathy in Athletes and the General Population

A Systematic Review and Meta-analysis

Sebastiano Nutarelli,^{*†} MS, Camilla Mondini Trissino da Lodi,^{*‡} MD, Jill L. Cook,[§] PhD,
Luca Deabate,^{*} MD, and Giuseppe Filardo,^{*||} MD, MBA, PhD

*Investigation performed at the Service of Orthopaedics and Traumatology, Department of Surgery,
EOC, Lugano, Switzerland*

- 28 Studies and over 28,000 participants found:
 - Athletes: 18.3% overall prevalence
 - No significant sex-based differences (only 10 studies included women)
 - Soccer: 6.1%
 - Basketball: 20.8%
 - Volleyball: 24.8%
 - Elite Athletes: 16.7%
 - Non-Elite Athletes: 19.9%
- General Population: 0.1% prevalence

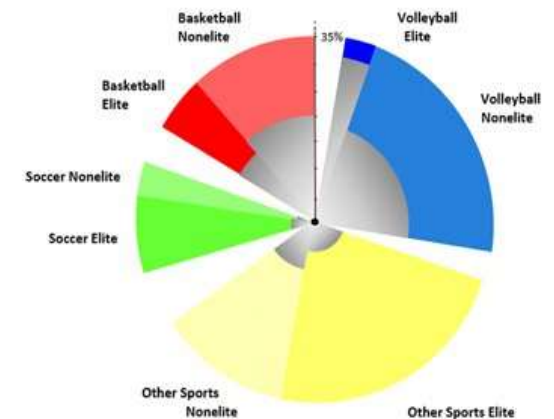


Figure 3. Prevalence of PT per level (elite/nonelite athletes) of sport participation for basketball, volleyball, soccer, and other sports. The magnified PT prevalence for each group is in gray. PT, patellar tendinopathy.

Clinical Case Introduction

- 16 y/o F Volleyball athlete, currently in-season (1 month left), with dx of (R) Patellar Tendinopathy for ~2 years
 - Worse with jumping, running, deep squats/lunges
 - VISA-P: 50/100
 - 97% LSI isometric R Quad Strength
 - 68.6% LSI isometric R Quad Max Rate of Force Development

- 1. What is the most evidence-informed initial management for an in-season athlete?**
- 2. What dosage is appropriate?**
- 3. Is pain safe during training/in-season?**

In-Season Management of Patellar Tendinopathy

The Effectiveness of Isometric Contractions Compared With Isotonic Contractions in Reducing Pain For In-Season Athletes With Patellar Tendinopathy

Chee Vang and Alexander Niznik

Take Away: Isometrics demonstrated greater reduction in pain immediately after intervention and remained reduced for 45 minutes compared to isotonic exercise



Table 2 Characteristics of Included Studies

	Rio et al ¹	Van ark et al ³	Rio et al ²
Study design	Randomized crossover	RCT	RCT
PEDro score	6/10	5/10	6/10
Participants	• 6 volleyball players (M = 6, F = 0; median age = 26.9 y) clinically diagnosed with PT. • Isometric group and isotonic group. • Performed both interventions a week apart. • Intervention was randomized. • Subjects trained twice per week. • Subjects played games once per week.	• 29 volleyball and basketball players (M = 27, F = 2; 16–32 y old) clinically diagnosed with PT. • Randomly assigned to an isometric group (mean age of 22.9 [4.9] y) or an isotonic group (mean age of 23.1 [4.7] y). • Subjects played or trained at least 3 times per week.	• 20 volleyball and basketball players (M = 18, F = 2; between 16 and 32 y old) clinically diagnosed with PT. • Randomly assigned to an isometric group (mean age of 22.9 [4.9] y) or an isotonic group (mean age of 23.1 [4.7] y). • Subjects played or trained at least 3 times per week.
Intervention(s) investigated	• Isometric group: 5 sets of 45-s quadriceps contractions at 70% 1RM using Biodex Pro. • Isotonic group: 4 sets of 8 repetitions at 8RM of quadriceps contractions using leg extension machine. • TUT and rest sets matched. • Subjects performed rehabilitation intervention once under supervision.	• Isometric group: 5 sets of 45-s quadriceps contractions at 80% 1RM using leg extension. • Isotonic group: 4 sets of 8 repetitions at 80% 8RM of quadriceps contractions on leg extension machine. • TUT and rest sets matched. • Subjects performed rehabilitation exercises 4 d/wk for 4 wk.	• Isometric group: 5 sets of 45-s quadriceps contractions at 80% 1RM using leg extension. • Isotonic group: 4 sets of 8 repetitions at 80% 8RM of quadriceps contractions on leg extension machine. • TUT and rest sets matched. • Subjects performed rehabilitation exercises 4 d/wk for 4 wk. • Instructions to avoid other quadriceps exercises during the intervention period. • 2.5% progressive overload weekly if able.
Outcome measure(s)	• Pain (NRS) during SLDS (measured at baseline, immediately, and 45-min postintervention). • No follow-up occurred after the intervention period.	• Pain (NRS) during an SLDS (measured at baseline and at 4-wk follow-up). • No follow-up occurred after the intervention period.	• Pain (NRS) during an SLDS (measured before and after every intervention session for a total of 4 wk). • No follow-up occurred after the intervention period.
Main findings	• Isometric group statistically significant pain reduction immediately after intervention ($P < .004$) and sustained at 45 min ($P < .001$). • Isotonic group statistically significant pain relief immediately after intervention ($P = .04$), however, was not sustained at 45 min.	• After 4 wk, isometric group ($P = .012$) and isotonic group ($P = .003$) statistically significant reduction in pain. • No statistically significant difference in pain between the 2 groups ($P = .208$).	• Isometric group statistically significant pain reduction immediately after each intervention session compared with isotonic group ($P = .001$). • Both groups reduced pain levels immediately.
Conclusion	• Isometric exercise: single session of isometric exercises significantly reduced patellar tendon pain immediately after intervention and remained reduced 45 min post. • Isotonic exercise: single session of isotonic exercises significantly reduced patellar tendon pain immediately after intervention but did not remain reduced at 45-min postintervention.	• Isometric exercise: 4 wk of isometric exercises resulted in significant pain reduction for subjects who were in-season with patellar tendinopathy. • Isotonic exercise: 4 wk of isotonic exercises also resulted in significant pain reduction for subjects who were in-season with patellar tendinopathy. • Training and competition loads were unaltered.	• Isometric contractions resulted in a greater reduction in patellar tendon pain immediately after intervention sessions over 4 wk.

Abbreviations: 1RM, 1-repetition maximum; 8RM, 8-repetition maximum; F, females; M, males; NRS, Numeric Pain Rating Score; PT, patellar tendinopathy; RCT, randomized controlled trial; SLDS, single-leg decline squat; TUT, time under tension.

Proper Dosage of Isometrics

Immediate and Short-Term Effects of Short- and Long-Duration Isometric Contractions in Patellar Tendinopathy

Stephen J. Pearson, PhD,* Sarah Stadler, BSc,† Hylton Menz, PhD,§ Dylan Morrissey, PhD,‡ Isabelle Scott, BSc,† Shannon Munteanu, PhD,§ and Peter Malliaras, PhD†

- 16 males recruited from State level volleyball and basketball leagues randomly assigned to 2 groups
- Short-Duration Intervention:
 - 24 sets of 10-sec hold / 20-sec rest
- Long-Duration Intervention:
 - 6 sets of 40-sec hold / 80-sec rest
- Time under Tension held constant at 4 minutes
- 5x per week over 4 weeks (Performed at 30-deg of knee flexion)
- Intensity: 18-80/20 on Borg Scale (85% MVC)

- Significant reduction in pain for SLDS and Hop Testing in both groups, no significant difference b/w groups
- Significant reduction in A-P thickness without any difference b/w groups

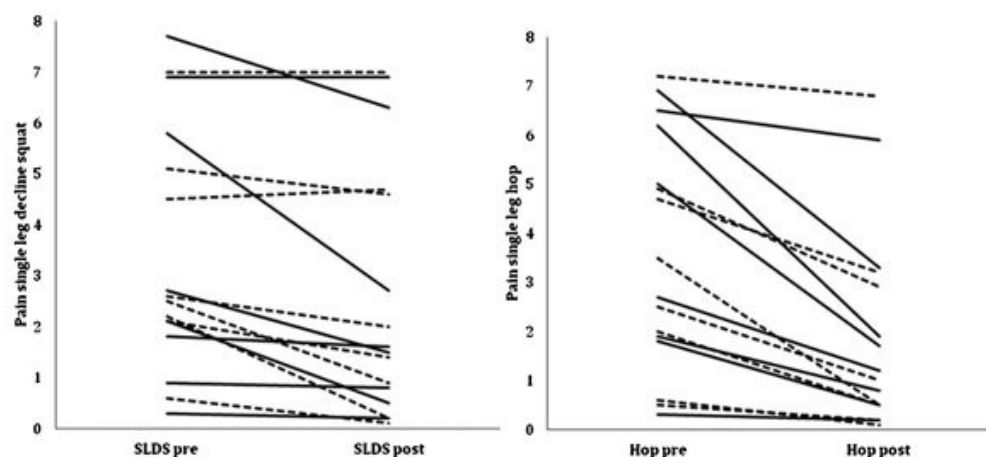


Figure 2. Immediate effects of long- and short-duration isometric loading on pain on SLDS and hop tests.

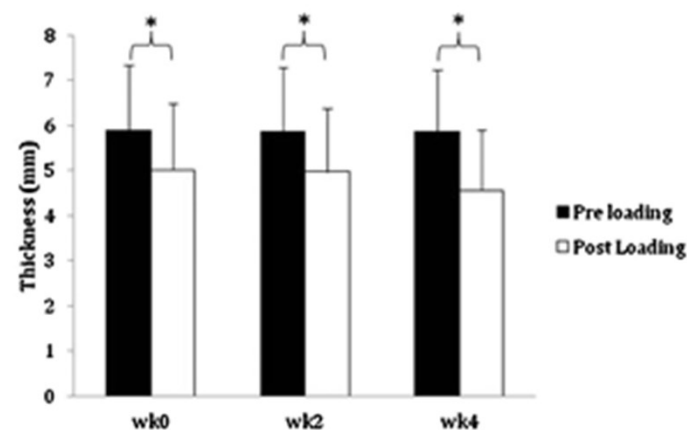


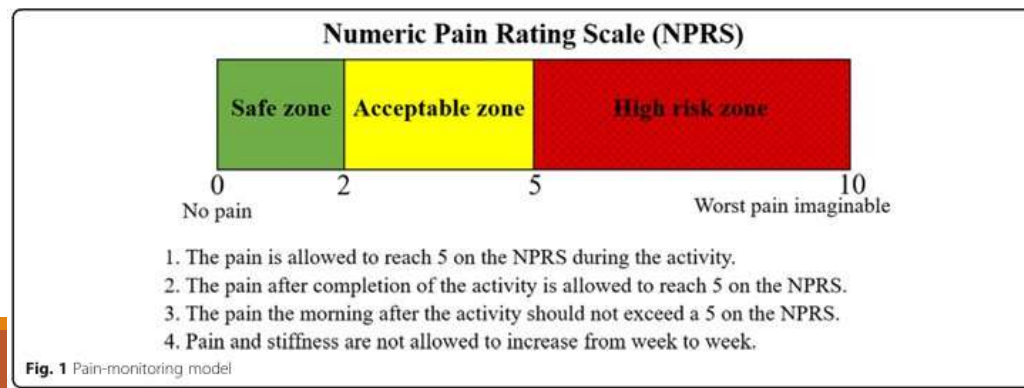
Figure 3. Mean $\pm$ SD values of patellar tendon thickness. *Significant within-session changes in thickness ($P < 0.05$).

- Take Away: Long- and short-duration isometric contractions are equally effective when total time under tension is equalized (4 minutes)

Pain-guided activity modification during treatment for patellar tendinopathy: a feasibility and pilot randomized clinical trial

Andrew L. Sprague^{1,2,3*} , Christian Couppé^{4,5,6}, Ryan T. Pohlig⁷, Lynn Snyder-Mackler^{1,2,8} and Karin Grävare Silbernagel^{1,2,8}

- Comparing 2 groups (Pain-Guided v. Pain-Free Activity)
 - PGA: using pain-monitoring model
 - Pain to not exceed 5/10 (NPRS) during or immediately after and the pain rating should return to pre-activity level by the following morning
 - PFA: not allowed to perform running, jumping, or provoking activities
 - Both groups underwent tendon loading exercises (3x per week for 12 weeks)



*PGA group had higher compliance to treatment compared to PFA Group

Table 2 Participants compliance with treatment, training diaries, activity modification, and satisfaction with treatment

	Pain-guided Mean (SD) Median (IQR)	Pain-free Mean (SD) Median (IQR)	Pain-free—complete cases ^a Mean (SD) Median (IQR)
Proportion of prescribed treatment sessions completed (%)	86.1 (13.0) 83.3 (22.2)	67.1 (30.7) 77.8 (20.1)	78.9 (11.7) 80.6 (11.1)
Proportion of weeks compliant with treatment (%)	92.3 (9.4) 91.7 (8.3)	76.4 (37.8) 91.7 (6.3)	91.7 (5.9) 91.7 (0.0)
Proportion of days training diary was completed (%)	98.4 (2.7) 100.0 (2.4)	81.3 (40.0) 98.8 (7.7)	97.6 (4.1) 100.0 (2.4)
Proportion of days compliant with activity restrictions (%)	97.3 (3.9) 100.0 (5.4)	80.2 (39.8) 98.8 (13.1)	96.2 (7.3) 100.0 (2.4)
Days of running or jumping per week (days/wk) ^b	1.9 (1.4) 1.5 (2.0)	0.0 (0.2) 0.0 (0.0)	0.0 (0.2) 0.0 (0.0)
Satisfaction with treatment at 6 weeks	9.0 (1.1) 9.0 (2.0)	7.3 (2.3) 7.0 (4.3)	
Satisfaction with treatment at 12 weeks	9.3 (1.1) 10.0 (1.0)	8.4 (2.1) 9.0 (2.0)	

^aParticipant that was lost to follow-up following COVID-19 was dropped for the complete cases analysis

^bFirst 6 weeks used since restrictions on running and jumping were only applied for the first 6 weeks of treatment

*KOOS-QOL were significantly higher for the PGA group

*VISA-P scores for PGA group were significantly higher than PFA group, demonstrating **decreased sx severity**

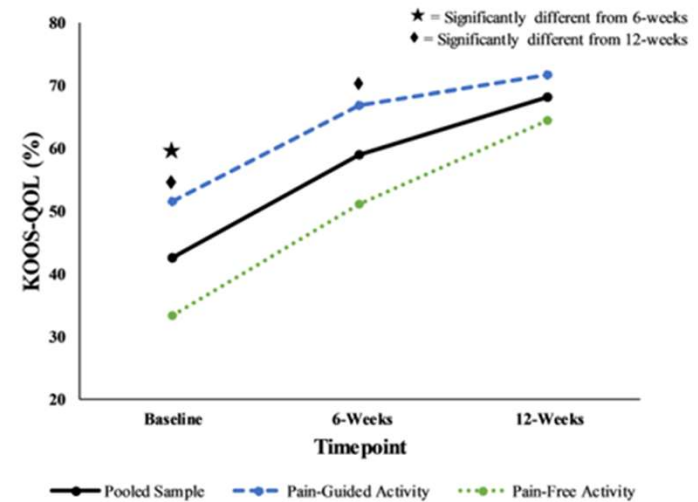


Fig. 5 Estimated marginal means for KOOS-QOL for the pooled sample and groups. Note: Statistical significance is for the pooled sample only and Y-axis is truncated

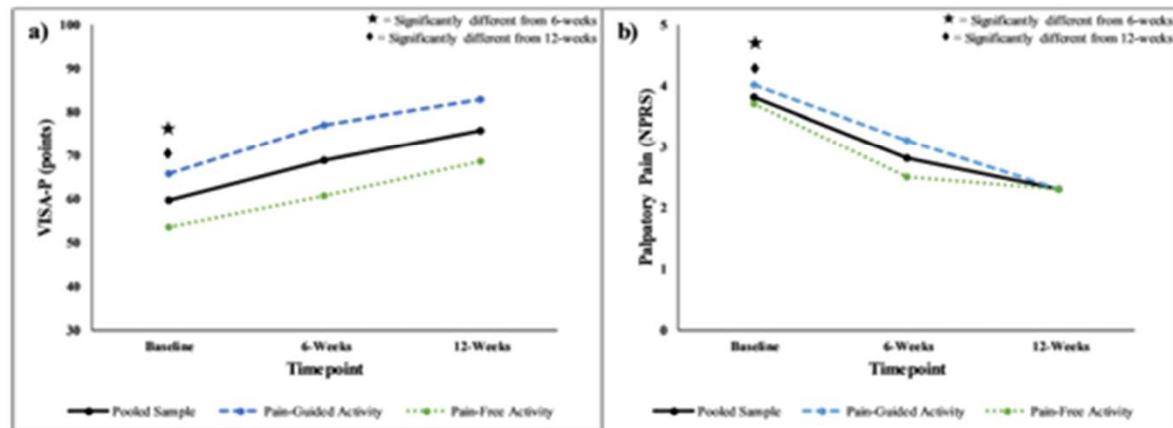


Fig. 4 Estimated marginal means for **a** VISA-P and **b** palpatory pain for the pooled samples and groups. Note: Statistical significance is for the pooled sample only and Y-axis is truncated

Application to Clinical Case

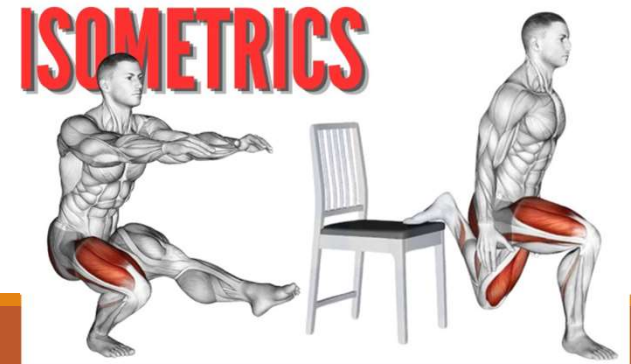
- Initial Tx Focus: Isometrics and Education

- Progressing intensity and duration as tolerated

- Duration: Total time under tension ~4 minutes, 2-3x per day (45 seconds x5 repetitions) ; work:rest ratio of 1:2
 - Intensity: 70-80% or <5/10 NPRS ("tolerable") - added resistance throughout rehab progression

- Performed prior to practice/competition and immediately after due to analgesic effect

- Education!!



Heavy Slow Resistance (HSR) or Eccentrics on Patellar Tendinopathy Management

Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review

- HSR

Hui Yin Lim^{1,2}  | Shi Hui Wong^{1,2}

- 2 included studies that demonstrated improvement in pain and function at 12-week f/u

- Eccentric

- 9/10 studies showed positive results for eccentric exercise in improving pain and function
- 1 Study compared to standard concentric exercise showing no significant difference between groups

TABLE 5 Summary of results—between groups

Author (year)	Level of study (NHMRC)	Comparator	Pain	Function
Isometric				
Rio et al. (2015)	III-2	Isotonic exercises	+	Not reported
Rio et al. (2016)	II	Isotonic exercises	+	=
van Ark et al. (2016)	II	Isotonic exercises	=	=
HSR				
Kongsgaard et al. (2010)	III-2	Healthy matched controls—no intervention	+	+
Romero-Rodriguez et al. (2011)	IV	Nil	+	+
Eccentric				
Biernat et al. (2014)	II	Control—continue with usual training	Not reported	+
Cannell et al. (2001)	II	Leg extension/curl group	=	=
Croisier et al. (2001)	IV	No comparator	+	+
Frohm et al. (2007)	II	One-legged eccentric training	+	=
Jonsson and Alfredson (2005)	II	Concentric exercises	+	+
Purdam et al. (2004)	III-2	Standard squat	+	+
Stasinopoulos et al. (2012)	III-1	Eccentric exercises with stretching	Not reported	-
Stasinopoulos and Stasinopoulos (2004)	II	Ultrasound and transverse friction	+	Not reported
Visnes et al. (2005)	II	Control—continue with usual training	Not reported for between group	=
Young et al. (2005)	II	Step squat exercises	=	=

Note. +: significant improvement; =: no difference between groups; -: lesser improvement than comparator; NHMRC: National Health and Medical Research Council.

Heavy Slow Resistance (HSR) or Eccentrics on Patellar Tendinopathy Management

Mixed comparison of intervention with eccentric, isometric, and heavy slow resistance for Victorian Institute of Sport Assessment Patella Questionnaire in adults with patellar tendinopathy: A systematic review and network meta-analysis

Yifei Li^{a,b}, Dong Sun^{a,b,*,*}, Yufei Fang^a, Zhenghui Lu^{b,c,f}, Feicun Shi^d, Gongju Liu^e,
Yaodong Gu^{a,b,*}

- Updated systematic review
- Lack of direct HSR comparing to Eccentric training
 - In the included studies HSR was performed in combination with other therapy/exercise

Comparison of Findings

ECCENTRICS

Pros:

- Affordable and easier to perform at home
- All eccentric training groups improved VISA-P scores compared to other interventions (1 exception)

Cons:

- Less effective when compared to training interventions that utilize multiple training methods (isometrics + moderate slow resistance or HSR)
- No long term (>24 weeks) studies were included
- Interventions varied but most utilized:
 - 25-degree Slant Board
 - 15 repetitions, 2x/day
 - 12 to 24-week program

HEAVY SLOW RESISTANCE (HSR)

Pro:

- All included studies demonstrates significant improvement in function and reduction in pain after 12 weeks and up to 52 weeks

Con:

- Need more specialized equipment to follow specific research protocol
- Intervention:
 - Deep Squats, Leg Press, and hack squats
 - 4 sets with 6-15 repetitions
 - 2-3x/week for 6 to 12 weeks

HSR or Eccentrics?

Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review

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- HSR has better research showing long-term outcomes
- Both have research showing benefits in pain and function
- Take away: Consider what the patient can tolerate, perform consistently, and their preference

What can I use to load if unable to utilize hack squat, leg press, or SLDS due to excessive pain or not having access to equipment?

Patellar Tendon Load Progression during Rehabilitation Exercises: Implications for the Treatment of Patellar Tendon Injuries

Rodrigo Scattone Silva^{1,2}, Ke Song³, Todd J. Hullfish³, Andrew Sprague⁴, Karin Grävare Silbernagel², Josh R. Baxter³

This article compared 35 different rehab exercises to help clinical guidance in progressive loading of the patellar tendon, creating the patellar tendon loading index

Patellar Tendon Loading Index

- Understanding biomechanical load to the patellar tendon to alter exercise selection to match patient tolerance, as well as a guide for exercise progression

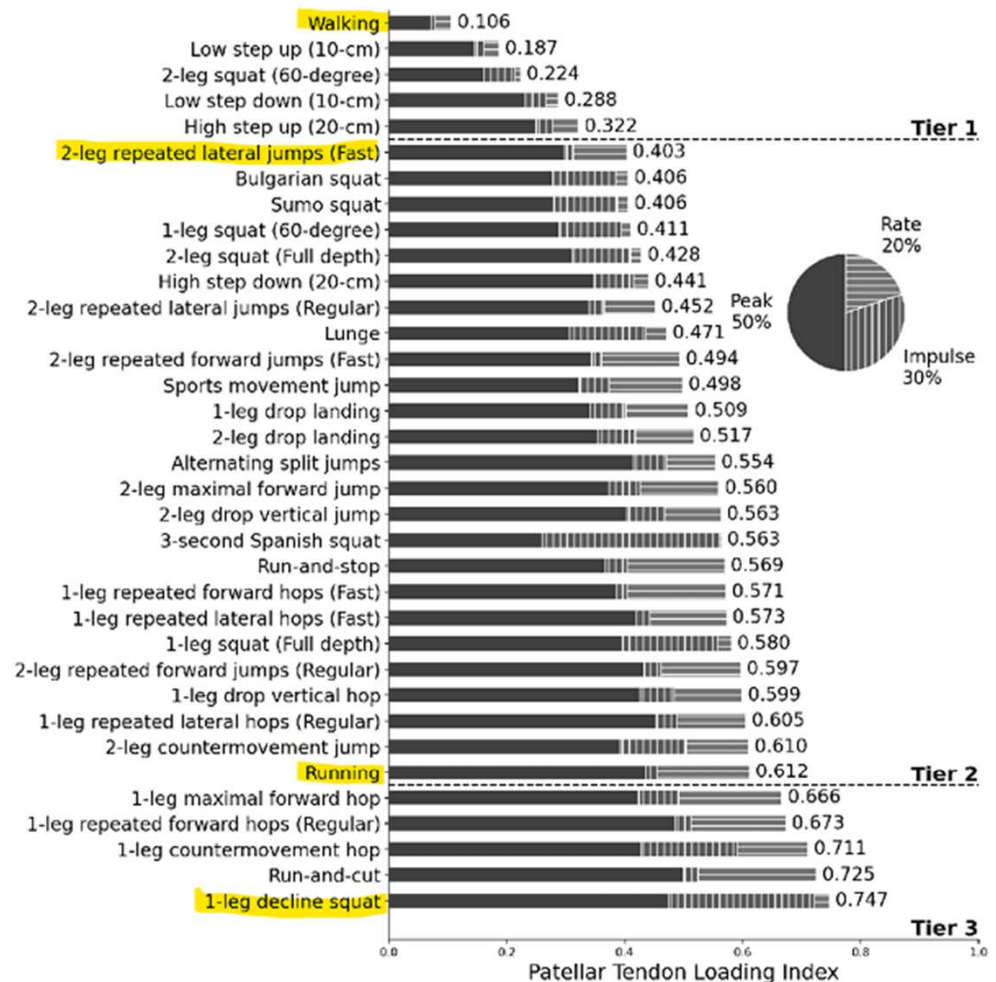


Figure 2. Patellar tendon loading index across 35 rehabilitation exercises, categorized as low (Tier 1), moderate (Tier 2), and high (Tier 3). Each loading index was determined with a 50% weight on loading peak (bodyweight), 30% weight on loading impulse (bodyweight * second), and 20% on loading rate (bodyweight / second).

Table 1.

Patellar tendon loading index, loading peak, loading impulse, and loading rate across 35 rehabilitation exercises (n=20).

	Exercise	Loading Index	Loading Peak (BW)	Loading Impulse (BW/s)	Loading Rate (BW/s)
Tier 1	Walking	0.106	0.8 ± 0.4	0.2 ± 0.1	13.4 ± 4.9
	Low Step Up	0.187	1.6 ± 0.3	0.4 ± 0.1	12.6 ± 2.9
	2-Leg Squat (60°)	0.224	1.8 ± 0.5	1.5 ± 0.5	4.7 ± 1.8
	Low Step Down	0.288	2.5 ± 0.5	0.9 ± 0.4	10.5 ± 2.5
	High Step Up	0.321	2.7 ± 0.4	0.7 ± 0.2	21.4 ± 3.5
	2-Leg Repeated Lateral Jumps (Fast)	0.403	3.3 ± 1.0	0.4 ± 0.2	44.0 ± 12.1
	Bulgarian Squat	0.406	3.0 ± 0.5	2.9 ± 0.7	10.1 ± 2.2
	Sumo Squat	0.406	3.1 ± 0.5	2.9 ± 0.7	9.1 ± 1.7
	1-Leg Squat (60°)	0.411	3.2 ± 0.7	2.9 ± 0.7	8.1 ± 2.6
	2-Leg Squat (Full)	0.428	3.4 ± 0.7	2.7 ± 0.5	9.2 ± 2.7
Tier 2	High Step Down	0.441	3.8 ± 0.5	1.8 ± 0.8	12.9 ± 3.1
	2-Leg Repeated Lateral Jumps (Regular)	0.452	3.7 ± 0.9	0.7 ± 0.2	42.2 ± 7.5
	Lunge	0.471	3.3 ± 0.6	3.6 ± 0.9	16.8 ± 4.7
	2-Leg Repeated Forward Jumps (Fast)	0.494	3.8 ± 1.3	0.4 ± 0.2	64.4 ± 20.3
	Sport Movement Jump	0.498	3.5 ± 0.7	1.4 ± 0.6	60.3 ± 15.4
	1-Leg Drop Landing	0.509	3.7 ± 0.8	1.7 ± 0.7	51.4 ± 9.3
	2-Leg Drop Landing	0.517	3.9 ± 0.8	1.7 ± 0.7	48.1 ± 9.5
	Alternating Split Jumps	0.554	4.5 ± 0.9	1.5 ± 0.4	40.1 ± 9.5
	2-Leg Maximal Forward Jump	0.560	4.1 ± 0.5	1.4 ± 0.5	64.4 ± 10.4
	2-Leg Drop Vertical Jump	0.563	4.4 ± 0.9	1.8 ± 0.5	46.1 ± 9.0
	3-Second Spanish Squat	0.563	2.8 ± 1.1	8.2 ± 3.0	1.6 ± 1.3
	Run-and-Stop	0.569	4.0 ± 0.9	1.0 ± 0.4	79.6 ± 20.7
	1-Leg Repeated Forward Hops (Fast)	0.571	4.2 ± 1.4	0.5 ± 0.2	80.3 ± 17.8
	1-Leg Repeated Lateral Hops (Regular)	0.573	4.6 ± 1.4	0.6 ± 0.2	63.2 ± 14.8
	1-Leg Squat (Full)	0.580	4.3 ± 0.7	4.4 ± 0.9	11.3 ± 2.4
	2-Leg Repeated Forward Jumps (Regular)	0.597	4.7 ± 0.8	0.8 ± 0.2	65.1 ± 13.9
	1-Leg Drop Vertical Hop	0.599	4.7 ± 1.1	1.6 ± 0.4	55.8 ± 10.3
	1-Leg Repeated Lateral Hops (Regular)	0.605	5.0 ± 1.1	1.0 ± 0.3	56.0 ± 9.5
	2-Leg Countermovement Jump	0.610	4.3 ± 0.7	3.1 ± 1.0	50.7 ± 10.5
	Running	0.612	4.8 ± 0.8	0.5 ± 0.1	75.7 ± 11.4

Patellar Tendon Loading Index

	Exercise	Loading Index	Loading Peak (BW)	Loading Impulse (BW/s)	Loading Rate (BW/s)
Tier 3	1-Leg Maximal Forward Hop	0.666	4.6 ± 0.8	1.9 ± 0.9	83.9 ± 16.2
	1-Leg Repeated Forward Hops (Regular)	0.673	5.3 ± 1.2	0.7 ± 0.2	77.0 ± 11.2
	1-Leg Countermovement Hop	0.711	4.7 ± 1.0	4.5 ± 1.3	57.4 ± 15.3
	Run-and-Cut	0.725	5.5 ± 1.2	0.7 ± 0.2	96.2 ± 18.3
	1-Leg Decline Squat	0.747	5.2 ± 0.6	6.8 ± 2.0	12.3 ± 2.4

* Loading index is the weighted sum of scaled and normalized peak loading, loading impulse, and loading rate. BW, bodyweight; s, second; 1-Leg, single-leg; 2-Leg, double-leg; Full, complete range of motion; Regular, self-selected speed; Fast, faster speed.

- Beginning stages of rehab, **loading peak and loading impulse**, are more important to progressively increase tendon's load tolerance⁷
- In the advanced stages (RTS) may be more important to focus on **loading rate**⁷

The Effect of Trunk and Shank Position on the Hip-to-Knee Moment Ratio in a Bilateral Squat

Kerri A. Graber, PT, DPT^a, Anne L. Halverstadt^a, Simone V. Gill, PhD, OT, OTR^b, Varsha S. Kulkarni, PhD^c, Cara L. Lewis, PT, PhD^a

- Hip-to-Knee moment ratio increased (larger hip moment and smaller knee moment) with increasing trunk angle and squat depth – Hip Dominant Movement Pattern
 - 1-degree increase in trunk angle increase hip-to-knee ratio by 2% -> **Less stress on Knee**
- Hip-to-Knee moment ratio decreased (smaller hip moment and higher knee moment, i.e. more demand for knee extensors) with increasing shank angle – Knee Dominant Movement Pattern
 - 1-degree increase in shank angle decrease the ratio by 2.9% -> **More stress on Knee**
- Take Away: Verbal cues to increase trunk flexion and land softly may help to improve load transmission⁷

The Effect of Trunk Moment

Kerri A. Grimmer, PhD
Kulkarni, Pooja

- Hip-to-Knee moment (i.e. moment) with i.e. movement pattern
 - 1-degree increase in knee flexion
- Hip-to-Knee moment (i.e. moment) – Knee Dominant
 - 1-degree increase in knee flexion
- Take Away: Very important to improve load



Figure 1: Depiction of hip-dominant (light gray) and knee-dominant (dark gray) squat positions at the same degree of knee flexion. The hip-dominant squat, with the knees staying behind the toes, better incorporates the hip extensors. The knee-dominant squat, with the knees moving anterior to the toes, primarily targets the knee extensors. While the two squats differ in knee position, the squats also differ in trunk position.

nee

, Varsha S.

and smaller knee
p Dominant

-> Less stress on

: and higher knee
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softly may help

Patellar tendon stress between two variations of the forward step lunge

[Matthew Zellmer](#)^a, [Thomas W Kernozek](#)^{a,*}, [Naghme Gheidi](#)^a, [Jordan Hove](#)^a, [Michael Torry](#)^b

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PMCID: PMC6523035 PMID: [31193251](#)

- Compared Forward Step Lunge with Knee In Front of Toes (FSL-FT) and Knee Behind Toes (FSL-BT)
 - Peak Patellar Tendon Stress FSL-FT > FSL-BT
 - Stress Impulse FSL-FT > FSL-BT
 - Quadriceps Force FSL-FT > FSL-BT



A: Forward Step Lunge with Knee in Front of Toes (FSL-FT)

B: Forward Step Lunge with Knee Behind Toes (FSL-BT)

Isotonic Loading Application to Clinical Case

- Pt enjoyed lifting weights and had access to school gym/Planet Fitness -> After presenting both options pt wanted to pursue HSR
- Initiated HSR once pt was transitioning to offseason to prevent over training effect and when she was able to tolerate (<5/10 NPRS) loading
- Continued with isometrics program daily and as warm up prior to HSR
- Initial Exercises: DL Squat (~60-degrees/to tolerance), Lateral Step Tap (4"->8"), Split Squat (tolerable range)
 - Tempo: 3-sec eccentric + 3-sec concentric
 - 3-4 sets per exercise
 - 12-15 reps (progressing to 6-8 reps as intensity and tolerance increased)
 - 2x per week

HSR Application to Clinical Case

- Pt enjoys present
- Initiated effect all
- Continued
- Initial Ex (>8"), Sp
 - Temp
 - 3-4 s
 - 12-1!
 - 2x pe



Range of Motion	Full knee extension to 90° of knee flexion
Rate of Loading	3-sec eccentric phase, 3-sec concentric phase (6-sec total) per repetition
Sets	4 sets each
Rest	2 minutes between sets
Repetitions/Load	Week 1: 15 repetition maximum (RM) Weeks 2-3: 12-RM Weeks 4-5: 10-RM Weeks 6-8: 8-RM Weeks 9-12: 6-RM

Fig. 2 Heavy-slow resistance training parameters for the **a** squat, **b** knee extension, and **c** leg press

> After
ning

4"-

HSR App

- Pt enjoy present
- Initiated effect all
- Continu
- Initial Ex (>8"), Sp
 - Temp
 - 3-4 s
 - 12-1!
 - 2x pe

Fig. 2 Heavy-slow

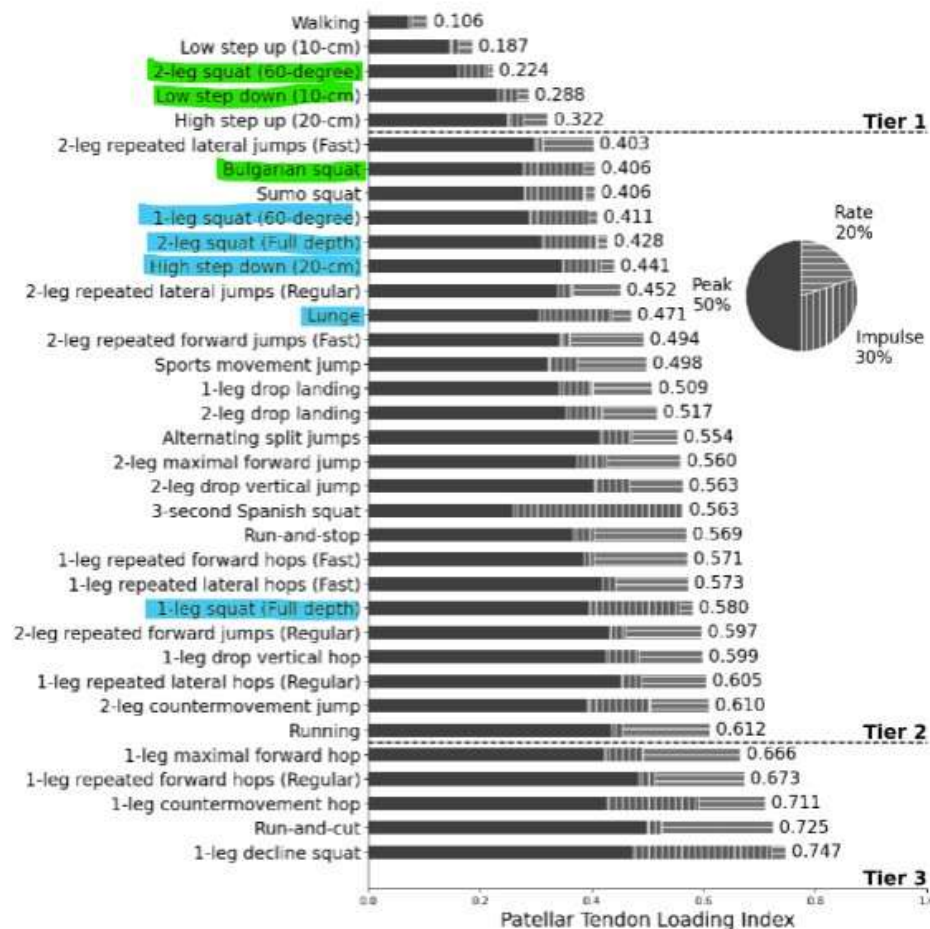


Figure 2.

Patellar tendon loading index across 35 rehabilitation exercises, categorized as low (Tier 1), moderate (Tier 2), and high (Tier 3). Each loading index was determined with a 50% weight on loading peak (bodyweight), 30% weight on loading impulse (bodyweight * second), and 20% on loading rate (bodyweight / second).

> After
ning
4"-

Plyometric Application to Clinical Case

- Once patient was able to tolerate without >5/10 NPRS, initiated in the clinic

	Sun	Mon	Tue	Wed	Thur	Fri	Sat
Iso	X (Rest)	X	X	X (Rest)	X	X	X (Rest)
HSR			X			X	
Plyo/RTP		X			X		

- Progressed plyometrics based on tolerance and loading rate

Plyomet

nical Practice

- Once patient in clinic

NPRS, initiated in the

		Exercise	Rate_Mean (xBW/s)	Fri	Sat
		3-second Spanish squat	1.6		
		2-leg squat (60-degree)	4.7		
		1-leg squat (60-degree)	8.1		
		Sumo squat	9.1		
		2-leg squat (Full depth)	9.2		
		Bulgarian squat	10.1		
		Low step down (10-cm)	10.5		
		1-leg squat (Full depth)	11.3		
		1-leg decline squat	12.3		
		Low step up (10-cm)	12.6		
		High step down (20-cm)	12.9		
		Walking	13.4		
		Lunge	16.8		
		High step up (20-cm)	21.4		
		Alternating split jumps	40.1		
		2-leg repetitive lateral jumps (Regular)	42.2		
Iso	X	2-leg repetitive lateral jumps (Fast)	44.0	X	X (Rest)
		2-leg drop vertical jump	46.1		
		2-leg drop landing	48.1		
HSR		2-leg countermovement jump	50.7	X	
		1-leg drop landing	51.4		
		1-leg drop vertical hop	55.8		
Plyo/RTP		1-leg repetitive lateral hops (Regular)	56.0		
		1-leg countermovement hop	57.4		
		Sports movement jump	60.3		
		1-leg repetitive lateral hops (Fast)	63.2		
		2-leg repetitive forward jumps (Fast)	64.4		
		2-leg maximal forward jump	64.4		
		2-leg repetitive forward jumps (Regular)	65.1		
		Running	75.7		
		1-leg repetitive forward hops (Regular)	77.0		
		Run-and-stop	79.6		
		1-leg repetitive forward hops (Fast)	80.3		
		1-leg maximal forward hop	83.9		
		Run-and-cut	96.2		

- Progressed p

loading rate

Summary of Progressing Across the Course of Treatment¹⁰

Stage	Indication to Initiate
1. Isometric loading	More than minimal pain during isotonic exercise*
2. Isotonic loading	Minimal pain during isotonic exercise*
3. Energy-storage loading	A.Adequate strength [†] and consistent with other side B.Load tolerance with initial-level energy-storage exercise (ie, minimal pain during exercise and pain on load tests returning to baseline within 24 h)*
4. Return to sport	Load tolerance to energy-storage exercise progression that replicates demands of training

Conclusion of Clinical Case

- Patient completed 10 sessions over the course of 12 weeks
- Outcomes:
 - Able to complete off-season practices without >5/10 pain (including jumping, running, etc.)
 - VISA-P: 75 (50 start)
 - No significant change in Max Quad Strength (started at >95% LSI)
 - 87.1% LSI R Quad Max Rate of Force Development (68.6% start)
- Discharged to continue HEP independently

Thank You!

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