DIU de la Pathologie Locomotrice liée à la Pratique du Sport

Année 2016-2017

Rééducation et prévention des lésions musculaires

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MCU-PH en Physiologie et Médecine du Sport

Service de Physiologie Clinique et de l'Exercice

Unité de Médecine du Sport

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Rééducation et prévention des lésions musculaires : Modèle des muscles ischio-jambiers

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Pourquoi s’intéresser aux lésions musculaires des ischio-jambiers ?

Lésions musculaires des ischio-jambiers

- 1ère blessure dans sports avec accélérations et sprints
- Foot ou Rugby :
  - ≈ 15% des lésions sur une saison
  - ≈ 18 jours d'absence par saison
  - lésions récidivantes : 15 à 30 %

Ekstrand et al. 2011, 2014, Engebretsen et al. 2013

TABLE 2
Incidence, Prevalence, and Nature of 4 Most Common Muscle Injuries

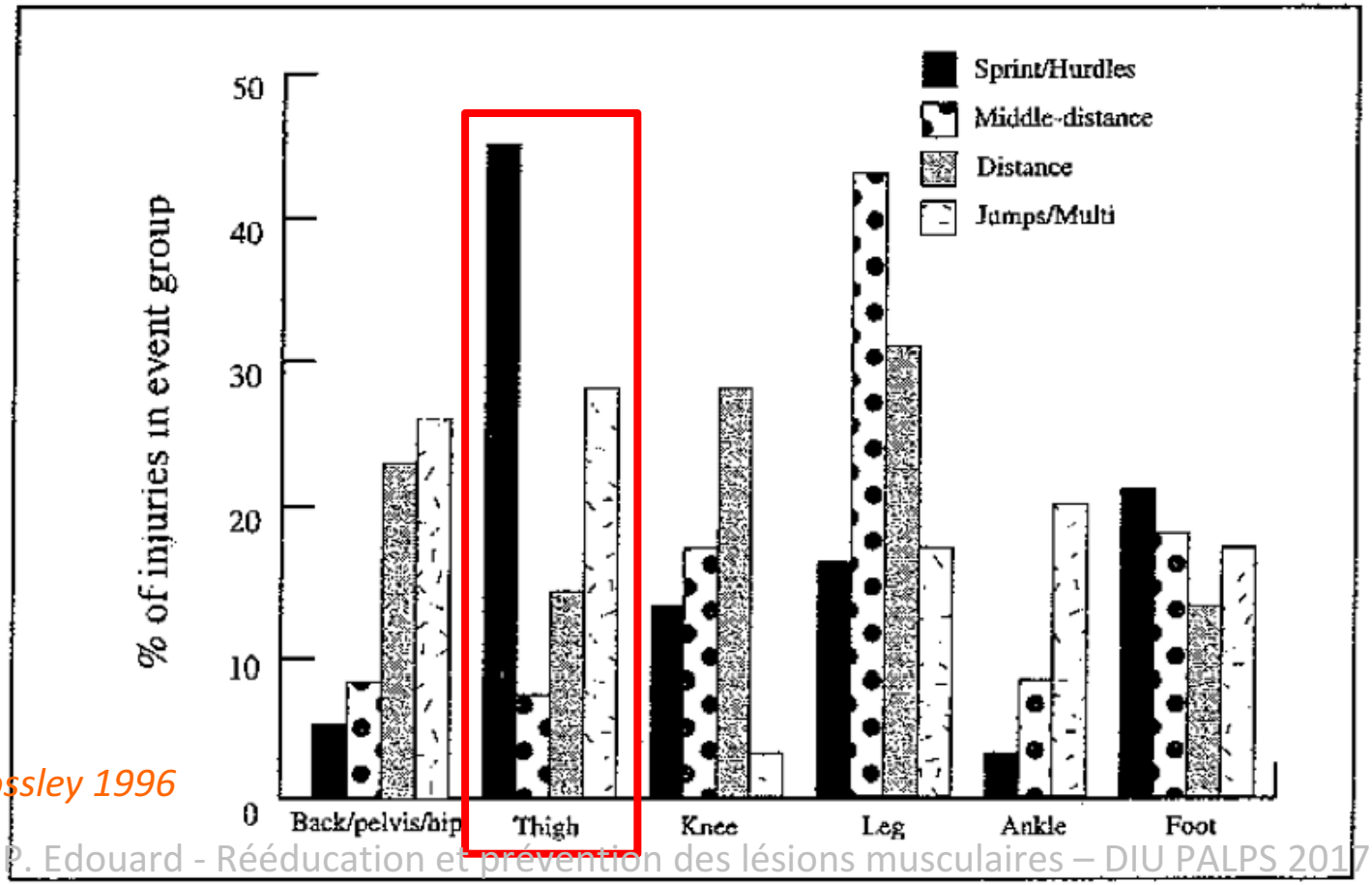
Ekstrand et al. 2011

	Hamstrings	Quadriceps	Adductors	Calf Muscles
n (% of total no. of injuries)	1084 (12)	485 (5)	672 (7)	368 (4)
Season prevalence, %	17	8	14	6
Total injury incidence (95% confidence interval)	0.92 (0.87-0.98)	0.41 (0.38-0.45)	0.57 (0.53-0.62)	0.31 (0.28-0.35)
Injury incidence, training[a]	0.43 (0.39-0.47)	0.28 (0.25-0.32)	0.32 (0.29-0.36)	0.18 (0.16-0.21)
Injury incidence, match[a]	3.70 (3.43-3.99)	1.15 (1.00-1.32)	2.00 (1.80-2.22)	1.04 (0.90-1.20)
Injury severity (%)				
Minimal (1-3 days)	140 (13)	60 (12)	119 (18)	50 (14)
Mild (4-7 days)	272 (25)	120 (25)	210 (31)	93 (25)
Moderate (8-28 days)	556 (51)	233 (48)	275 (41)	177 (48)
Severe (>28 days)	116 (11)	72 (15)	68 (10)	48 (13)
Days of absence/injury, mean ± SD	14.3 ± 14.9	16.9 ± 19.2	14.0 ± 24.3	14.7 ± 14.4
Injury burden[b]	13.2 (13.0-13.4)	7.0 (6.8-7.1)	8.0 (7.8-8.2)	4.6 (4.5-4.7)
Reinjuries (%)	174 (16)	81 (17)	124 (18)	48 (13)

[a]Injury incidence for muscle injuries expressed as number of injuries/1000 hours of total exposure (95% confidence interval).

Lésions des membres inférieurs et musculaires = 1ère pathologies en athlétisme

Figure 4: Anatomical site of injury in each event group



Bennell & Crossley 1996

Lésions musculaires des ischio-jambiers

- 1ère blessure en championnat d'athlétisme (≈17%)

Malliaropoulos et al. 2009 et 2011, Edouard et al. 2011, 2014, 2016, Alonso et al. 2012

Table 1 Incidences of injuries and hamstring muscle injuries per 1000 registered athletes and relative risks (RR) of injury with lower and upper limits of 95% of confident interval (± 95% CI) in male and female athletes during outdoor (WOC 2009, WOC 2011, WOC 2013, EOC 2012, EOC 2014) and indoor (WIC 2014, EIC 2011, EIC 2013, EIC 2015) championships.

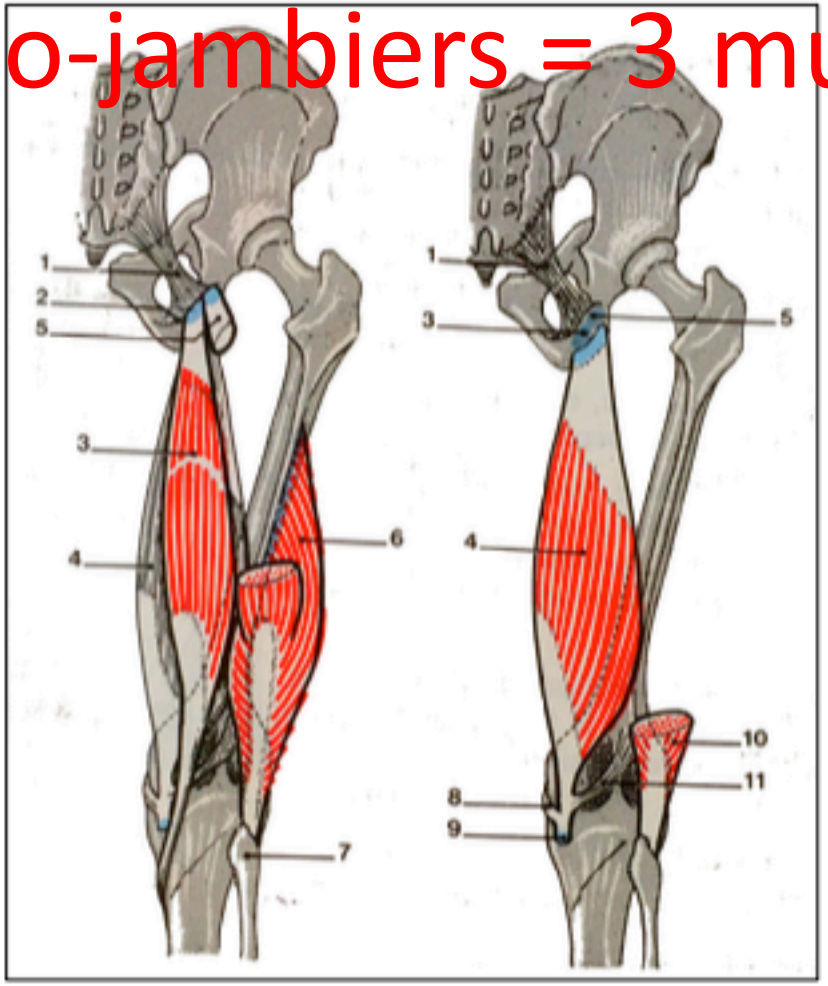
	Outdoor and indoor championships					
	Male		Female		RR	(95%CI)
Incidence of injuries						
All[£#]	113.7	±8.4	87.5	±8.2	1.30	(1.18-1.43)* small
In-competition[£#]	87.7	±7.6	65.9	±7.2	1.33	(1.19-1.49)* small
Time-loss in-competition injuries[£#]	43.9	±5.5	33.2	±5.2	1.32	(1.12-1.56)* small
Incidence of hamstring muscle injuries[1]						
All[£]	22.4	±3.4	11.5	±2.2	1.94	(1.42-2.66)* moderate
In-competition[£]	17.4	±3.0	8.8	±1.9	1.98	(1.38-2.83)* moderate
Time-loss in-competition injuries	10.9	±2.4	6.5	±1.7	1.67	(1.09-2.56)* small

*Significant relative risk between male and female athletes ($p<0.05$).
[£] Significant difference between outdoor and indoor championships for male athletes ($p<0.05$).
[#] Significant difference between outdoor and indoor championships for female athletes ($p<0.05$).

Edouard et al. 2016

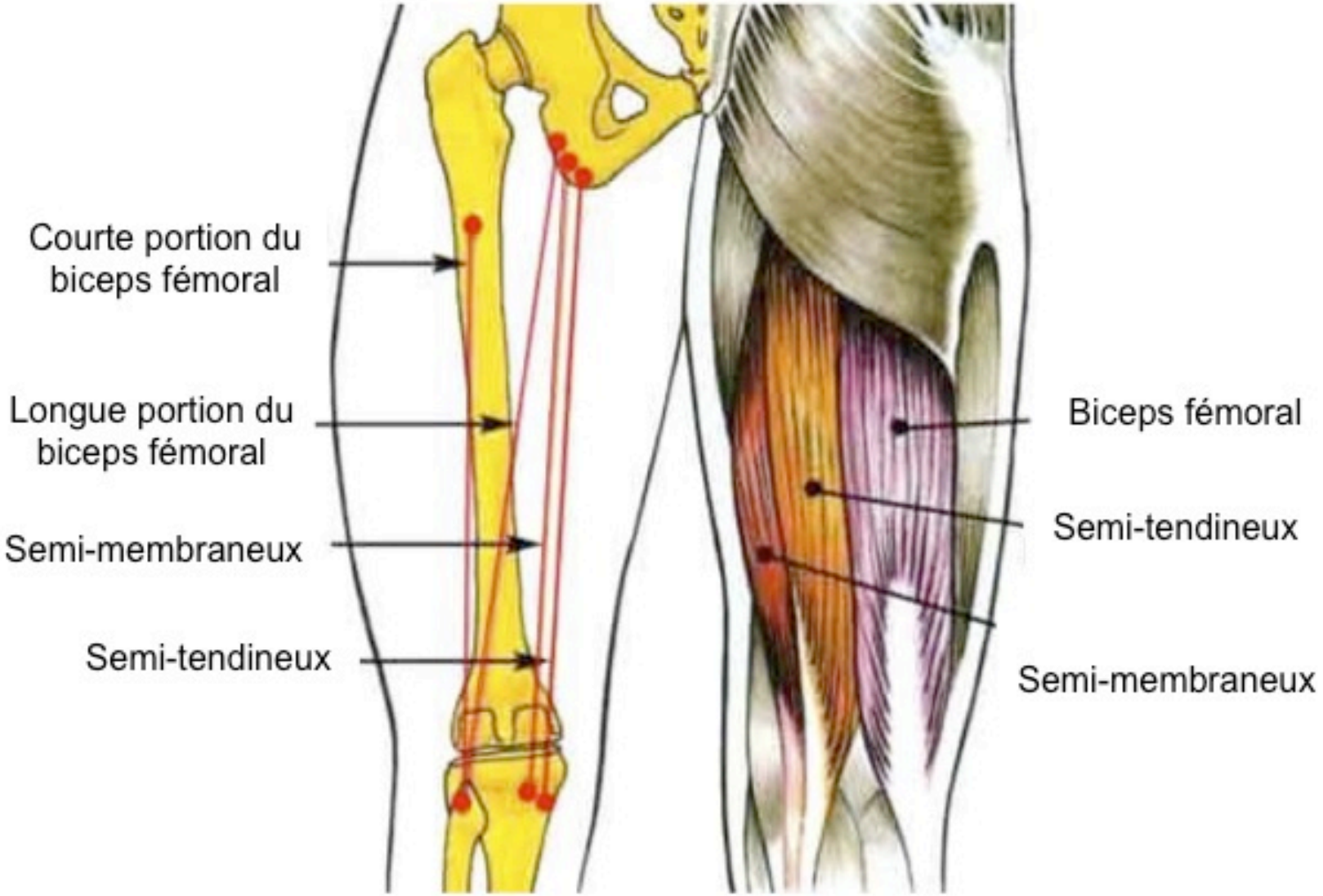
Quelle est l’anatomie des ischio-jambiers ?

Ischio-jambiers = 3 muscles



1 : Ligament sacro-tubéral
2 : Tubérosité ischiatique
3 : Muscle semi-tendineux
4 : Muscle semi-membraneux
5 : Chef long du biceps fémoral
6 : Chef court du biceps fémoral
7 : Tête de la fibula
8 : Expansion médiale du muscle semi-membraneux
9 : Insertion principale du muscle semi-membraneux
10 : Muscle biceps fémoral
11 : Expansion latérale du muscle semi-membraneux

Rouvière Anatomie


Courte portion du biceps fémoral
Longue portion du biceps fémoral
Semi-membraneux
Semi-tendineux
Biceps fémoral
Semi-tendineux
Semi-membraneux

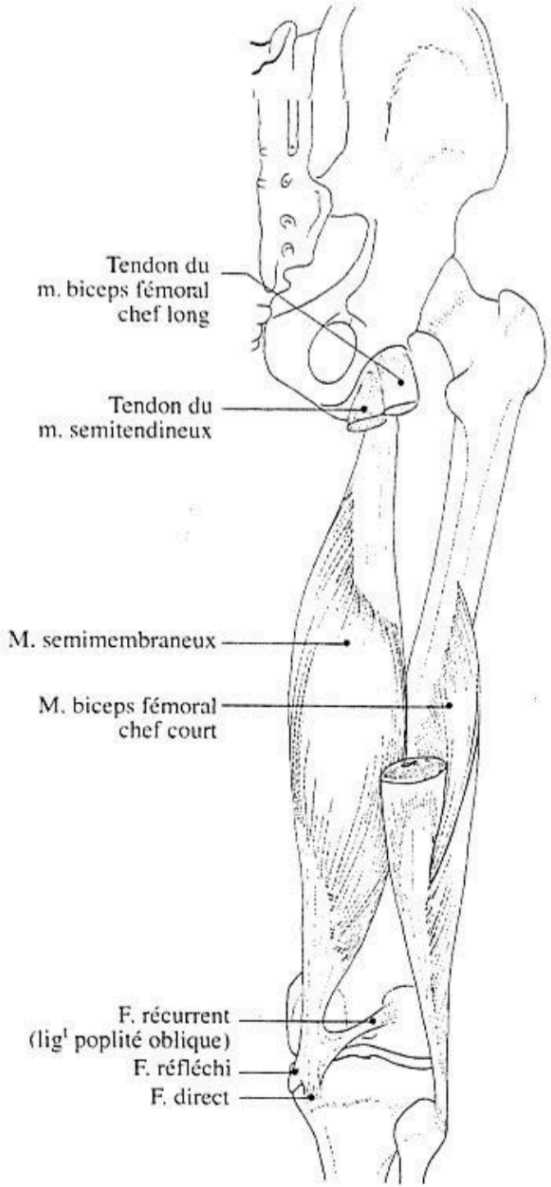
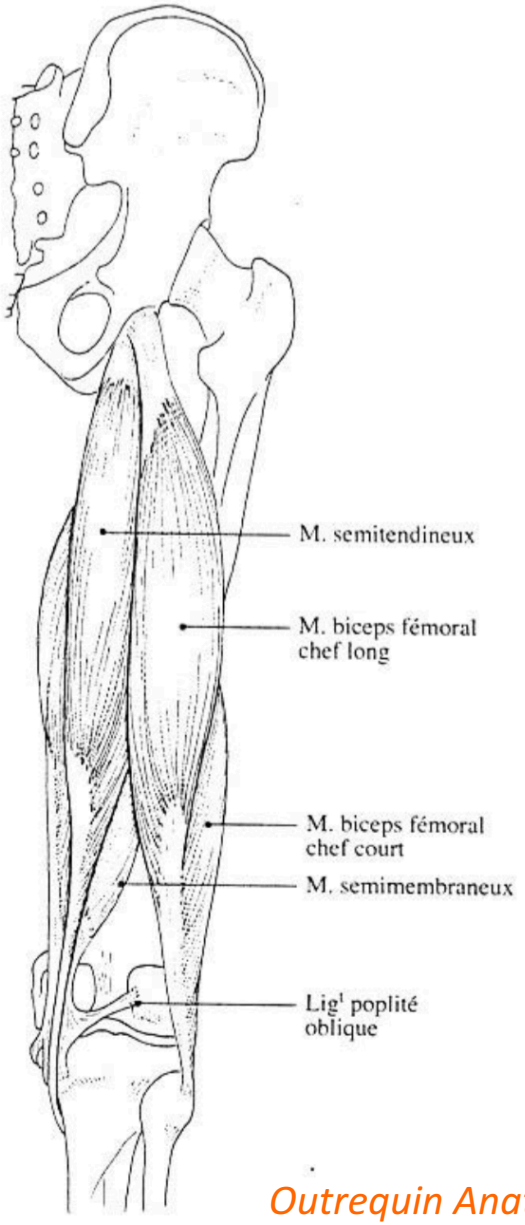


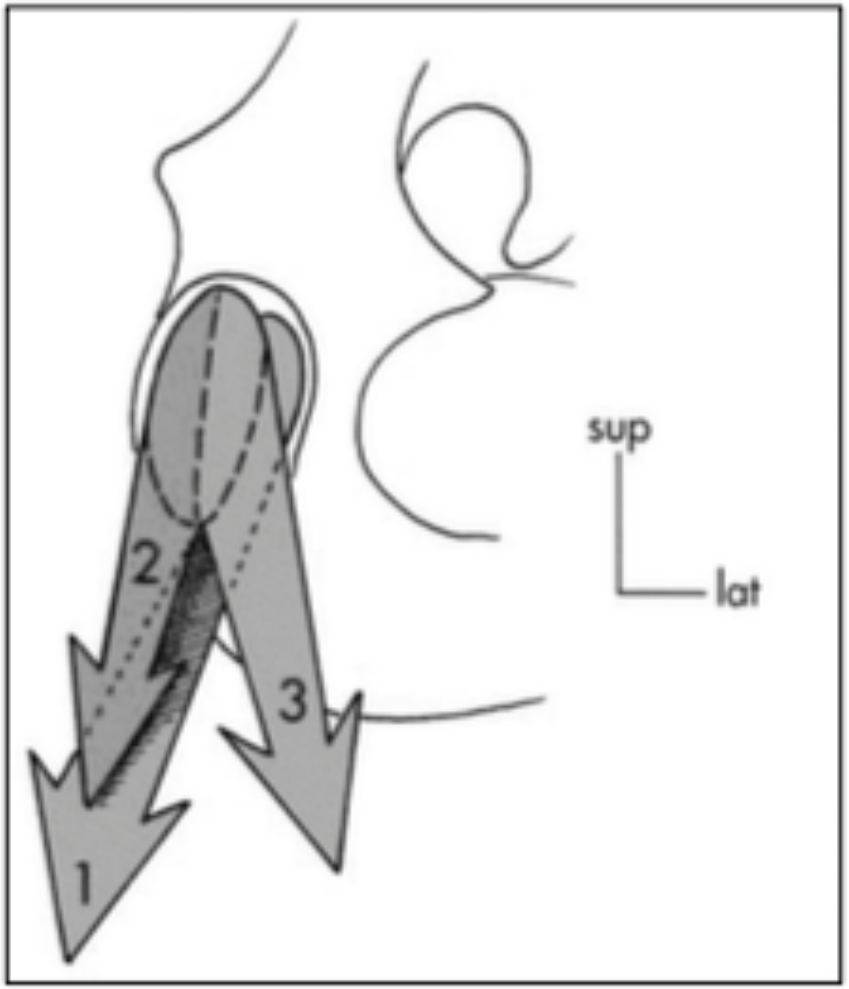
Fig. 20-4. Le muscle semimembraneux



Outrequin Anatomie Clinique

Fig. 20-5. Les muscles semitendineux et biceps fémoral

Insertion proximale



1 : Muscle semi-membraneux
2 : Muscle semi-tendineux
3 : Muscle biceps fémoral (chef long)

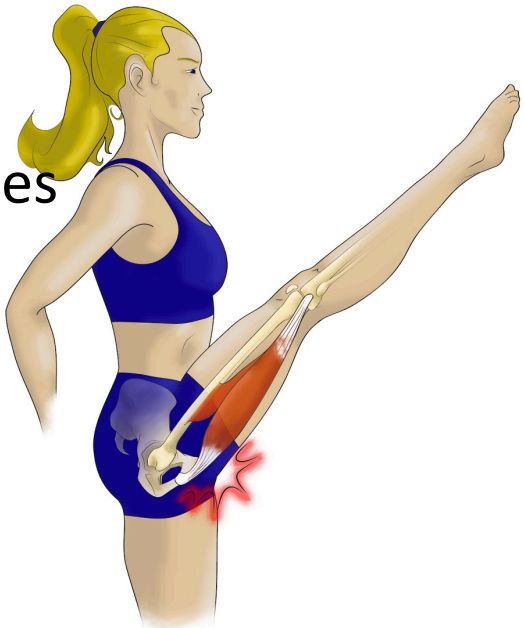
Dufour 2007

Anatomie

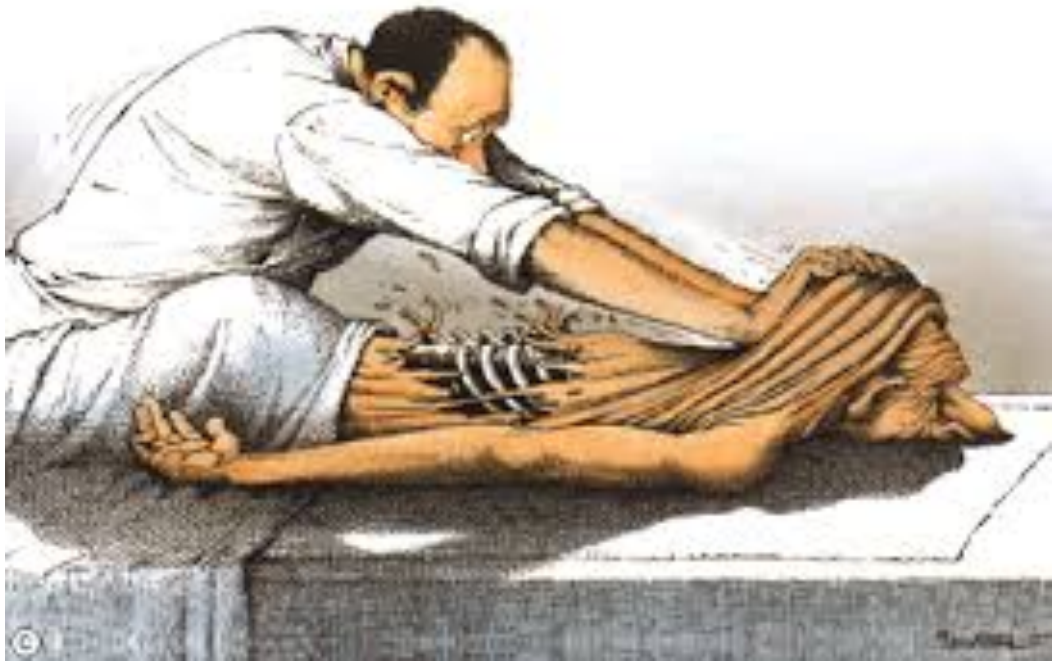
- Biceps fémoral :
  - Le plus souvent lésé (70-80%)
  - 2 chefs : longue et courte portions et 2 innervations
  - Action statique :
    - Maintien de la hanche lors de l'inclinaison antérieure du tronc
    - Stabilité de l'articulation fémoro-tibiale
  - Action dynamique :
    - Extension de la hanche (longue portion seule)
    - Flexion et rotation latérale du genou
- Semi-tendineux et semi-membraneux :
  - Action dynamique de Flexion et rotation latérale du genou

Biomécanique

- Muscles bi-articulaires
- Variation étirement et tension musculaire
  - en fonction des positions articulaires
- Actions :
  - Extension hanche + Flexion genou
  - Actions simultanées => tractions opposées
- Position d'étirement maximal :
  - Hanche fléchie et genou tendu



Rééducation



Muscle Injuries

Biology and Treatment

The American Journal of Sports Medicine, Vol. 33, No. 5
DOI: 10.1177/0363546505274714
© 2005 American Orthopaedic Society for Sports Medicine

Tero A. H. Järvinen,*† MD, PhD, Teppo L. N. Järvinen,*† MD, PhD, Minna Kääriäinen,*† MD, PhD, Hannu Kalimo,‡§ MD, PhD, and Markku Järvinen,*†‖ MD, PhD

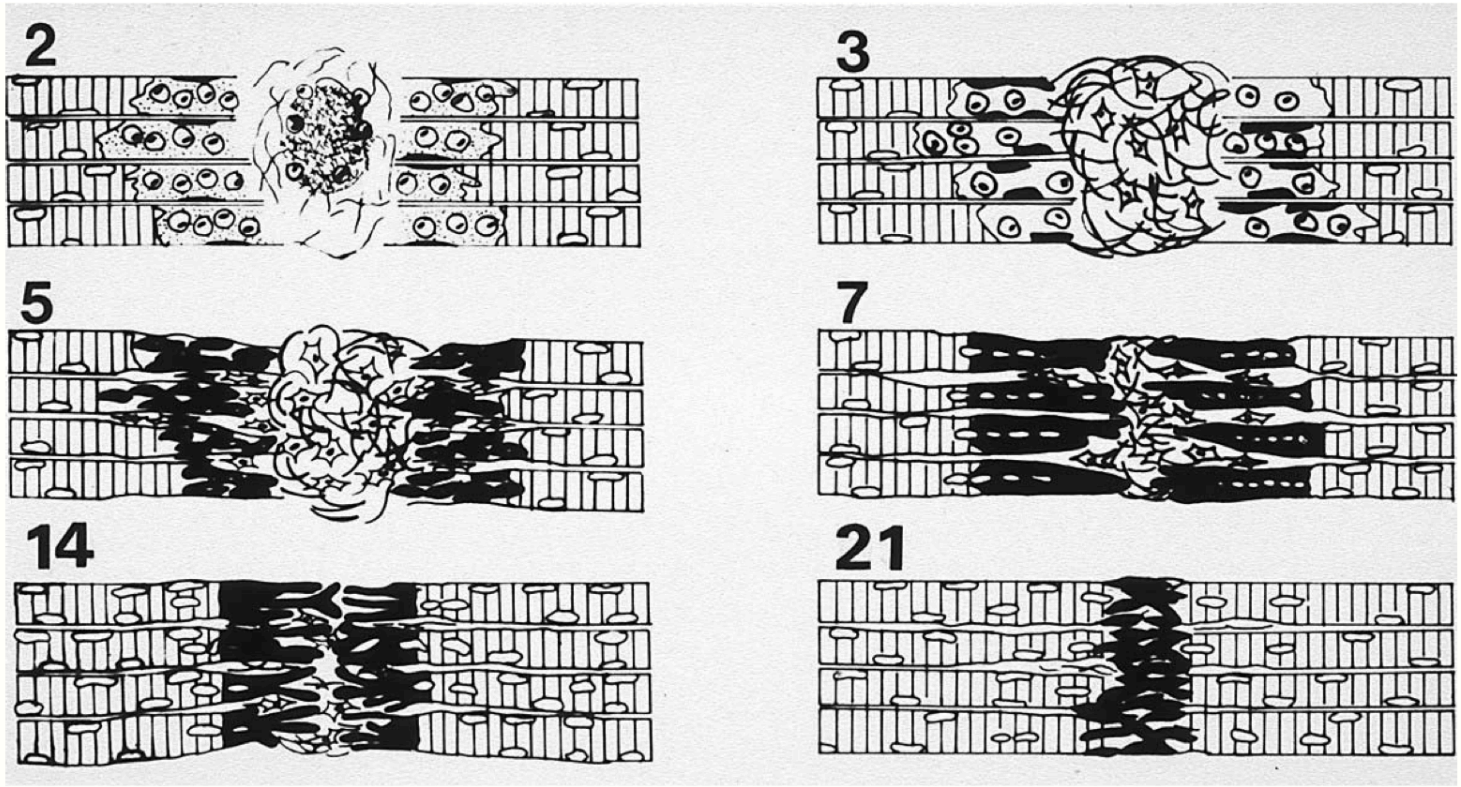


Figure 2. A schematic illustration of the healing skeletal muscle. Day 2: the necrotized parts of the transected myofibers are being removed by macrophages while, concomitantly, the formation of the connective tissue scar by fibroblasts has begun in the central zone (CZ). Day 3: satellite cells have become activated within the basal lamina cylinders in the regeneration zone (RZ). Day 5: myoblasts have fused into myotubes in the RZ, and the connective tissue in the CZ has become denser. Day 7: the regenerating muscle cells extend out of the old basal lamina cylinders into the CZ and begin to pierce through the scar. Day 14: the scar of the CZ has further condensed and reduced in size, and the regenerating myofibers close the CZ gap. Day 21: the interlacing myofibers are virtually fused with little intervening connective tissue (scar) in between.

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- Phase de destruction :
  - Nécrose cellulaire
  - inflammation
- Phase de réparation

  et Phase de remodelage :
  - Régénération cellulaire
  - Formation du tissu conjonctif de soutien

Tissue-healing time line – loading capacity

	0-3 days	4-14 days	3-4 wk	5-7 wk	2-3 mo	3-6 mo	6 mo –1 yr	2yr
TENDON								
Tendinitis								
rupture								
MUSCLE								
Exercise induced								
Grade I								
Grade II								
Grade III								
LIGAMENT								
Grade I								
Grade II								
Grade III								
Lig graft								
BONE								

Cools lecture IOC Diploma 2014 from Snyder-Mackler in Andrews & Wilk 2012

TRAITEMENT

- En urgence :
  - Contention / compressi
  - Glaçage
  - Surélévation
  - Repos relatif
- En secondaire :
  - Repos auto-limité
  - Respect des délais de cicatrisation
  - Etirements + Contractions isométrique DOUX

Muscle Injuries

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- Immobilisation courte
- Mobilisation précoce :
  - Capillarisation
  - Régénération myofibres
  - Orientation myofibres
  - 3-7 jours post-blessures

Am J Physiol Cell Physiol 294: C467–C476, 2008.
First published December 12, 2007; doi:10.1152/ajpcell.00355.2007.

Recovery of skeletal muscle mass after extensive injury: positive effects of increased contractile activity

Hélène Richard-Bulteau, Bernard Serrurier, Brigitte Crassous, Sébastien Banzet, André Peinnequin, Xavier Bigard, and Nathalie Koulmann

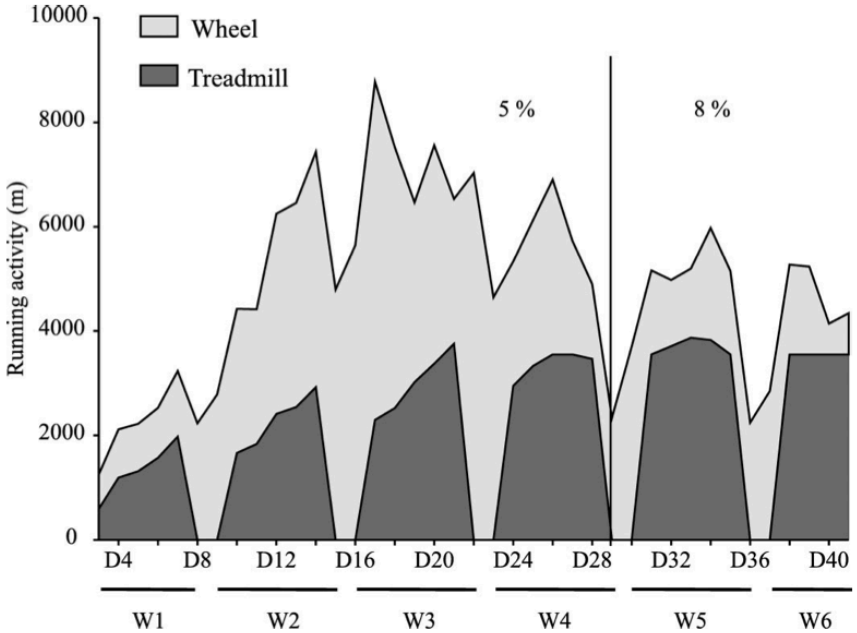

Fig. 1. Running distances. Active (Act) rats were placed into individual cages with access to purpose-built running wheels connected to an integrated system providing the total distance run daily (Wheel). These animals were also submitted to a daily forced treadmill running exercise 5 days/wk. The running distance (Treadmill) increased over time until the fourth week, due to the progressive increase of the speed and duration of the exercise. The intensity of this treadmill exercise was higher during *weeks 5* and *6* than during *week 4* for the same distance run, due to the increase of the slope from 5% to 8%. W, week; D, day.

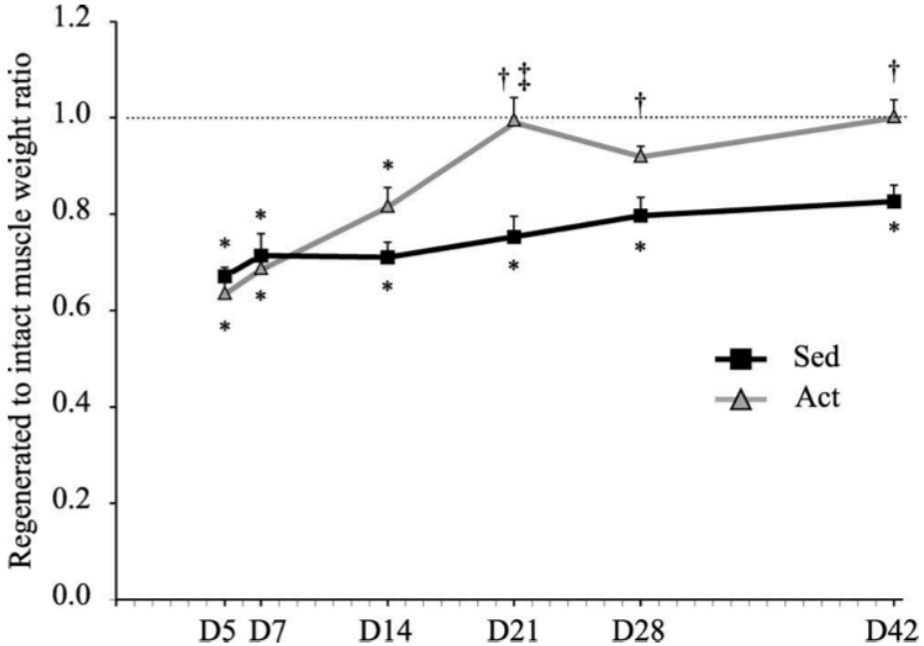

Fig. 2. Relative regenerated (Reg) soleus muscle weight. Reg muscle weight was expressed as the ratio of the absolute weight of Reg muscle to the contralateral intact (Int) muscle weight. Data are presented as means ± SE. The dotted line represents the full recovery of muscle weight compared with the contralateral Int muscle. *Significantly different from the Int group; †significantly different from the sedentary (Sed) group; ‡significantly different from the previous time for the same group.

Am J Physiol Cell Physiol 294: C467–C476, 2008.
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Centre de Recherches du Service de Santé des Armées, La Tronche, France

Submitted 5 August 2007; accepted in final form 4 November 2007

Table 2. *Morphological caracteristics of soleus muscle*

	Int-Sed	Int-Act	Reg-Sed	Reg-Act
Muscle cross-sectional area, mm^2				
Day 21	3.33±0.28	3.73±0.21	2.42±0.27*	3.00±0.23
Day 42	3.73±0.22	4.05±0.12	2.58±0.19*	3.40±0.28†
Fiber cross-sectional area, μm^2				
Day 21	2,595±74	2,421±128	817±62*	1,332±72*†
Day 42	2,686±103	2,651±252	1,006±45*	1,222±40*
Total number of fibers				
Day 21	1,279±92	1,552±79	2,991±277*	2,310±263*†
Day 42	1,400±91	1,571±98	2,565±155*	2,772±192*†‡

Data are presented as means ± SE. Muscle and fiber cross-sectional areas were determined after hematein-eosin-safran staining by analyzing pictures covering the entire muscle. Data are shown for *days 21* and *42* of intact (Int)-sedentary (Sed), Int-active (Act), regenerated (Reg)-Sed, and Reg-Act soleus muscles. More than 1,000 fibers were analyzed. *Significantly different from the Int group; †significantly different from the Sed group; ‡significantly different from the previous time for the same group.

Prise en charge thérapeutique

- **Phase initiale**
  - Critères pour passer à la phase suivante :
    - Marche normale sans douleur
    - Course à pied très très lente sans douleur
    - Contraction isométrique sous-maximale (50-70%)

      le genou à 90° de flexion en décubitus ventral

Prise en charge thérapeutique

- **Phase de remodelage**
  - Objectif = régénération d'un muscle fonctionnel
    - Élastique
    - Contractile
  - Renforcement musculaire:
    - Isométrique
    - Concentrique
    - Excentrique
  - Etirements
  - Exercices infra-douloureux !!!

Prise en charge thérapeutique

- **Phase de remodelage**
  - Critères pour passer à la phase suivante :
    - Amplitude articulaire physiologique
    - Souplesse des IJ physiologique
    - Force musculaire des IJ physiologique

      coté à 5/5 au testing manuel
    - Course à pied à 50% sans douleur

Prise en charge thérapeutique

- **Phase fonctionnelle**
  - Objectif = retour à la compétition sans récidive
  - Renforcement musculaire excentrique
  - Etirements
  - Augmentation progressive intensité et volume
  - Travail global
  - Exercices infra-douloureux !!!

Prise en charge thérapeutique

- **Phase fonctionnelle**
  - Critères pour reprendre la compétition :
    - Si tous les critères :
      - Souplesse et amplitude
      - Force musculaire
      - Course à pied et sprint
    - sont réalisés :
      - à intensité maximale
      - sans douleur

Prise en charge thérapeutique

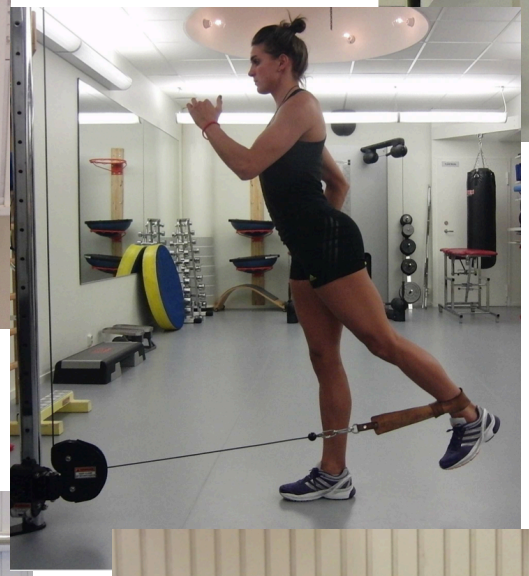
- **Intervenants dans le parcours de soin**
  - Nombreux intervenants :
    - entraineur, préparateur physique, responsable et dirigeant de club, fédération sportive, médecin, kinésithérapeute, ostéopathe, psychologue, agent/manageur, famille, gourou…
  - Problématique = Non respect du parcours de soin traditionnel
  - Objectif :
    - Médecin coordinateur
    - Communication +++
    - Respect du secret médical
- **Education du sportif, patient et entourage :**
  - Exercices de prévention et d'auto-rééducation
  - Respect du parcours de soin

Acute hamstring injuries in Swedish elite sprinters and jumpers: a prospective randomised controlled clinical trial comparing two rehabilitation protocols

Carl M Askling,[1,2] Magnus Tengvar,[3] Olga Tarassova,[1] Alf Thorstensson[1]

Br J Sports Med 2014;**48**:532–539.

L Protocol



C Protocol

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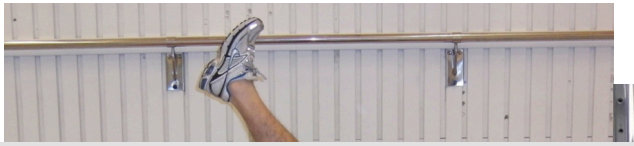


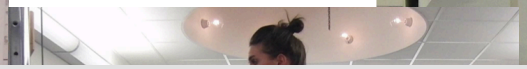
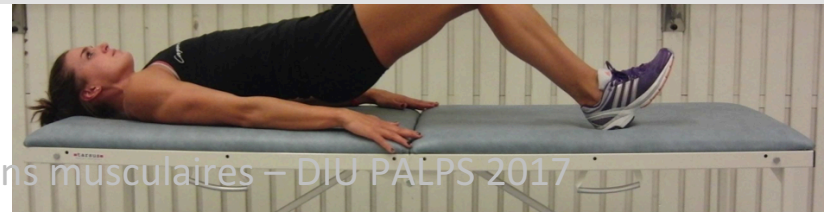


Table 1 Descriptive, MRI and palpation data, as means±1 SD (median and range) or ratios (%) for athletes in the L-protocol and the C-protocol, respectively

	L-protocol (n=28)	C-protocol (n=28)	p Value (effect size)
Age (years)	21±4 (19, 15 to 29)	19±3 (18, 15 to 29)	0.167 (0.443)*
Height (cm)	178±9 (176, 162 to 193)	180±8 (181, 165 to 193)	0.520 (−0.174) *
Mass (kg)	71±9 (70, 53 to 86)	71±10 (75, 53 to 87)	0.890 (−0.019) *
Female (%)/male (%)	32/68	32/68	1.000 (0) †
Sprinting-type (%)/stretching-type (%)	93/7	93/7	1.000 (0) †
Proximal free tendon (PT) not involved (%)/PT involved (%)	57/43	57/43	1.000 (0) †
Distance from proximal injury pole to ischial tuberosity (mm)	75±83 (65, −30 to 250)	73±70 (50, −20 to 250)	0.864 (0.031) *
Injury length (mm)	145±85 (105, 30 to 310)	149±65 (155, 40 to 295)	0.520 (−0.060) *
Peak palpation pain, distance to ischial tuberosity (cm)	10±7 (9, 1 to 26)	10±7 (7, 2 to 24)	0.994 (0.010) *

*Mann-Whitney U test (Cohen's d).
†χ^2 test π. The level of significance was set at $p \leq 0.05$.



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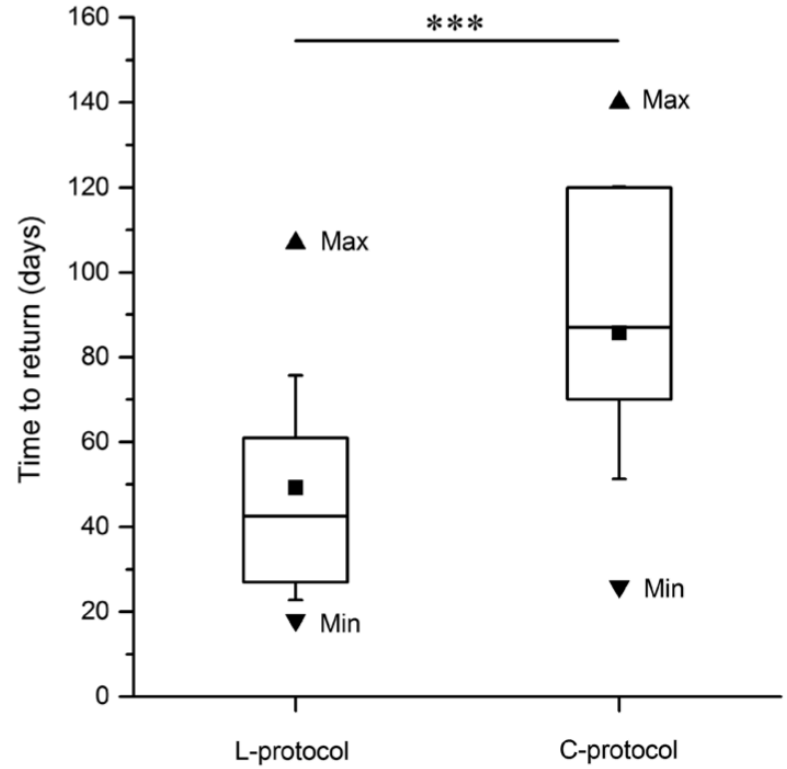


Figure 7 Time to return, in days, in the L-protocol (n=28) and C-protocol (n=28). The boxes represent IQRs in the boxes, the horizontal lines represent median values and black squares represent mean values; whiskers=mean±1 SD. *** Denotes significant difference ($p<0.001$, Mann-Whitney U test).

March 8, 2017

A Multifactorial, Criteria-based Progressive Algorithm for Hamstring Injury Treatment.

Mendiguchia J, Martinez-Ruiz E, Edouard P, Morin JB, Martinez-Martinez F, Idoate F, Mendez-Villanueva A.

Med Sci Sports Exerc. 2017 Mar 8. doi: 10.1249/MSS.0000000000001241. [Epub ahead of print]

PMID: 28277402

Sprint Mechanics and Performance included in final functional steps

PREPARE REPAIR

A multifactorial, individualized, criteria-based progressive algorithm for hamstring injury treatment

Jurdan MENDIGUCHIA[1], Enrique MARTINEZ-RUIZ[2], Pascal EDOUARD[3,4,5], Jean–Benoît MORIN[6], Francisco MARTINEZ-MARTINEZ[7], Fernando IDOATE[8], Alberto MENDEZ-VILLANUEVA[9]

Abstract

Introduction: Given the prevalence of hamstring injuries in football, a rehabilitation program that effectively promotes muscle tissue repair and functional recovery is paramount to minimize re-injury risk and optimize player performance and availability.
Purpose: To assess the concurrent effectiveness of administering an individualized and multifactorial criteria-based algorithm (RA) on hamstring injury rehabilitation in comparison to employing a general rehabilitation protocol (RP).
Methods: Implementing a double-blind randomised controlled trial approach, two equal groups of 24 football players (48 total) completed either an RA group or a validated RP group five days following an acute hamstring injury.
Results: Within 6 months after return to sport, 6 hamstring re-injuries occurred in RP versus 1 in RA [relative risk = 6 (90% confidence interval: 1-35); clinical inference: very likely beneficial effect]. The average duration of return to sport was possibly quicker (ES=0.34±0.42) in RP (23.2±11.7 days) than in RA (25.5±7.8 days) (-13.8%, 90%CI: -34.0 to 3.4%; clinical inference: possibly small effect). At the time to return to sport, RA players showed substantially better 10-m time, maximal sprinting speed as well as greater mechanical variables related to speed (i.e., maximum theoretical speed and maximal horizontal power) than the RP.
Conclusions: Although return to sport was slower, male football players who underwent an individualized, multifactorial, criteria-based algorithm with a performance- and primary risk factor-oriented training program from the early stages of the process markedly decreased the risk of re-injury compared to a general protocol where long length strength training exercises were prioritized.

Table 1. Baseline characteristics of patients

	Rehabilitation Protocol (n = 24)	Rehabilitation Algorithm (n = 24)
Age (years)	22.9 ± 6.0	24.0 ± 4.4
Body mass (kg)	72.7 ± 13.1	74.1 ± 8.3
Height (m)	1.77 ± 0.09	1.76 ± 0.07
Playing Position		
Defender	9 (38)	8 (33)
Midfielder	4 (17)	4 (17)
Attacker	9 (38)	12 (50)
Goalkeeper	2 (8)	0 (0)
Playing Status		
Starting	22 (92)	20 (83)
Non-starting	2 (8)	4 (17)
Injury Type		
Sprinting	13 (54)	13 (54)
Stretching	8 (33)	6 (25)
Other	3 (13)	2 (8)
Unknown	0 (0)	3 (13)
Previous hamstring injuries	6 (25)	5 (21)

Data are either shown as mean ± standard deviation (SD) for continuous variables or frequency and valid column percentage (%) for categorical variables.

Table 2. Rehabilitation and return-to-sport algorithm programme for hamstring injury.

	REGENERATION PHASE	FUNCTIONAL PHASE
Manual Therapy	Manual therapy: - Plantar fascia, gastrocnemius and hamstring (avoiding injury site) massage - Lumbar Z-joint mobilization - Sliding Neural Mobilization (3 x 12 reps) NMES	Manual therapy: - Plantar fascia, gastrocnemius and hamstring (injury site included) massage - Lumbar Z-joint mobilization **1. 2. 3**
Flexibility	Psoas static flexibility with pelvic retroversion (4 x 15 sec) Quadriceps dynamic mobility (2 x 8 reps) Hamstring dynamic mobility with fitball (2 x 8 reps) Hamstring dynamic mobility supine (2 patterns) (2 x 8 reps)	Hamstring dynamic mobility + contralateral psoas flexibility (2 x 5 reps) Hamstring wall flexibility (Push/Pull) (3 x 3 reps) **2. 3**
Gluteus	**Gluteus Maximus** (Choose an option daily as pain tolerated)**:** **Option A** Prone hip extension (2 x 10 reps x 3 sec) Single leg bridge + contralateral kick (as tolerated) (2 x 5 reps x 3 sec) Double leg bridge (50% BW; 3 x 6 reps x 3 sec) **Option B** Hip thrust (40% BW; 3 x 6 reps x 3 sec) Single leg bridge + contralateral kick (as tolerated) (10% BW; 2 x 4 reps x 3 sec) Single leg hip thrust + contralateral kick (as tolerated) (3 x 6 reps x 3 sec) **Gluteus Medius:** Clamshell with band (3 x 6 reps x 3 sec) Side lying hip abduction with band (3 x 6 reps x 3 sec)	**Gluteus Maximus** (Choose an option)**:** **Option A** Single leg hip thrust (10% BW; 3 x 4 reps x 3 sec) Double leg hip thrust (60% BW; 3 x 8 reps x 3 sec) Walking sled push (75% BW; 15 m x 2 reps) **Option B** Single-leg foot and shoulder elevated hip thrust + contralateral kick (2 x 4 reps x 3 sec) Single leg back extension + perturbations (2 x 4 reps) Swing leg hip extension + contralateral hip flexion (2 x 3 changes) **Gluteus Medius:** Side step running with band (5 m x 5 go and back) Monster running with band (5 m x 5 go and back) **2**
Hamstring strength	Prone isometrics (mid and long length) (2 x 5 reps x 5 sec) Standing long length isometrics (2 x 5 reps x 5 sec) Supine isometrics (tolerated degrees) (2 x 5 reps x 3 sec) Submaximal eccentric manual resistance in prone (intensity as tolerated) (2 x 8 reps)	(4 Hamstring strength exercises per session selecting 2 hip dominant and 2 knee dominant) **HIP dominant** Double leg deadlift with 4 kg medicine Ball (2 x 8 reps) Lunge (15% BW; 2 x 6 reps) Single leg deadlift with 15kg + step up (2 x 6 reps) **KNEE dominant** Double leg slide curl (2 x 6 reps) Nordic hamstring (2 x 4 reps) Sprinter eccentric leg curl (2 x 6 reps) **2**

Plyometrics		Double leg hurdle hop with trunk flexion (2 x 4 reps) Double broad jump with 5 kg (2 x 4 reps) 2 consecutive explosive scissor jumps (3 times) Single leg horizontal jump (2 x 3 reps)	**2**
Ankle stabilizers	Double leg hamstring / gastrocnemius disassociation drill (3 x 6 reps) Single leg hamstring / gastrocnemius disassociation drill (2 x 6 reps) Step bounding side to side (25% BW; 2 x 10 reps)	Ankle drill 1 (20% BW; 10 m x 4 reps) Ankle drill 2 (20% BW; 10 m x 4 reps)	**2**
Lumbopelvic control	Side bridge feet in bench + perturbation (2 x 5 reps x 5 sec) Birdog (2 x 5 reps x 5 sec) Long lever posterior pelvic plank (2 x 4 reps x 5 sec) Leg scissors arms on the floor (2 x 5 reps x 5 sec)	Stir the pot with fitball (3 x 2 reps) Leg Scissors arms on the chest (2 x 5 reps x 5 sec) Single-leg stand rotating reaches 4 kg (2 x 6 reps) TRX helicopter (2 x 4 reps) Sprinter push/pull with pulleys (2 x 6 reps)	**2. 3**
Running technique	**Frontal plane** running drills Low- to moderate-intensity sidestepping (10 m x 5 reps) Low- to moderate-intensity grapevine stepping (10 m x 5 reps) Low- to moderate-intensity steps forward and backward over a tape line while moving sideways (10 m x 5 reps) **Sagittal plane** running drills (vertical emphasized execution specially first days or painful subjects) - 8 running exercise drills (statics in place dynamics over 8m) Running 5 m + 5 m deceleration (4 reps) Running 10 m + 5 m deceleration (3 reps) Running 15 m + 5 m deceleration (2 reps)	**Warm Up:** Hamstring Ballistic stretching (2 x 6 reps) Static "B" drill with resisted band (2 x 5 reps) Hurdle drills (1 set walking lower intensity, 1 set bounding higher intensity) Hurdle drill 1 (2 reps) Hurdle drill 2 (2 reps) Hurdle drill 3 (2 reps) Hurdle drill 4 (2 reps) Military march (15 m x 2 reps) Lunge + deadlift (4 reps for each leg) Lunge + "B" drill (4 reps for each leg) From Skipping to running (20 m x 4 reps) Sprint bounding (15 m x 3 reps) Running with hurdle jumps (15 m x 1 rep) Sprinting 5 m (3 reps), 10 m (3 reps), 15 m (4 reps), 20 m (3 reps), 30 m (2 reps) and 40 m (1 rep) (15 sec of rest per each 1 sec sprinting) Sled push resisted accelerations (30% BW) 5 m (3 reps) and 10 m (2 reps)	**1**

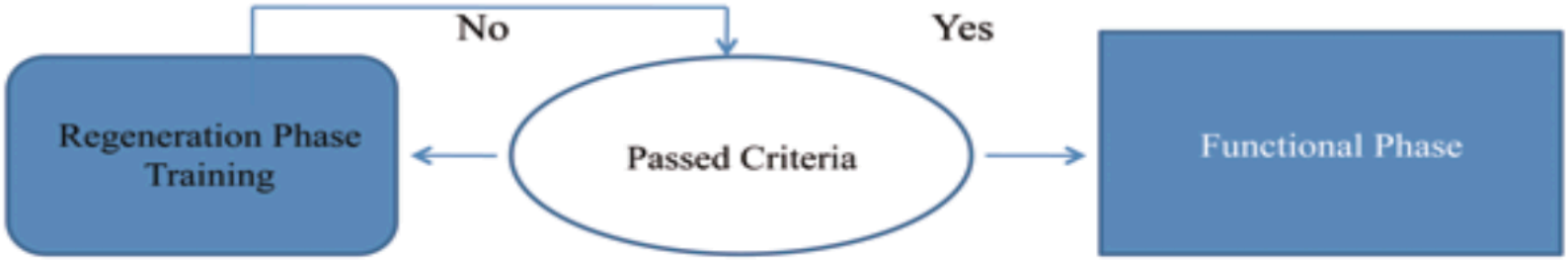
* Mild discomfort allowed during exercises execution

Reps, repetitions; m, meter; sec, seconds; BW, body weight; NMES, Neuromuscular electrical stimulation.

1 = Contents corresponding to the training day 1; **2** = Contents corresponding to the training day 2; **3** = Contents corresponding to the training day 3. Minimum of 3 blocks 1-2-3 in the Functional phase before return-to-sport.

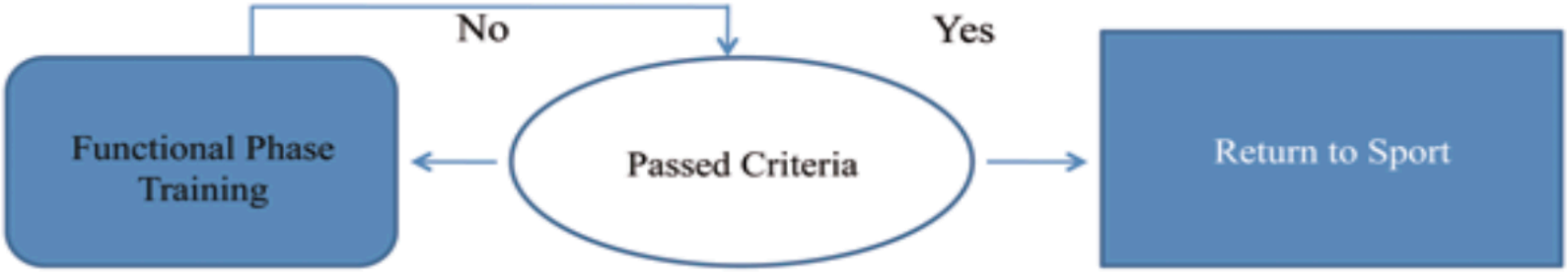
Regeneration Phase

Variable	Test	Criteria for Progression
Pain after injury	Prone with knee flexed to 15° (10)	No pain
Isolated strength at long muscle lengths	Prone with knee flexed to 15° (21)	< 10% asymmetry
Neural deficiencies	Slump test (6)	No pain
Hamstring flexibility	Active knee extension (AKE) test (31)	< 10% asymmetry
Hip flexor flexibility	Modified Thomas test (MTT) (17)	+5 symmetry below horizontal



Functional Phase

Variable	Test	Criteria for Progression
Pain	Palpation (10)	No pain
Peak torque (H/H) and conventional ratio (H/Q)	Isokinetic knee flexion/extension at $60°\cdot s^{-1}$ (8)	< 10% H/H and H/Q > 0.45 (Biodex) or > 0.47 (Cybex)
Hip extension strength	Prone hip extension (37)	< 10% asymmetry between legs
Distance	Triple hop test (16)	< 10% asymmetry between legs
Endurance (Repetition number)	Single leg bridge test (13)	> 25 and < 10% asymmetry between legs
Torsion capabilities	ASLR test (22)	No compensations
Insecurity and Pain	Askling H-test (2, 3)	No pain and insecurity



Regeneration phase

A Multifactorial, Criteria-based Progressive Algorithm for Hamstring Injury Treatment.

Mendiguchia J, Martinez-Ruiz E, Edouard P, Morin JB, Martinez-Martinez F, Idoate F, Mendez-Villanueva A.

Med Sci Sports Exerc. 2017 Mar 8. doi: 10.1249/MSS.0000000000001241. [Epub ahead of print]
PMID: 28277402

Table 3. Re-injury number and relative risk at 6 months after return to sport by allocated group

			Protocol vs. Algorithm		
	Protocol	*Algorithm*	*Relative risk (90% CI)*	*Chances for beneficial/trivial/harmful*	*Clinical inference*
Re-injury number (%)	6 (25%)	1 (4%)	6 (1; 35)	95/2/3	Very likely beneficial

Time to RTS

The average duration of RTS was possibly quicker (ES = 0.34 ± 0.42) in the RP group (23.2 ± 11.7 days) compared to the RA group (25.5 ± 7.8 days) (-13.8%, 90%CI: -34.0 to 3.4; 70/28/2%, possibly small effect).

2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern

Br J Sports Med 2016;**50**:853–864.

Clare L Ardern,[1,2,3] Philip Glasgow,[4,5] Anthony Schneiders,[6] Erik Witvrouw,[1,7]
Benjamin Clarsen,[8,9] Ann Cools,[7] Boris Gojanovic,[10,11] Steffan Griffin,[12]
Karim M Khan,[13] Håvard Moksnes,[8,9] Stephen A Mutch,[14,15] Nicola Phillips,[16]
Gustaaf Reurink,[17] Robin Sadler,[18] Karin Grävare Silbernagel,[19] Kristian Thorborg,[20,21]
Arnlaug Wangensteen,[1,8] Kevin E Wilk,[22] Mario Bizzini[23]

Figure 1 The three elements of the return to sport (RTS) continuum.

1. Return to participation. The athlete may be participating in rehabilitation, training (modified or unrestricted), or in sport, but at a level lower than his or her RTS goal. The athlete is physically active, but not yet 'ready' (medically, physically and/or psychologically) to RTS. It is possible to train to perform, but this does not automatically mean RTS.
2. Return to sport (RTS). The athlete has returned to his or her defined sport, but is not performing at his or her desired performance level. Some athletes may be satisfied with reaching this stage, and this can represent successful RTS for that individual.
3. Return to performance. This extends the RTS element. The athlete has gradually returned to his or her defined sport and is performing at or above his or her preinjury level. For some athletes this stage may be characterised by personal best performance or expected personal growth as it relates to performance.

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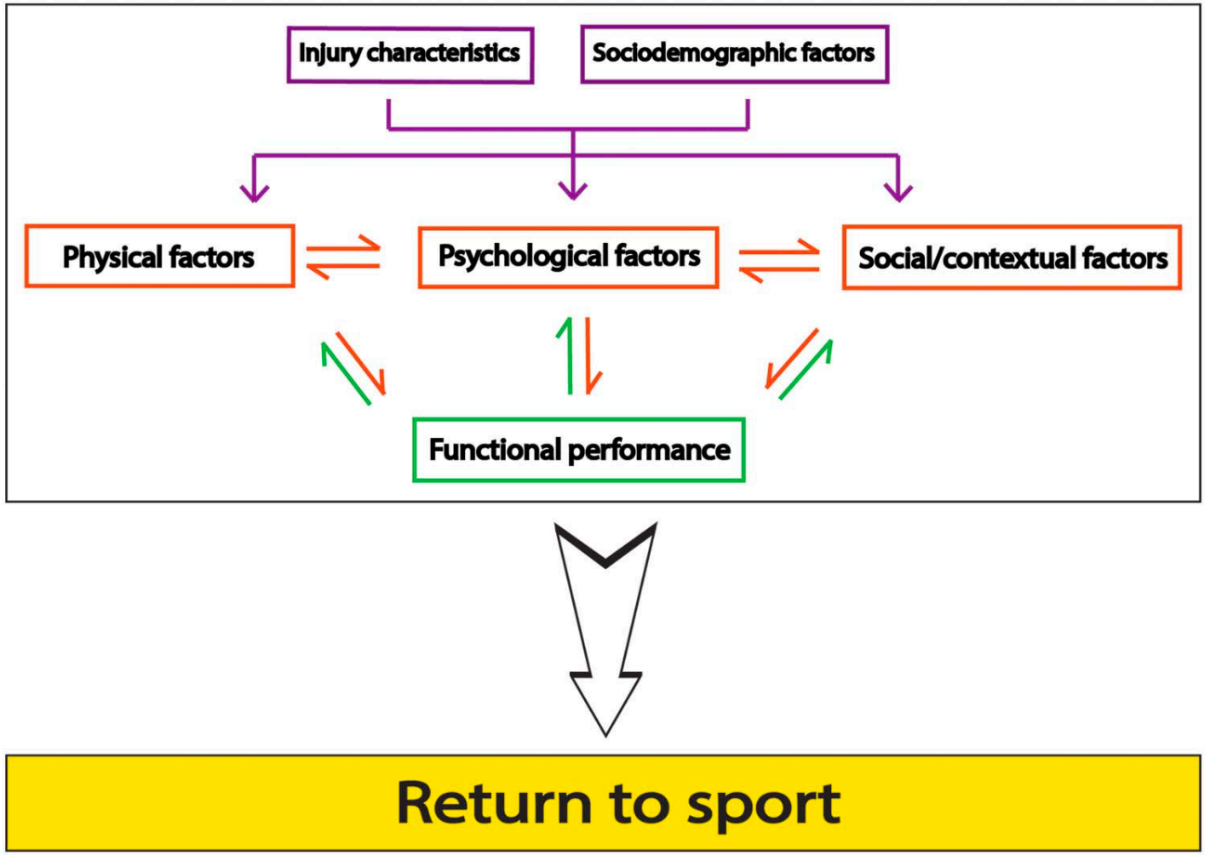

Figure 3 Biopsychosocial model of RTS after injury.[151] Examples of physical, psychological and social factors that may influence RTS are listed (reproduced with permission).

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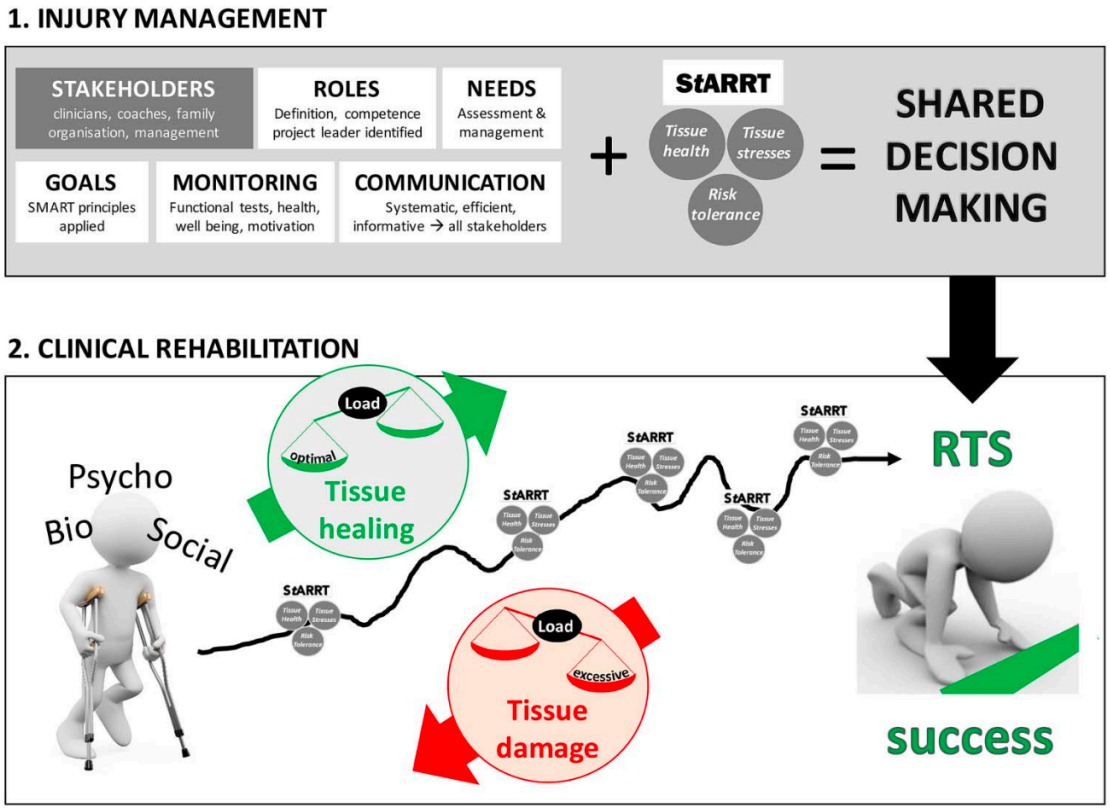


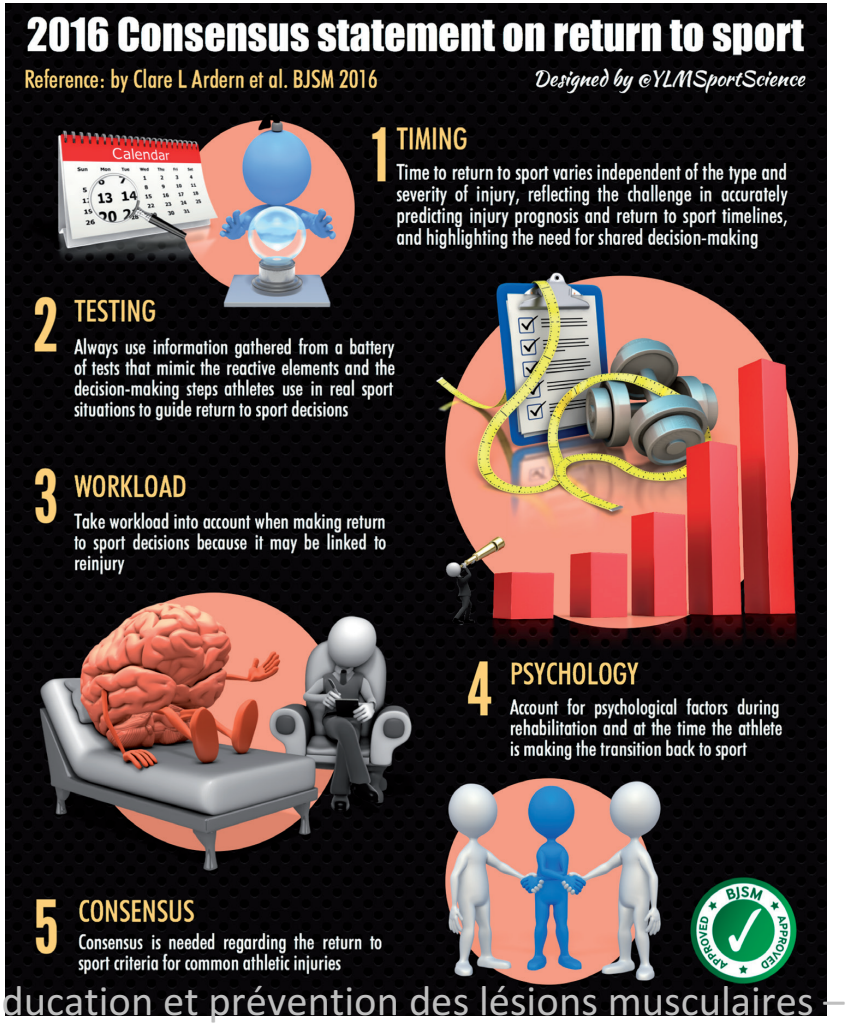
Figure 4 Integrating RTS information to make an optimal decision. The top part (1) describes the management aspects that need to be addressed to lead the rehabilitation project. The bottom part (2) shows the progression of rehabilitation on a timeline, where load is progressively increased to promote tissue healing, but can be excessive and require adaptation to avoid damage. These adaptations go thorough iterations where the StARRT model is applied at different time points until eventual full RTS. Final decisions are reached by applying a shared decision-making process.

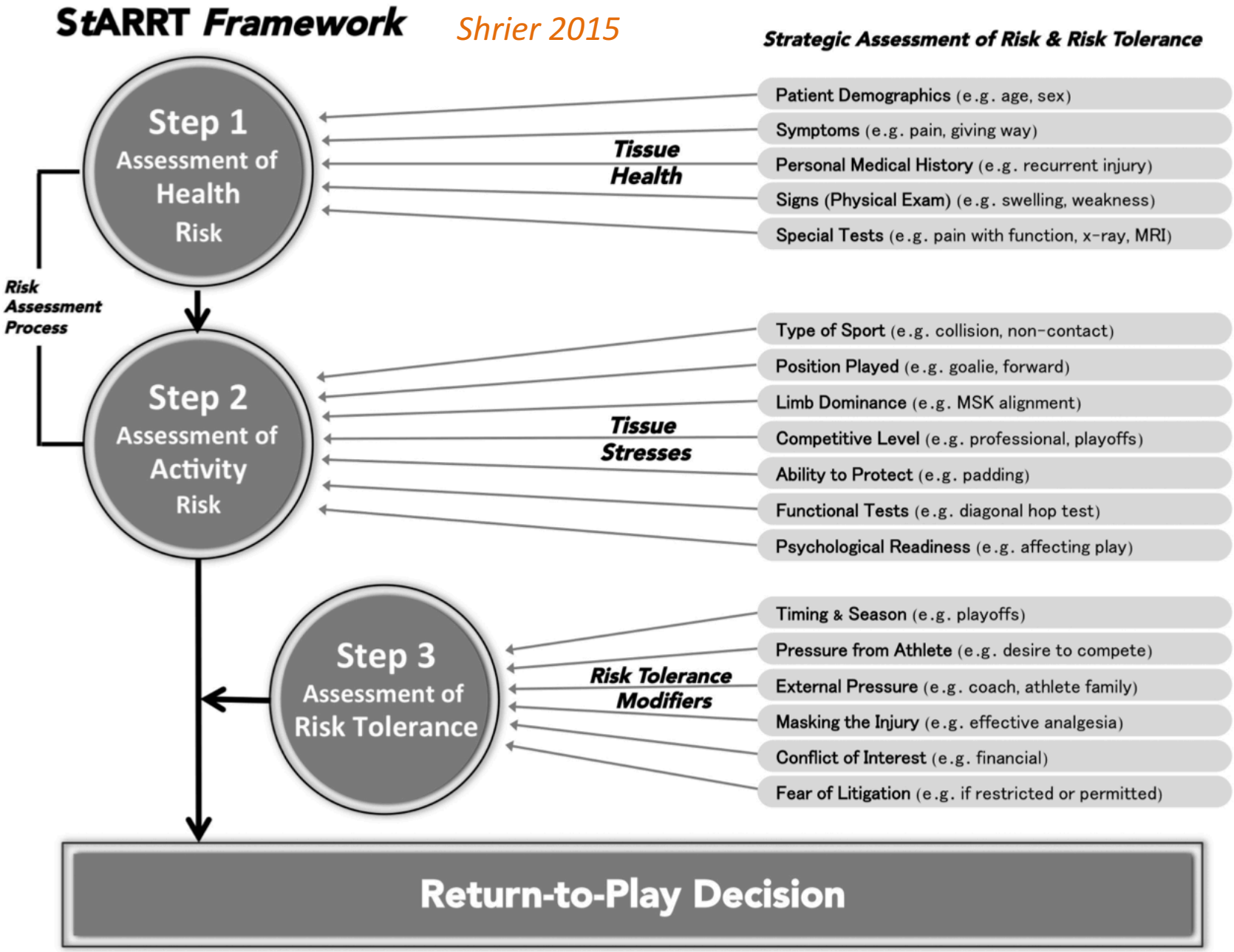
R. Edouard - Réadaptation et prévention des blessures en sport - DIU PALPE 2017

Downloaded from http://bjsm.bmj.com/ on March 30, 2017 - Published by group.bmj.com
BJSM Online First, published on February 17, 2017 as 10.1136/bjsports-2016-097468

Infographic: 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern

Clare L Ardern,[1,2] Philip Glasgow,[3] Anthony G Schneiders,[4] Erik Witvrouw,[5,6] Benjamin Clarsen,[7] Ann MJ Cools,[8] Boris Gojanovic,[9,10] Steffan Griffin,[11] Karim Khan,[12] Håvard Moksnes,[13] Stephen Mutch,[14,15] Nicola Phillips,[16] Guus Reurink,[17] Robin Sadler,[18] Karin Gravare Silbernage,[19] Kristian Thorborg,[20] Arnlaug Wangensteen,[21,22] Kevin Wilk,[23] Mario Bizzini[24]




StARRT Framework
Shrier 2015
Strategic Assessment of Risk & Risk Tolerance
Step 1
Assessment of
Health
Risk
Tissue
Health
Patient Demographics (e.g. age, sex)
Symptoms (e.g. pain, giving way)
Personal Medical History (e.g. recurrent injury)
Signs (Physical Exam) (e.g. swelling, weakness)
Special Tests (e.g. pain with function, x-ray, MRI)
Risk
Assessment
Process
Step 2
Assessment of
Activity
Risk
Tissue
Stresses
Type of Sport (e.g. collision, non-contact)
Position Played (e.g. goalie, forward)
Limb Dominance (e.g. MSK alignment)
Competitive Level (e.g. professional, playoffs)
Ability to Protect (e.g. padding)
Functional Tests (e.g. diagonal hop test)
Psychological Readiness (e.g. affecting play)
Step 3
Assessment of
Risk Tolerance
Risk Tolerance
Modifiers
Timing & Season (e.g. playoffs)
Pressure from Athlete (e.g. desire to compete)
External Pressure (e.g. coach, athlete family)
Masking the Injury (e.g. effective analgesia)
Conflict of Interest (e.g. financial)
Fear of Litigation (e.g. if restricted or permitted)
Return-to-Play Decision

Return to play criteria after hamstring muscle injury in professional football: a Delphi consensus study

Mattia Zambaldi,[1,2] Ian Beasley,[3] Alison Rushton[2]

Table 4 Return to play (RTP) criteria with relative assessment methods reaching consensus in round 3

	RTP criteria	MEAN	SD	Coefficient of variation	Percentage agreement
1	Perform maximal sprints	4.94	0.24	4.77	100.00
	Assessment				
	using wearable GPS technology	4.72	0.57	12.17	94.44
	based on the player's self-reported maximal perceived effort	4.33	0.69	15.83	88.89
	on 10 and 30 meters timed acceleration tests	4.17	0.51	12.35	94.44
2	Achieve maximal linear speed	4.78	0.43	8.95	100.00
	Assessment				
	using wearable GPS technology	4.72	0.46	9.76	100.00
	based on the player's self-reported maximal perceived effort	4.22	0.55	12.99	94.44
3	Complete at least one football-specific field testing session at maximal performance and under fatigue conditions	4.78	0.43	8.95	100.00
4	Perform a progressive running plan with running performance eventually matching preinjury levels	4.78	0.43	8.95	100.00
5	Player's self-reported feeling of confidence and readiness to RTP	4.72	0.46	9.76	100.00
6	Full hamstring muscle strength as compared with the uninjured side and/or to preinjury benchmark values	4.44	0.51	11.50	100.00
7	Reach GPS-based targets of external load, based on player-specific or position-specific match markers, which include number of sprints, accelerations, decelerations, changes of direction, maximal speed, high-speed running distance	4.28	0.67	15.64	88.89
8	Recovery of full aerobic and anaerobic fitness performance	4.28	0.75	17.58	83.33
9	No pain in the muscle	4.28	1.27	29.79	83.33
	Assessment				
	on functional activities on the field and in particular during maximal sprinting	4.72	0.96	20.29	94.44
	on maximal voluntary contraction	4.50	0.99	21.89	94.44
	on full range flexibility	4.33	0.97	22.39	94.44
10	Full muscle flexibility, equal to the uninjured side and/or to preinjury benchmark values	4.22	0.43	10.13	100.00
	Assessment				
	with AKE (active knee extension)	4.33	0.59	13.71	94.44
	with passive SLR (straight leg raise)	4.17	0.62	14.84	88.89
	with active SLR (straight leg raise)	4.06	0.87	21.53	77.78
11	Complete at least two full trainings with the team prior to be available for match selection	4.17	0.79	18.86	88.89
12	Good lumbopelvic motor control	4.00	0.49	12.13	88.89

Return to play after hamstring injuries in football (soccer): a worldwide Delphi procedure regarding definition, medical criteria and decision-making

Nick van der Horst,[1] FJG Backx,[1] Edwin A Goedhart,[2] Bionka MA Huisstede,[1] on behalf of HIPS-Delphi Group

Box 2 Items* included to start discussion on definition and criteria for RTP after hamstring 182 injury

Items for discussion on definition of RTP after hamstring injury

- Availability for match selection and/or full training
- Clearance by medical staff
- A completed game
- Full activity
- A 100% recovery score on fitness and skill testing
- Absence of symptoms on injured leg
- Completion of a rehabilitation program
- Reaching pre-injury level

Items for discussion on criteria for RTP after hamstring injury

- Medical staff clearance
- Absence of pain
- Similar hamstring strength
- Similar hamstring flexibility
- Functional performance

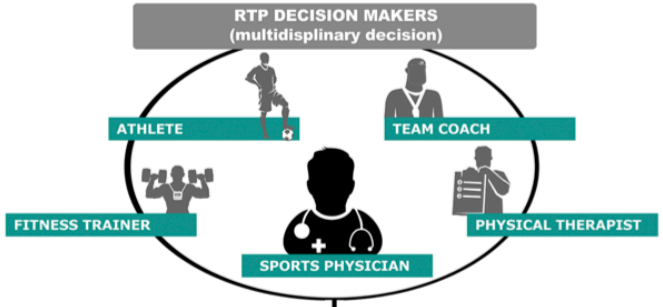
*All items were derived from a systematic review.on definition and criteria for RTP after hamstring injury.[22]

Table 1 Expert advice on performance on field testing to assess eligibility for RTP after hamstring injury

Clinical test	%*	Clinical test	%*
Position-specific GPS-targeted match-specific rehabilitation	**82**	20 m sprint	57
Repeated sprint ability test	**76**	Nordic hamstring exercise	55
Single leg bridge	**71**	Triple hop test	53
Deceleration drills	**71**	Muscular endurance	45
Acceleration drills	68	YoYo/shuttle run test	43
T-test	63	Speed testing	39
40 m sprint	61	Functional movement screen	35
H-test	58	Single hop test	33

*Percentage of experts stating this test could be suggested for functional performance assessment. Consensus (eg, ≥70%) was only achieved for the tests presented in bold letters.
GPS, global positioning system; RTP, return to play.

RTP MODEL FOR HAMSTRING INJURIES IN FOOTBALL



DEFINITION OF RTP

The moment the player has received criteria-based medical clearance and is mentally ready for full availability for match selection and/or full training

RTP CRITERIA TO INCLUDE

- Absence of pain on palpation
- Absence of pain during strength and flexibility testing
- Absence of pain during functional performance
- Absence of pain after functional testing
- Similar hamstring flexibility[a] Both the passive and active straight leg raise test should be assessed
- Psychological readiness / athlete's confidence
- Performance on field testing:
  - * Repeated Sprint Ability test
  - * Deceleration drills
  - * Single leg bridge
  - * Position specific GPS targeted match specific rehabilitation
- Medical staff clearance

POTENTIAL RTP CRITERION[b]

- Similar eccentric hamstring strength[a c]

RTP CRITERIA TO EXCLUDE

- Similar concentric / isometric hamstring strength[a]
- Neuromuscular function
- MRI
- Completion of a number of full friendly matches
- Completion of a number of full training sessions

[a] *0-10% difference compared to pre-injury data and/or uninjured side - depending on which data are available or are most reliable for the individual player according to the medical staff.*
[b] *Expert panel remained divided on this criterion but agreed that both visions should be included as a potential criterion.*
[c] *There were two differing views in the Delphi group. 1: This item is important as the eccentric phase is the contraction mode in which injury occurs and that strength asymmetries should be eliminated because they can increase injury risk; 2: strength measurements are not functional, asymmetries are normal, and reliability of strength measurement is influenced by many factors.*

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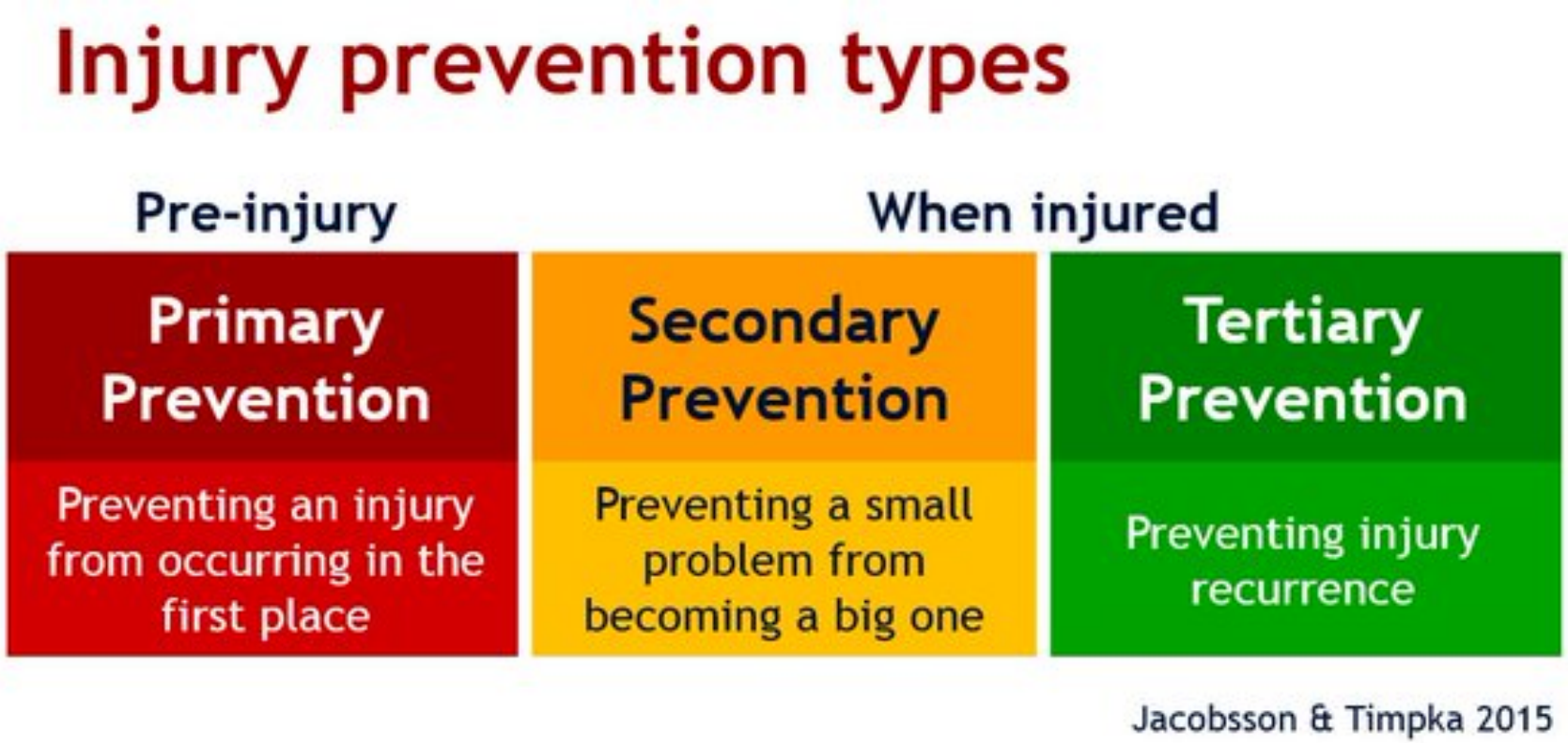
Figure 2 The RTP model for hamstring injuries in football for RTP decision-making, RTP definition and RTP criteria after hamstring injury. GPS, global positioning system; RTP, return to play.

Prévention

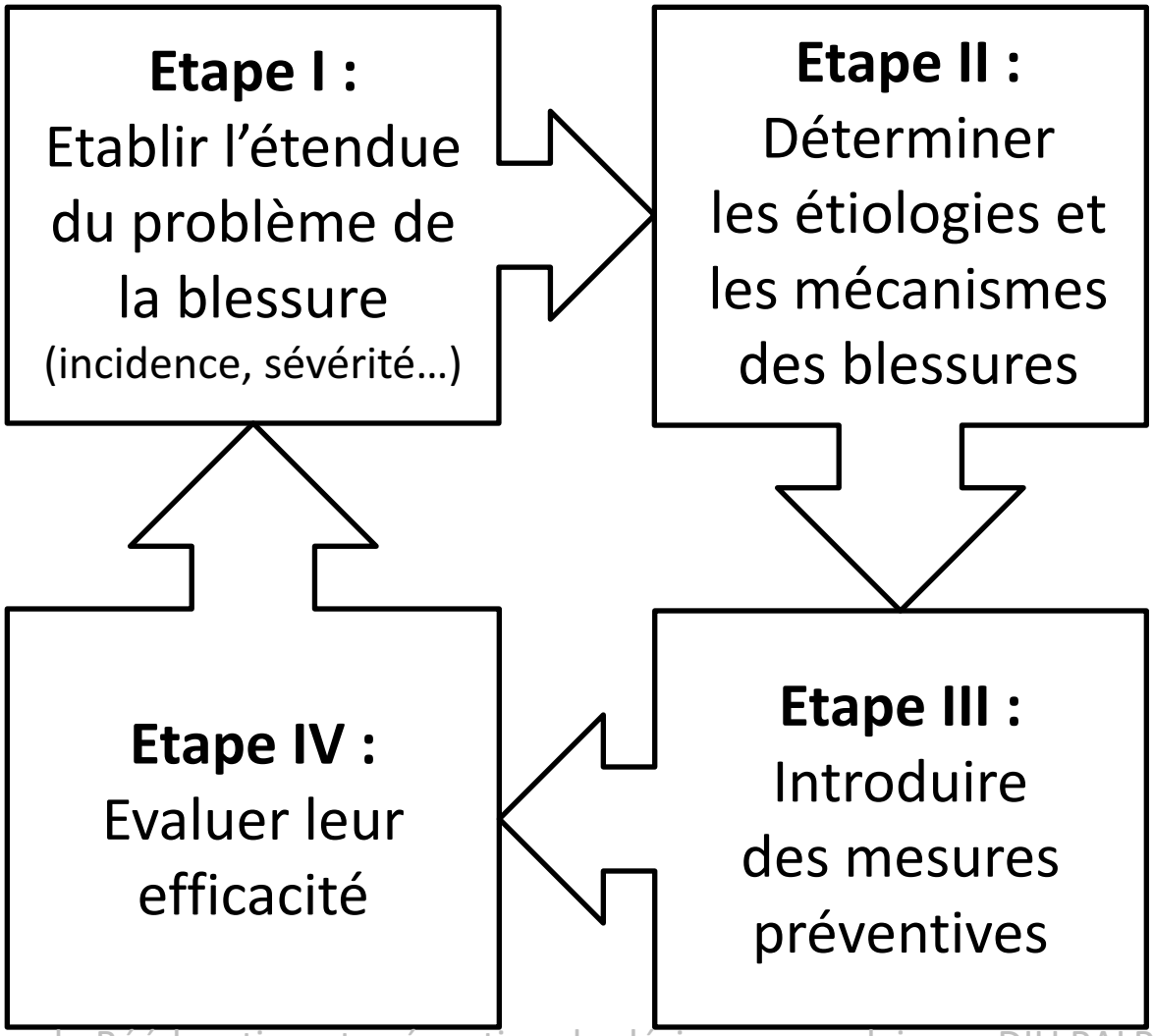
Pourquoi ?

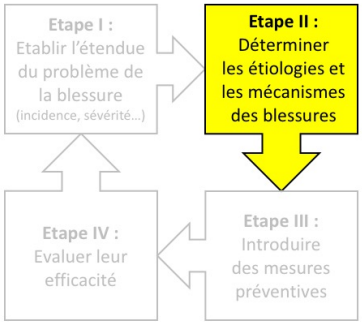
Mieux vaut prévenir que guérir !



Séquence de prévention des blessures

van Mechelen et al. 1992

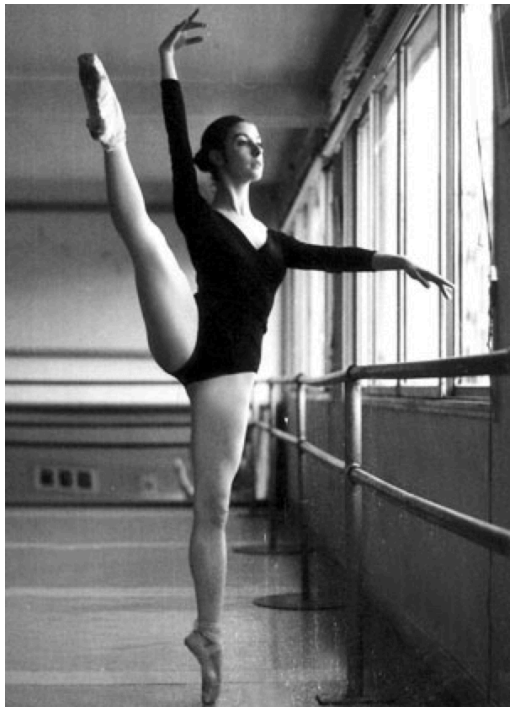




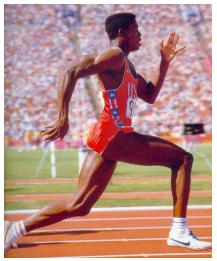
Quels sont les mécanismes des lésions musculaires des ischio-jambiers ?

Physiopathologie : Causes et Mécanismes

- **Causes :**
  - Contraction excentrique
  - Etirement musculaire
  - indépendante ou concomitante ?



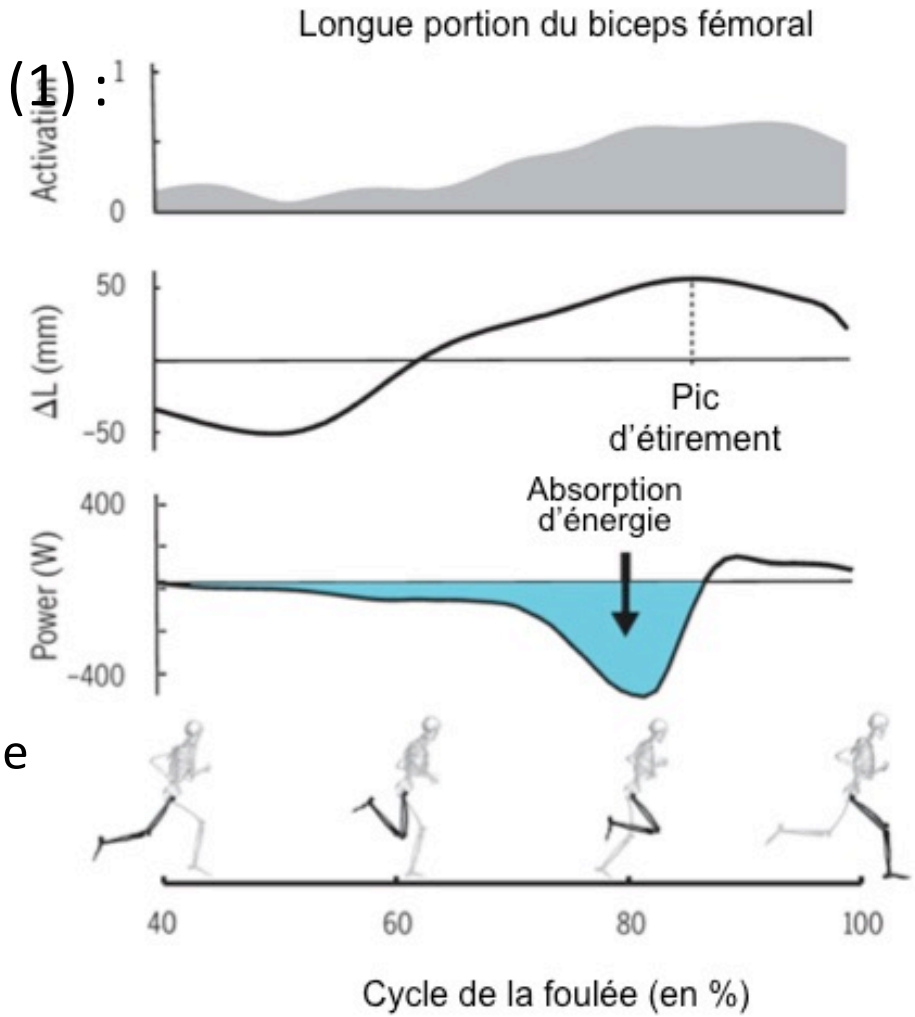
- **Mécanismes :**



  - En course
  - Lors d'étirements doux et lents
  - Lors d'étirements rapides et violents

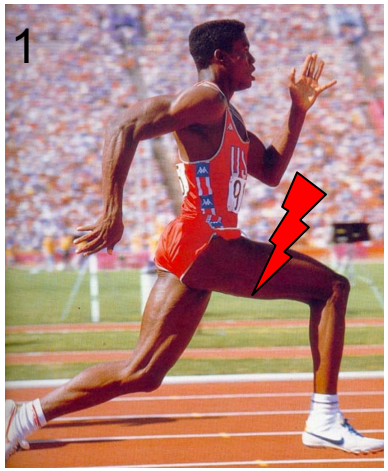
En course

- Phase terminale de la jambe libre (1) :
  - Etirement musculaire
  - Action frénatrice
  - Contraction excentrique
- Reprise d'appui au sol (2) :
  - Contraction concentrique
  - Pic de force
- Changement brutal de mode de contraction :
  - Passage de l'excentrique au concentrique
  - Avec contraction musculaire maximale



En course

- Phase terminale de la jambe libre (1)
  - Etirement musculaire
  - Action frénatrice
  - Contraction excentrique
- Reprise d'appui au sol (2) :
  - Contraction concentrique
  - Pic de force
- Changement brutal de mode de contraction :
  - Passage de l'excentrique au concentrique
  - Avec contraction musculaire maximale



Lors d'étirements rapides et violents (shoot ou tacle)

- Etirement musculaire maximale
- Contraction musculaire excentrique

Il semble que le paramètre de « FORCE » apparaît dans les mécanismes actuellement connus de survenue des lésions musculaires des ischio-jambiers…

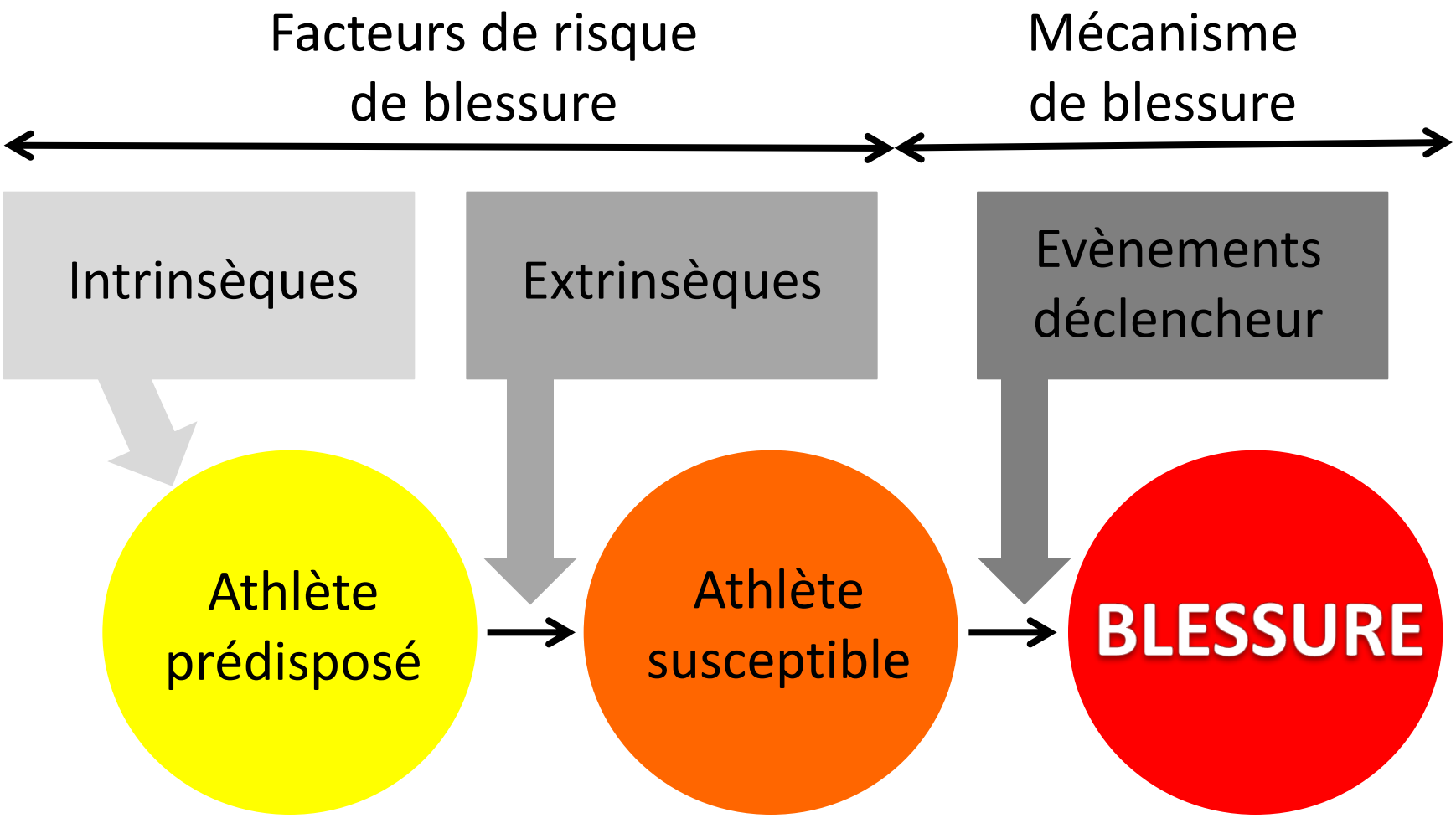
To be continued…

Quelles sont les facteurs de risque des lésions musculaires des ischio-jambiers ?

Facteurs de risque de blessure

Mécanisme de blessure

Bahr & Krosshaug 2005



Bahr & Krosshaug 2005

Facteurs de risque

Médical

- Non modifiables :
  - Age (>23 ans risque = x4)
  - Antécédent d'une lésion (risque = x11)
  - Ethnie (↗ risque si noir)
- Modifiables :
  - Augmentation de force du quadriceps
  - Déséquilibre musculaire IJ/Q :
    - Risque plus élevé si Ratio Ischio-jambiers / quadriceps < 50-60%
    - Risque plus élevé si Déficit de 8 à 15% par rapport au côté controlatéral

  Souplesse / flexibilité
  - Fatigue musculaire :
    - Augmentation du nombre de blessure avec la fatigue
    - Diminution du Ratio Ischio-jambiers / quadriceps avec la fatigue
  - Autres :
    - Reprise trop précoce, Mauvaise rééducation, Mauvais échauffement
    - Troubles de la coordination et de la stabilisation du bassin

Croisier et al. 2008, Opar et al. 2012, Freckleton et al. 2013

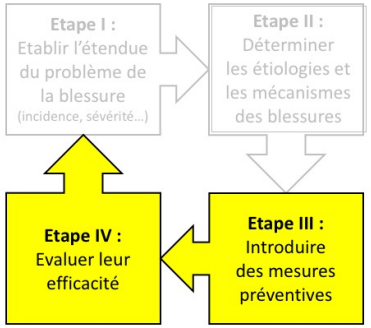
Facteurs de risque

- En athlétisme :
  - Circonstances : 1er partie de saison *Yeung et al. 2009*
  - Sexe : garçons > filles *Opar et al. 2013*
  - Age : Masters > jeunes *Opar et al. 2013*
  - Disciplines : 4x400m > 4x100m *Opar et al. 2013*
  - Antécédent (grade II) *Malliaropoulos et al. 2011*
  - Ratio IJ/Q à 180° $.sec^{-1}$ < 60% *Yeung et al. 2009*

Médical

Il semble que le paramètre de « FORCE » apparaît dans les facteurs de risque actuellement connus de survenue des lésions musculaires des ischio-jambiers…

To be continued…



Quels sont les moyens de prévention des lésions musculaires des ischio-jambiers ?

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The role of warmup in muscular injury prevention*

MARC R. SAFRAN, MD, WILLIAM E. GARRETT JR, MD, PhD,
ANTHONY V. SEABER,† RICHARD R. GLISSON, AND BETH M. RIBBECK, MS

ABSTRACT

This study is an attempt to provide biomechanical support for the athletic practice of warming up prior to an exercise task to reduce the incidence of injury. Tears in isometrically preconditioned (stimulated before stretching) muscle were compared to tears in control (nonstimulated) muscle by examining four parameters: 1) force and 2) change of length required to tear the muscle, 3) site of failure, and 4) length-tension deformation. The tibialis anterior (TA), the extensor digitorum longus (EDL), and flexor digitorum longus (EDL) muscles from both hindlimbs of rabbits comprised our experimental model.

Isometrically preconditioned TA ($P < 0.001$), EDL ($P < 0.005$), and FDL ($P < 0.01$) muscles required more force to fail than their contralateral controls. Preconditioned TA ($P < 0.05$), EDL ($P < 0.001$), and FDL ($P < 0.01$) muscles also stretched to a greater length from rest before failing than their nonpreconditioned controls. The site of failure in all of the muscles was the musculotendinous junction; thus, the site of failure was not altered by condition. The length-tension deformation curves for all three muscle types showed that in every case the preconditioned muscles attained a lesser force at each given increase in length before failure, showing a relative increase in elasticity, although only the EDL showed a statistically significant difference. From our data, it may be inferred that physiologic warming (isometric preconditioning) is of benefit in preventing muscular injury by increasing the and length to failure and elasticity of the muscle-tendon unit.

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The role of warmup in muscular injury prevention*

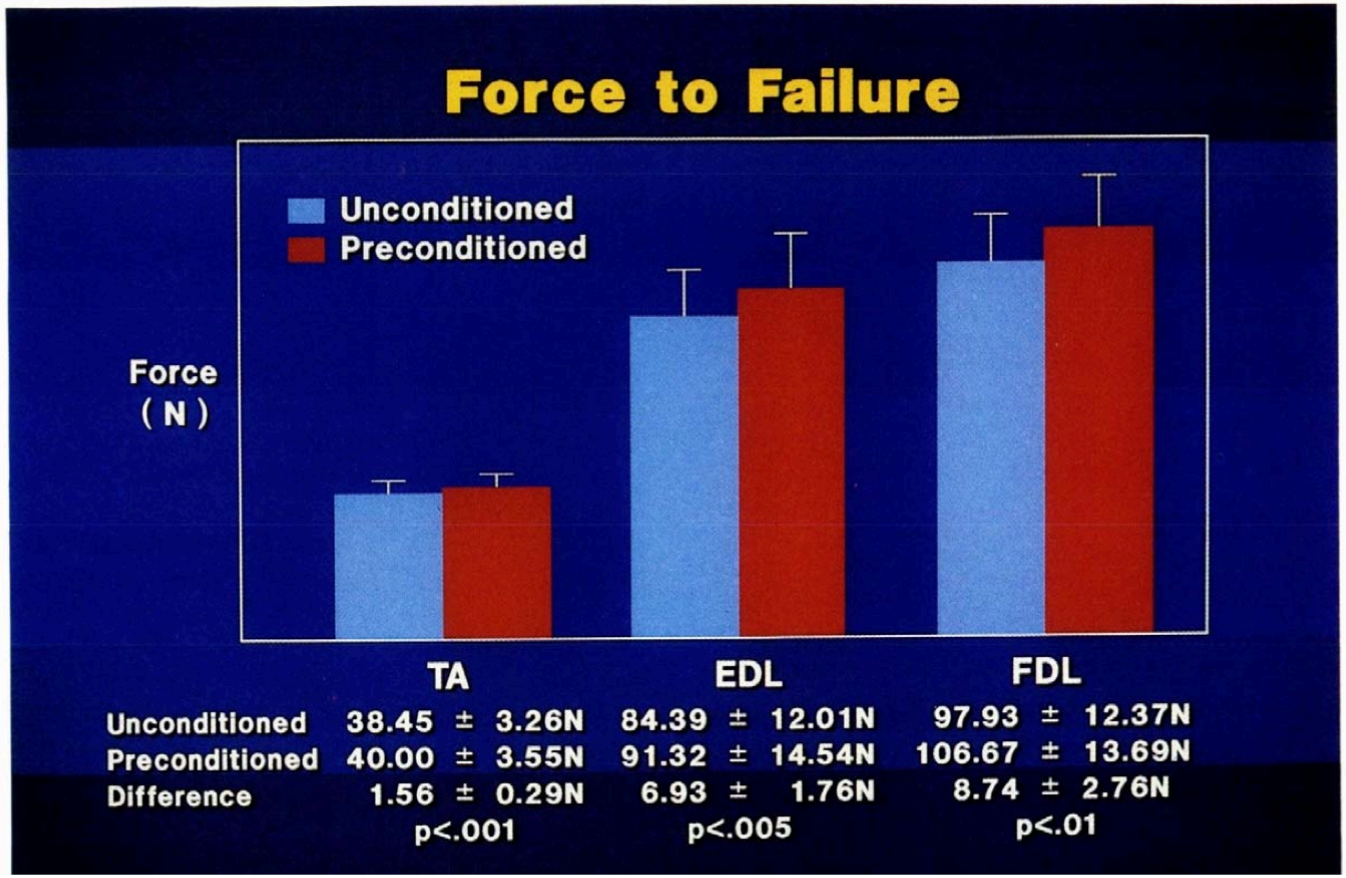

Figure 1. Average force to failure for preconditioned and unconditioned TA, EDL, and FDL muscles. All values are means ± SD ($N = 60$).

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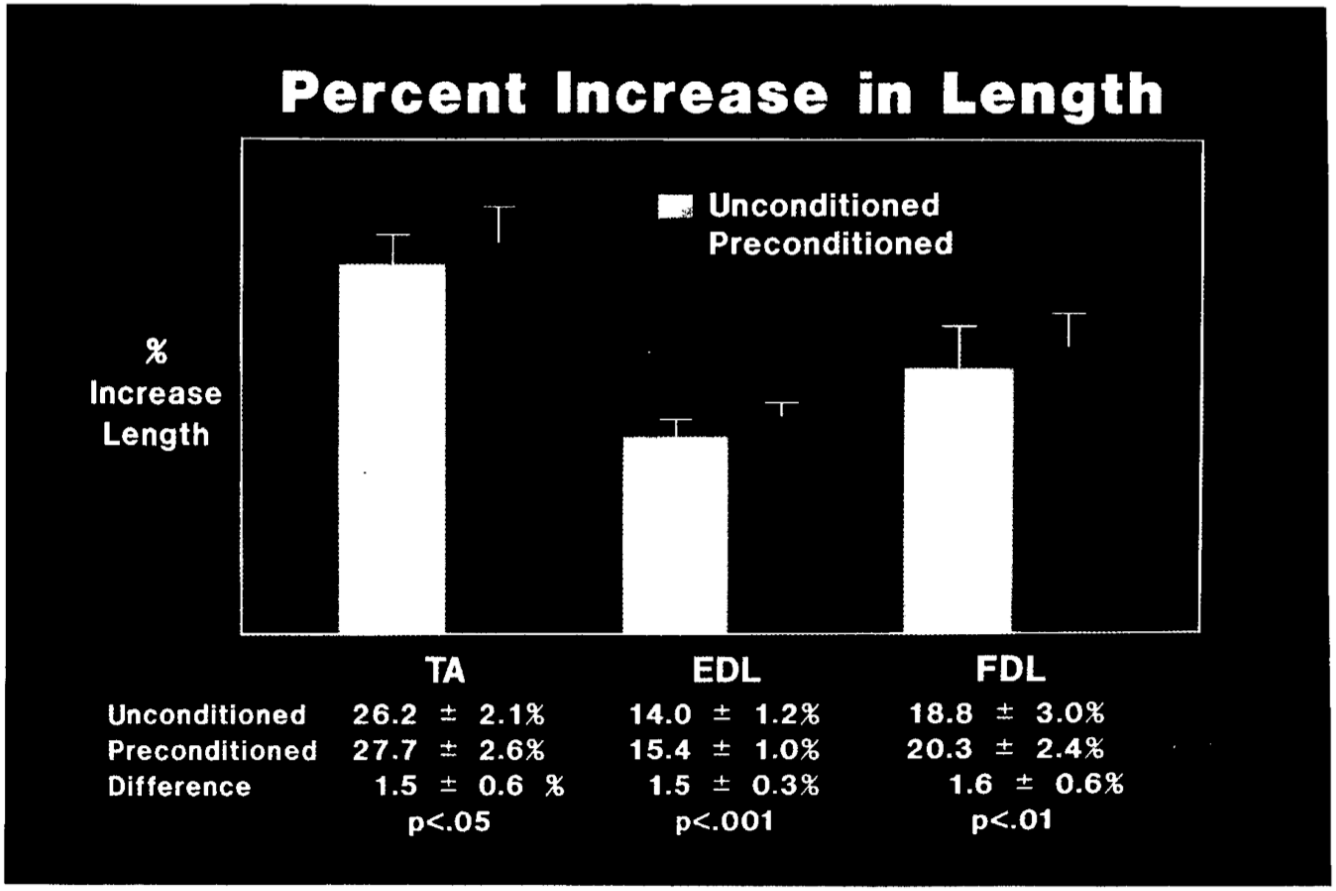

Figure 2. Average percent increase in length before failure of preconditioned and unconditioned TA, EDL, and FDL muscles. All values are means ± SD ($N = 60$).

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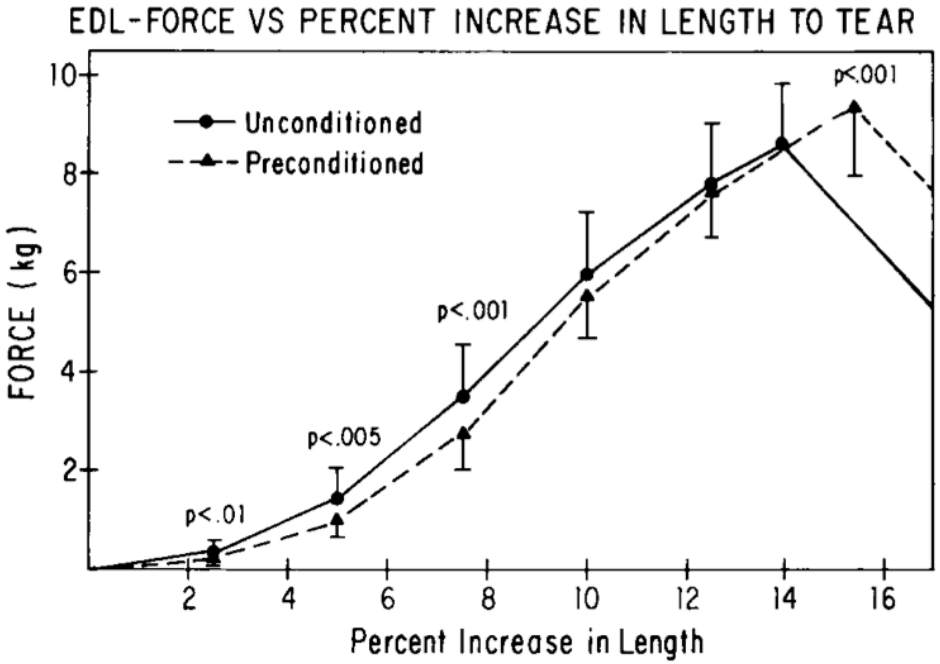


Figure 3. Average length-tension curves for preconditioned and unconditioned EDL muscles. All values are means ± SD ($N = 60$).

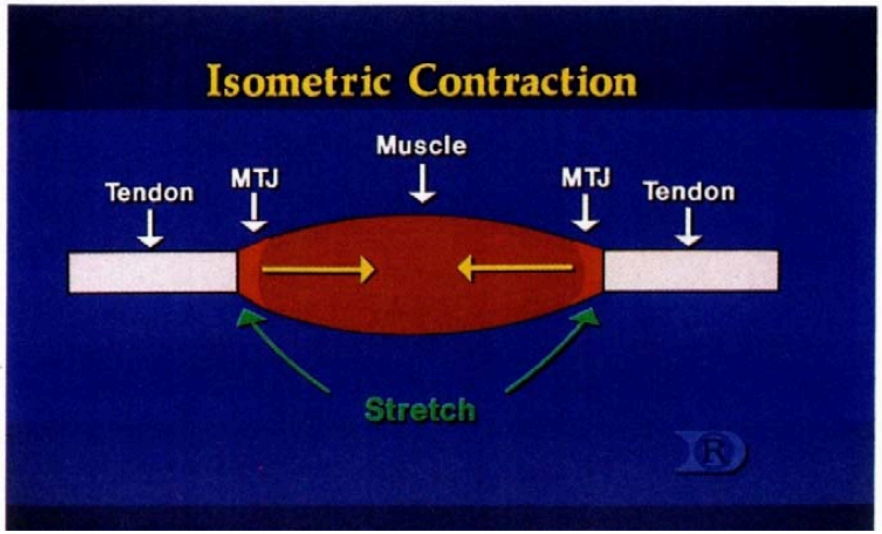
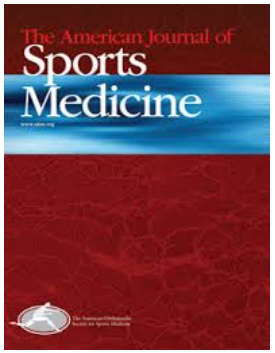


Figure 4. Diagram depicting stretch in the muscle-tendon unit as a result of isometric contraction. Stretch occurs primarily at the MTJ.



Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players

Jean-Louis Croisier,*† PhD, PT, Sebastien Ganteaume,† PT, Johnny Binet,† PT, Marc Genty,‡ MD, and Jean-Marcel Ferret,§ MD

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DOI: 10.1177/0363546508316764
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Through isokinetic testing, an imbalanced strength profile was determined in the preseason using statistically selected cutoffs[8] for the following parameters: bilateral differences of 15% or more in concentric and/or eccentric on the hamstrings; a concentric ratio (on at least 1 leg) of less than 0.47 or 0.45 on Cybex or Biodex, respectively; and a mixed ratio of less than 0.80 or 0.89 on Cybex or Biodex, respectively. Criteria for being allocated to the groups of players with imbalances corresponded to a significant deficiency in at least 2 of the following parameters: concentric (at 60 deg/s or 240 deg/s) bilateral asymmetry; eccentric (at 30 deg/s or 120 deg/s) bilateral asymmetry; concentric H/Q ratio (at 60 deg/s or 240 deg/s); and mixed H_{ecc}/Q_{conc} ratio (Table 1).

Groups	Logistic Regression	Relative Risk	Confidence Interval (95%)
AB[a]	0.0003	4.66	2.01-10.8
AC[a]	0.0493	2.89	1.00-8.32
AD	0.56	1.43	0.44-4.71
BC	0.36	0.62	0.23-1.71
BD[a]	0.044	0.31	0.10-0.97
CD	0.30	0.50	0.13-1.85

[a]Represents a significant ($P < .05$) difference between both groups.

TABLE 2
Hamstring Injury Frequency in Professional Soccer Players

Group	Players, n (n = 462)	Injuries, n (n = 35)	Injury Frequency, %
A[a]	246	10	4.1
B[b]	91	15	16.5
C[c]	55	6	11
D[d]	70	4	5.7

[a]Group A had no preseason strength imbalance.
[b]Group B had preseason strength imbalances but no subsequent specific compensating training.
[c]Group C had preseason strength imbalances and subsequent compensating training, but no isokinetic control test aimed at verifying the parameter normalization.
[d]Group D had preseason strength imbalances and a subsequent compensating training until the parameter normalization was proved by repeated isokinetic control tests.

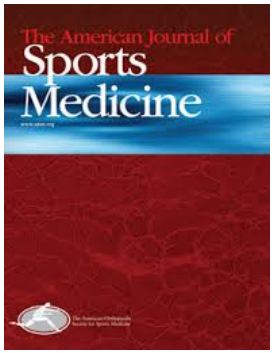

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Tableau 8.4. Critères retenus par Croisier *et al.* [9] pour retenir un déséquilibre musculaire lors de l'évaluation isocinétique des fléchisseurs et extenseurs du genou en début de saison : le sujet doit présenter au moins deux des critères suivants.

Paramètres	Seuils
Différence entre les deux côtés en concentrique (à 60°/s ou 240°/s)	≥ 15 %
Différence entre les deux côtés en excentrique (à 30°/s ou 120°/s)	≥ 15 %
Ratio IJ/Q (à 60°/s ou 240°/s)	< 0,47 (sur Cybex®) < 0,45 (sur Biodex®)
Ratio IJ30°/s (exc.)/Q240°/s (conc.)	< 0,80 (sur Cybex®) < 0,89 (sur Biodex®)

IJ : ischio-jambiers ; Q : quadriceps ; conc. : concentrique ; exc. : excentrique.

Preventive Effect of Eccentric Training on Acute Hamstring Injuries in Men's Soccer

A Cluster-Randomized Controlled Trial

Jesper Petersen,*† MD, PhD, Kristian Thorborg,† PT, PhD,
Michael Bachmann Nielsen,‡ MD, PhD, DMSc, Esben Budtz-Jørgensen,§ MSc, PhD,
and Per Hölmich,† MD

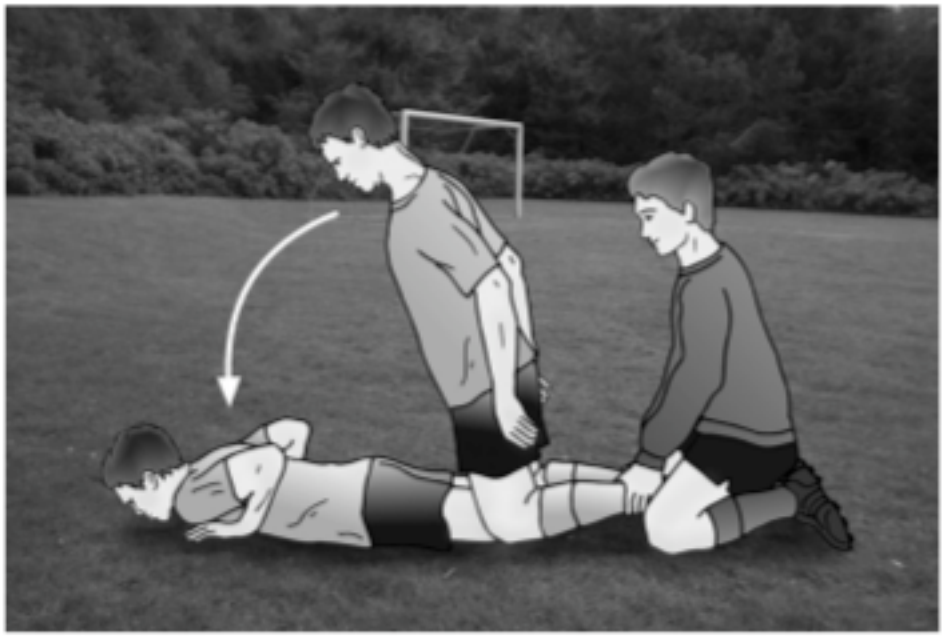


Figure 2. The Nordic hamstring exercise.

TABLE 1
Training Protocol for the Nordic Hamstring Exercise

Week	Sessions Per Week	Sets and Repetitions
1	1	2 × 5
2	2	2 × 6
3	3	3 × 6-8
4	3	3 × 8-10
5-10	3	3 sets, 12-10-8 reps
10+	1	3 sets, 12-10-8 reps

TABLE 3
Acute Hamstring Injuries in Intervention Versus Control Groups[a]

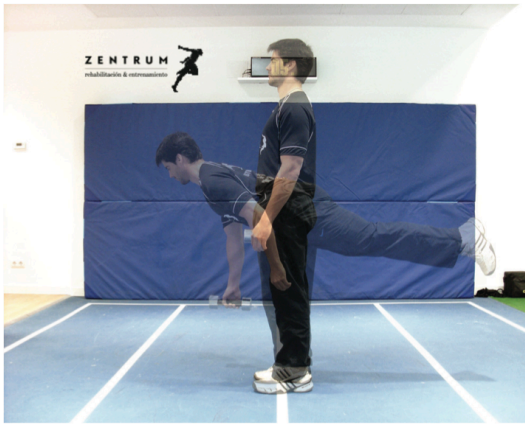
Injury Type	Allocation Group	No. of Injuries	Player Seasons at Risk	Injury Rate Per 100 Player Seasons	NNT (95% CI)	Unadjusted Rate Ratio (95% CI)	Adjusted Rate Ratio (95% CI)	*P* Value
Total	Intervention (n = 461)	15	390	3.8	13 (9-23)	0.292 (0.136-0.631)	0.293[b] (0.150-0.572)	<.001
	Control (n = 481)	52	396	13.1				
New	Intervention (n = 461)	12	348	3.1	25 (15-72)	0.380 (0.150-0.965)	0.410 (0.180-0.933)	.034
	Control (n = 481)	32	352	8.1				
Recurrent[d]	Intervention (n = 49)	3	42.0	7.1	3 (2-6)	0.156 (0.046-0.525)	0.137[c] (0.037-0.509)	.003
	Control (n = 54)	20	43.7	45.8				

[a]NNT, number needed to treat; CI, confidence interval.
[b]Rate ratio adjusted for age of players, competition level, and previous injury.
[c]Rate ratio adjusted for age of players and competition level.
[d]Recurrence of injuries sustained in the 12-month period prior to the trial.

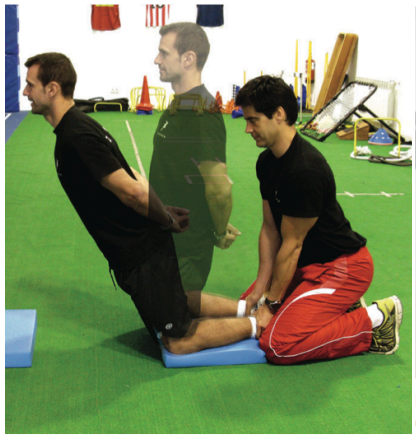
Hamstring exercises for track and field athletes: injury and exercise biomechanics, and possible implications for exercise selection and primary prevention

Nikos Malliaropoulos,[1] Jurdan Mendiguchia,[2] Hercules Pehlivanidis,[1] Sofia Papadopoulou,[1] Xavier Valle,[3,4,5] Peter Malliaras,[6] Nicola Maffulli[6]

Br J Sports Med 2012;**46**:846–851.



rinter eccentric leg curl. Example o open kinetic chain
e dominant exercise. Concentric knee flexion during



amstring. Example of open kinetic chain bilate
cise. Hamstring muscles maximally contract
tending action as lowering throughout the range

Figure 6 Barbell leg curl. Example of closed kinetic chain (fixed distal segment) double leg HIP dominant exercise. Concentric knee flexion during ascending and eccentric knee flexion during descending is created with the only movement of hip. Barbell grip add posterior trunk muscle involvement.

Figure 7 Loaded lunge box drops. Example of progression in strai
Single leg closed kinetic chain hip dominant exercise. Drop jump fro
a height is done and therefore strain is achieved at the hamstrings c
to increases in external hip flexion moments counteracted by intern

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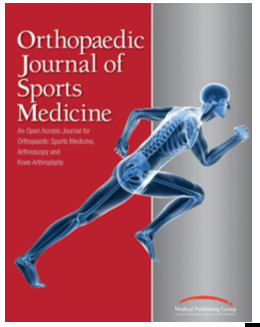
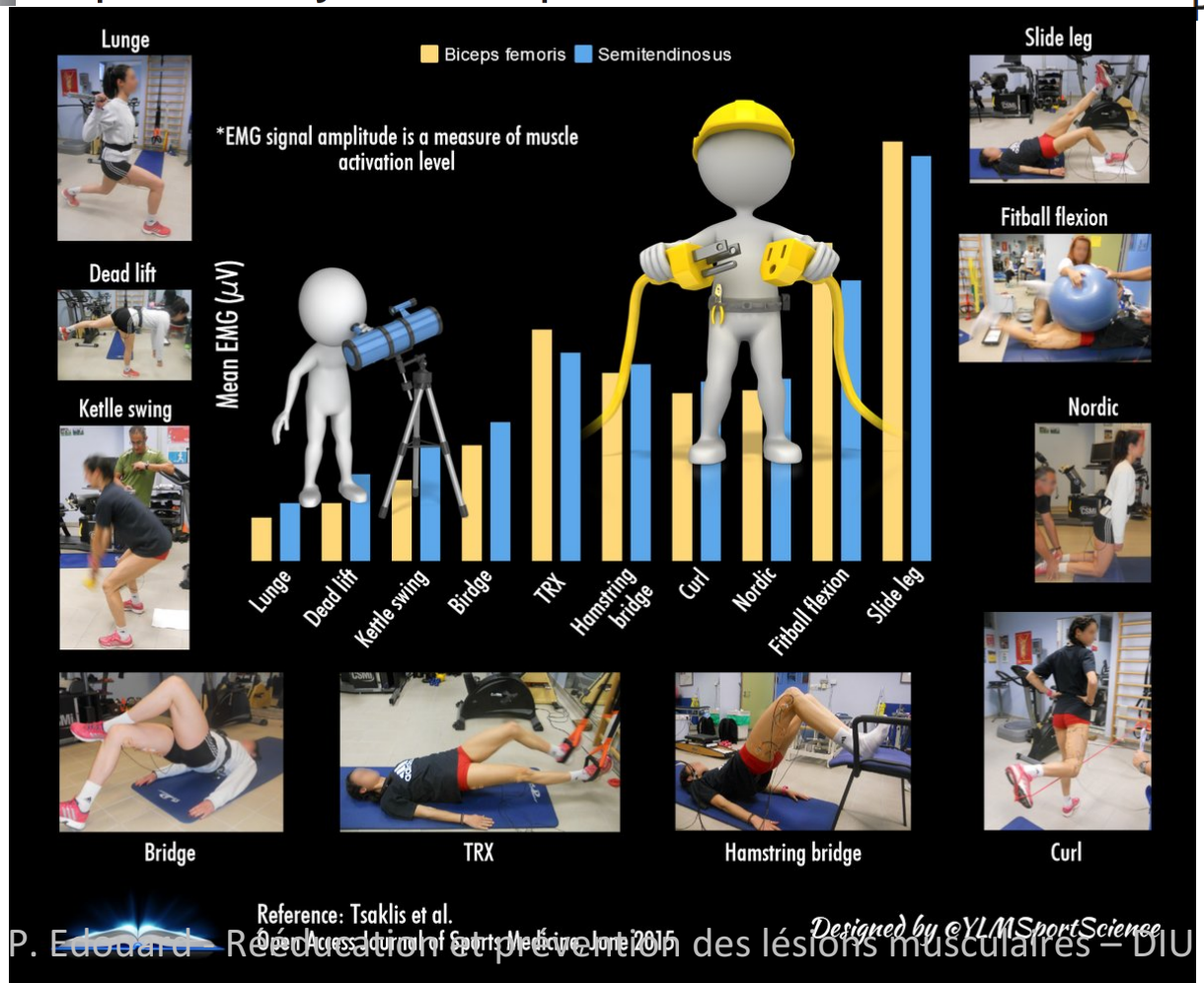


Muscle and intensity based hamstring exercise classification in elite female track and field athletes: implications for exercise selection during rehabilitation

Open Access Journal of Sports Medicine 2015:6 209–217

Panagiotis Tsaklis[1,2]
Nikos Malliaropoulos[3–5,10]
Jurdan Mendiguchia[6]
Vasileios Korakakis[7–9]
Kyriakos Tsapralis[11]
Debasish Pyne[5]
Peter Malliaras[10]



Regional Muscle Use During Hamstring Strengthening Exercises

Reference: by Mendez-Villanueva, Suarez-Arrones et al. PLoS ONE 2016

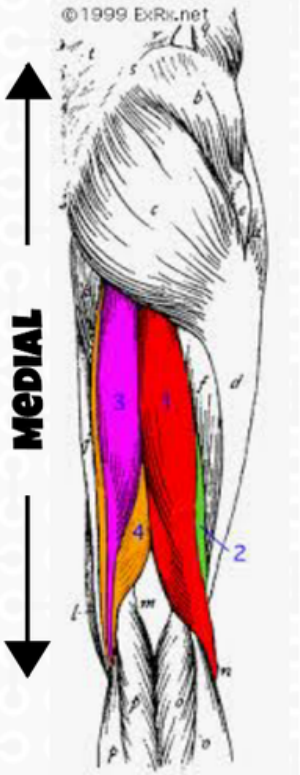
Flywheel leg-curl

Nordic hamstring

Russian belt

Hip-extension conic-pulley

PROXIMAL



DISTAL

		Flywheel leg-curl	Nordic Hamstring	Russian belt	Hip-extension conic-pulley
Biceps Femoris (long head)	Proximal	+		+	++
	Medial	++		+	
	Distal	++	+	+	
Biceps Femoris (short head)	Proximal	++	++	+	
	Medial	++	++		
	Distal	++	++	+	
Semitendinosus	Proximal	++	++	++	+
	Medial	++	++	++	++
	Distal	++	++	+	
Semimembranosus	Proximal			++	
	Medial	++		+	
	Distal			+	

Designed by @YLMSportScience

Remerciements particuliers au Pr Jean-Benoît MORIN (Nice), Jurdan Mendiguchia (Espagne) et Dr Pierre Samozino (Chambéry)

Merci de votre attention

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