Rehabilitation and return to performance

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Significant Knowledge Gaps Between Clinical Practice and Research on Femoroacetabular Impingement: Are We on the Same Path?

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The 'Path':

Where are we starting from, where are we going?

Kemp & Risberg, 2018
Ardern et al., 2016

Presentation outline – the path

- Part A: *Context (where are we starting from?)*
- Part B: *Rehabilitation and return to performance (where are we going?)*

Establish our philosophy from the outset: What are we returning the player to?

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

'Performance' has to be the answer –

To impact team success, and for player welfare (*avoid premature return)

Ardern et al., 2016

If we are pursuing a 'return to performance' following injury

'Always begin with the end goal in mind' –

Therefore, we need to have a understanding from the outset regarding:

- *What are we preparing for/ what are the requirements of competition?*
- *Which attributes do we therefore need to progressively restore?*
- *Which other attributes that will help the cause do we also now have time to develop?*

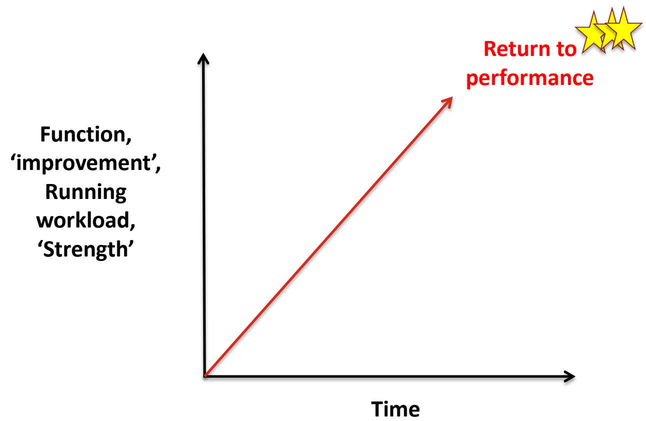
What exactly are we preparing for?
Some general running requirements to consider.

Data from a number of field-based sports shows:
(*From soccer, rugby union, rugby league, field hockey):

- A 10-15m sprint velocity effort every 90 seconds
- 10-22m sprints are repeatedly recorded during critical times of play and during performance of key tactical skills
- 11% of game time (in soccer) is spent completing sprint velocity running

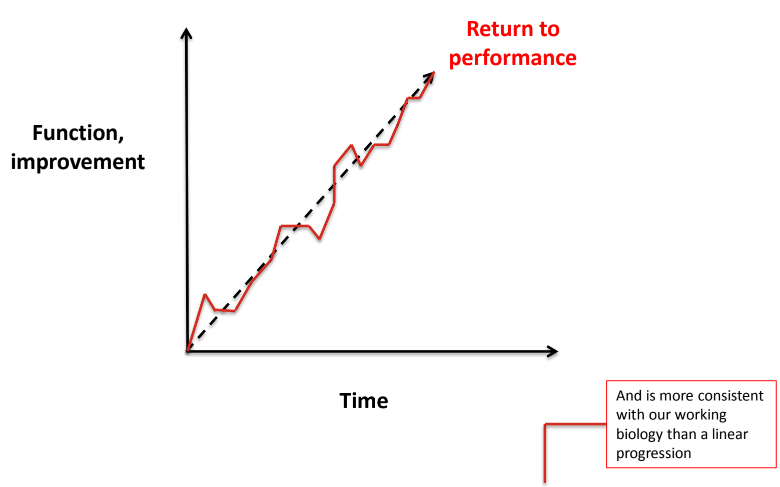
Comfort et al., 2012
Helegrud et al., 2004

How we like to think this overall process progresses



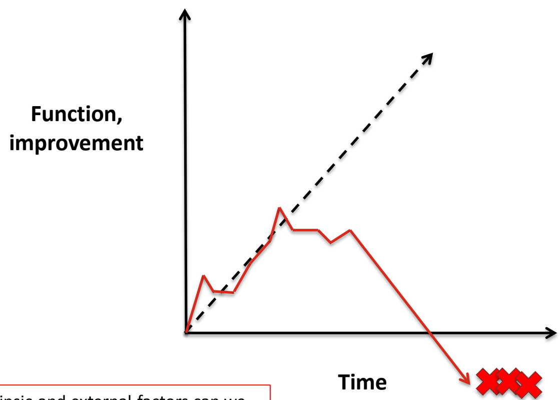
(The fabled and beautiful linear progression)

Confronting the reality



*Despite what we would like to think; intentions, diligent planning and ego

An unwanted reality –
what we are working to avoid, but can happen



*Which intrinsic and external factors can we address (effectively), to counteract this situation?

*These factors may not always be related to 'pathology'

Did not return, or returned prematurely (below capacity) and there were consequences

To simplify things –
it is a question of how get from point A to point B

Clinical state, acute injury

- *Pain*
- *Weakness*
- *Movement impairments*
- *Unavailable for selection*
- *'Chronic rehabber'*

Return to performance

- *Pain-free (or controlled)*
- *Strong, powerful, resilient to future or subsequent injury*
- *Movement and mobility permits athletic motions and skills*
- *Available for selection (and expected to perform straight away)*

Gabbett et al., 2016
Toohey et al., 2017

A question of getting from point A to point B

Clinical state, acute injury

Return to performance

What needs to occur during rehabilitation?

Which abilities and capacities need to be redeveloped?

How do we do this safely and in a fashion that keeps the athlete healthy in the long term?

Which key principles drive our decision-making?

Gabbett et al., 2016
Toohey et al., 2017

BUT – These presentations can be complex in terms of anatomy and patho-anatomical relationships.

FIGURE 3. Palpation areas and defined clinical entities for groin pain in athletes according to the Doha agreement. Images reproduced with permission from Weir et al[105] and from Brukner and Khan[13] (*Brukner & Khan's Clinical Sports Medicine*, 5th ed. ©2016 McGraw-Hill Education).

Athletes With Adductor- and Pubic-Related Groin Pain

Athletes With Iliopsoas-Related Groin Pain

Athletes With Inguinal-Related Groin Pain

Athletes With Hip-Related Groin Pain

Athletes With Multiple Entities

Thorborg et al., 2018

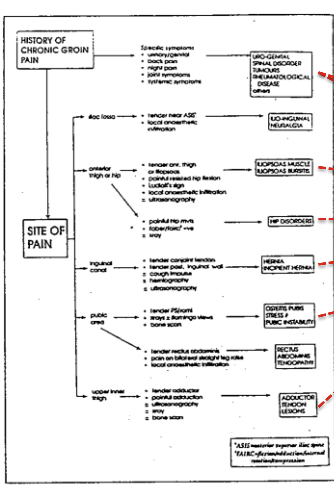
Part of the challenge rehabilitating athletes

"Coexisting painful structures along with a lack of histological pathology studies make it challenging to identify a specific diagnosis on which to focus treatment"

"descriptive terminology in use remains both wide and confusing"

King et al., 2018
Thorborg et al., 2018

Perspectives regarding pathology



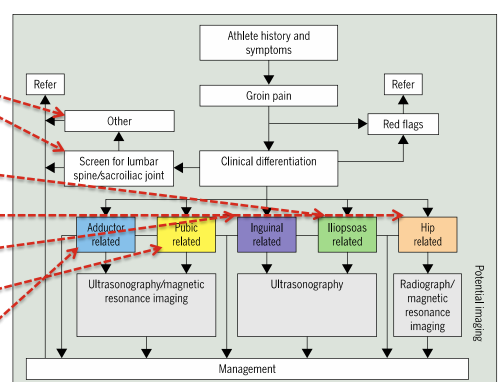


FIGURE 1. Framework for the clinical examination of athletes with groin pain.

2018

1995

Lovell, 1995
Thorborg et al., 2018

Regarding prevention and management of ‘osteitis pubis’: Clinical perspectives of AFL physios from 10 years ago

Table 2
External and internal factors identified by respondents

	External factors	Internal Factors	
King et al., 2018	Training intensity	Immature skeleton	
King et al., 2018	Training volume	Hypermobility	
Serner et al., 2017	Kicking	Motor moron	Freke et al., 2018; Lewis et al., 2018
	Trauma	Hypomobility	King et al., 2018 Kloskowa et al., 2016
Serner et al., 2017; King et al., 2018	Change of direction	Intrapelvic asymmetry	
King et al., 2018	Recovery time	Technique deficits	King et al., 2018
	Ground hardness		
	No. of games played		

***Irrespective of nomenclature for pathology and factors; How significantly has the landscape changed regarding external and internal factors to address in player management?**

Pizzari et al., 2008

Regardless – we know that hip and groin time-loss injuries continue to be an issue in sport

- Hip and groin injuries account for 14% of injuries
- Most commonly these injuries are ‘*adductor-related*’ (63%)
- Despite a ‘decreasing trend’ in rates of hip and groin injury – the injury burden has remained at a consistent (comparable) level over the 15 year study period (2001/2 to 2015/6)

Werner et al., 2018

Why do we need to rehabilitate players well? Consider some of the effects of long-standing hip and groin pain.

- Hip adductor muscle weakness (various positions, various tests)
- Weakness in other hip muscles (most)
- Reduced or abnormal hip range of motion
- Reduced muscle volume (architecture)
- Reduced contractile endurance throughout the kinetic chain
- Movement impairments and performance of dynamic tasks

***Things can become very difficult in the presence of an array of impairments/ restrictions**

Nevin et al., 2014
Kloskowa et al., 2016
Lewis et al., 2018
Freke et al., 2018
King et al., 2018

Recognise the factors that may predispose athletes to future hip or groin pain and injury

- Previous history of acute groin injury
- Hip adductor muscle weakness (in various positions)
- Lower hip adductor: abductor strength ratio (?)
- Faster 40m sprint test result for acute time-loss injuries (*consider injury mechanisms from Serner et al., 2017)
- Pain provocation during adductor strength testing
- Pain provocation during functional testing of ‘abdominals’ for acute time-loss injuries
- ***Higher level of competition (*do not underplay this finding)**

Engebretson et al., 2010
Taylor et al., 2011
Holmich et al., 2010
Tyler et al., 2001

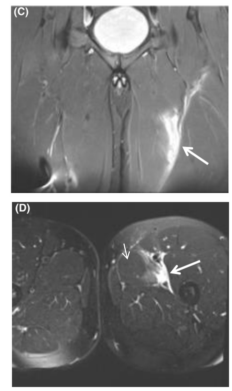
The muscles injured may provide context and direction for building capacity

Which adductor muscles most commonly fail?

- **Adductor longus (55.9%) –**

  Most commonly at the MTJ of the distal tendon (37%), the IM MTJ of the proximal tendon (26%) and the proximal insertion (26%)

- Adductor brevis (16.2%), pectineus (15.3%)

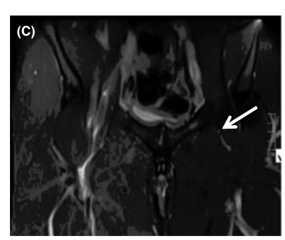


Serner et al., 2017

The muscles injured may provide context and direction for building capacity

Which of the hip flexor muscles are most commonly fail?

- Rectus femoris (48.5%)
- Iliacus (36.4%)
- Psoas major (21.2%)



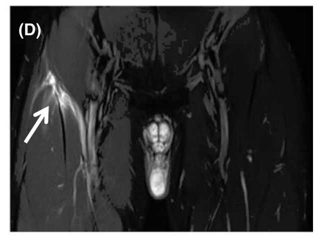
Serner et al., 2017

Mechanism of injury informs rehabilitation – acute hip flexor injuries are kicking and running injuries.

For all acute hip flexor injuries –

Most commonly a **kicking mechanism (42.4% of all muscle injuries)**, followed by **sprinting (21.2%)**

- Rectus femoris – kicking (62.5%), sprinting (25%)
- Iliacus – change of direction (41.7%)
- Psoas – injured during kicking, tackling, COD, sliding, falling and nil-specific mechanism
- Sartorius – Sprinting (50%), kicking (25%)



Serner et al., 2017
Serner et al., 2017

If these are some of the common sites of muscle injury – we need to look locally and understand the function of these tissues

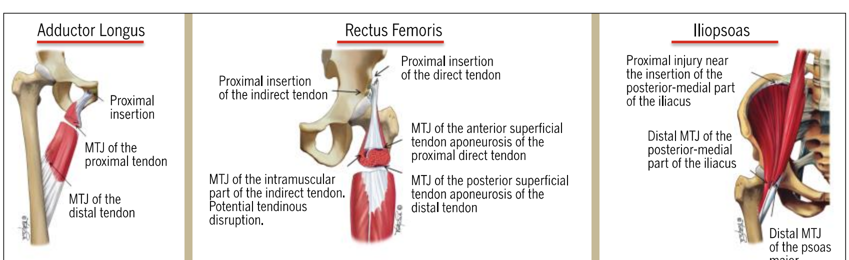
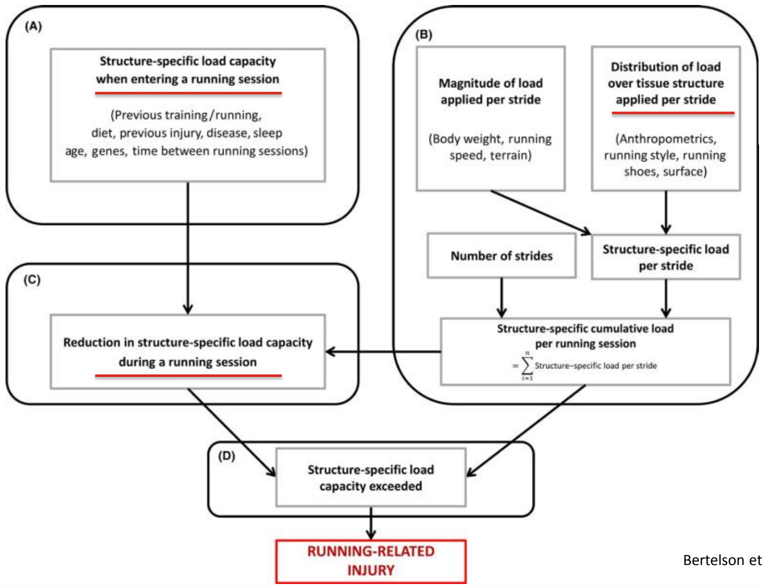


FIGURE 2. Typical anatomical locations of acute groin injuries in athletes. Images reproduced with permission from Serner et al.[87,88] Abbreviation: MTJ, myotendinous junction.

Thorborg et al., 2018
Serner et al., 2017
Serner et al., 2017

And we also need to think broadly: A framework for the etiology of running-related injuries



Bertelson et al., 2017

If movement is one factor driving injury; and we then turn to movement as a tool to restore function – we need to understand it as best we can.

A principle to challenge thought during rehabilitation (1):

"the force generated by a muscle acts to accelerate instantaneously not only the segments to which it attaches and the joints that it spans, but also all other segments and joints."

Zajac et al., 2001

If movement is one factor driving injury; and we then turn to movement as a tool to restore function – we need to understand it as best we can.

A principle to challenge thought during rehabilitation (4):

"It is important to recognize that the primary function of a muscle can be to simply redistribute energy among segments rather than produce or dissipate energy."

Zajac et al., 2001

If movement is one factor driving injury; and we then turn to movement as a tool to restore function – we need to understand it as best we can.

A principle to challenge thought during rehabilitation (5):

"Muscle force can cause significant segmental energy redistribution irrespective of whether the muscle produces mechanical work output by shortening (acting concentrically), dissipates energy by lengthening (acting eccentrically), or neither by staying a constant length (acting isometrically)."

Zajac et al., 2001

Part B: Rehabilitation and return to performance

How is rehabilitation sequenced following injury?

Early rehabilitation phase

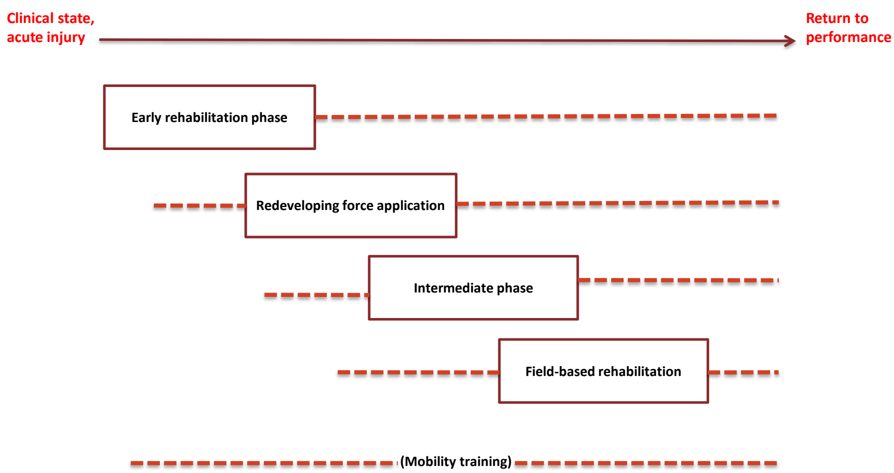
Redeveloping force application

Intermediate preparatory phase

Field-based rehabilitation

*This is the order of introduction, but all elements remain and are included in the plan concurrently

How is rehabilitation sequenced following injury?



*Sensible overlap should exist with the primary focus over time; and no stimulus is removed, but rather each are timed appropriately

Which biomotor abilities are we targeting, and therefore how are we prescribing exercise?

One starting point is to recognise the differences in each of the biomotor abilities that permit high level function:

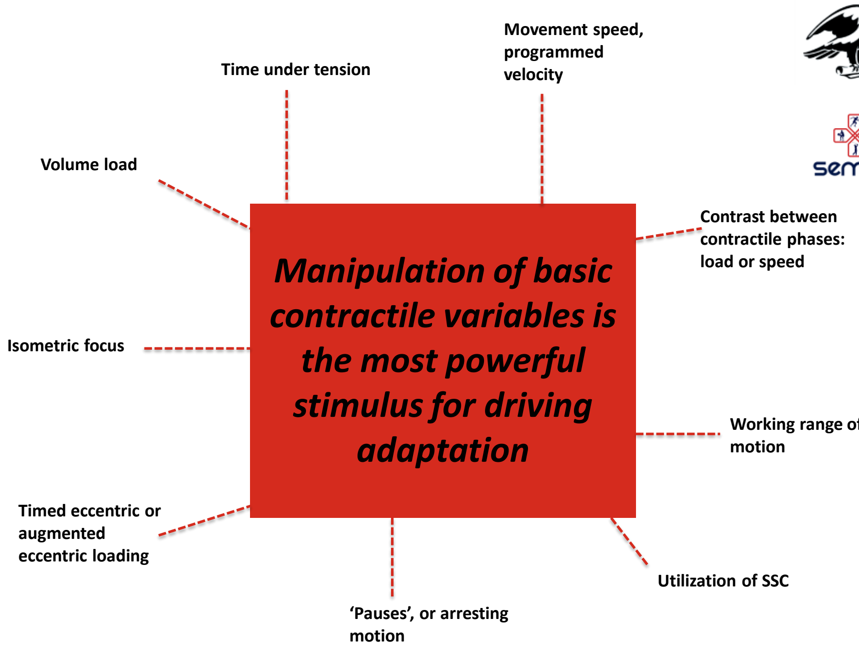
- Dynamic stability, neuromuscular control
- Strength (‘*absolute force generating capacity*’)
- Power (‘*successful, time-dependent application of force*’)
- Elastic profile, stretch-shortening cycle (*SSC*)
- Mobility (‘*freedom of movement*’)

1. How are these traits different?

2. How do we effectively bring about adaptations in each domain?

3. How is this done in the presence of pathology?

Wilson et al., 2012
Coffey & Hawley, 2007



A reality of our situation –

We do not need more exercises;
we need more variations of the exercises we already have

Early rehabilitation phase

Tenets of early rehabilitation

1. Low load activation exercises in non weight bearing positions are combined with closed kinetic chain exercises as early as clinically appropriate
2. Sensible early exposure to eccentric muscle action through range is ok – Clinical monitoring of pain and weakness are an ongoing guide
3. Building low load contractile strength endurance using both isotonic and isometric exercises
4. ***Do not let other elements of the kinetic chain detrain; and rehabilitation may also be an opportunity to in fact achieve some further adaptations that will assist in later stages of rehab, and in performance once returned**

BUT – for early management of hip and groin conditions to be effective, we require early detection

Strength loss/ adductor muscle weakness in athletes (Australian rules, soccer, Gaelic football):

- *In the week preceding the onset of groin pain*
- *At the week of pain onset*
- *Pre-season (baseline) weakness prior to commencement of training*
- *Can differentiate between players currently with and without groin pain*

Pizzari et al., 2008
Crow et al., 2010
Delahunt et al., 2017
Malliaris et al., 2009
Kloskowa et al., 2016

Early rehabilitation exercise streams from the literature

Referenced relating to hip, adductor and abdominal-related groin pain:

1. *'Core stability' training of 'muscles related to the pelvis' (?) and trunk*
2. *'Adductor strengthening' – isotonic, isometric, eccentric focus*
3. *'Adductor endurance'*
4. *'Abductor strengthening'*
5. *'External rotator training'*
6. *'Gluteal strength', 'Gluteal endurance'*
7. *'Global hip strengthening' (including the 'flexors')*
8. *'Back extensors'*
9. *'Abdominal muscles'*

How do we know where to start and what to address?

***Differentiate between prescriptions targeted at activation, an endurance profile and a strength/power profile; otherwise we end up in a middle ground and don't train anything effectively**

Choi et al., 2011
Holmich et al., 2010
Shu et al., 2011
Leetun et al., 2004
Briggs et al., 2013
Machotka et al., 2009

We utilize motor control exercises to address mechanical aberrations associated with hip and groin pain

- Altered hip and pelvic motion during dynamic unilateral tasks

  "variations in hip mechanics can become more pronounced after fatigue"

- Hip muscle weakness (adductors, extensors, abductors, **flexors**)

  Consider MOI, and requirements of running

- Reduced hip range of motion
- Reduced performance during dynamic control and balance tasks
  *Strength and range of motion deficits accounting for approximately 50% of the variance in performance

  "with the relationship between strength and function possibly becoming stronger once a threshold of weakness is met in an injured state"

Lewis et al., 2018
Freke et al., 2018

A useful model to consider during rehabilitation: "Rehabilitation focused on intersegmental control"

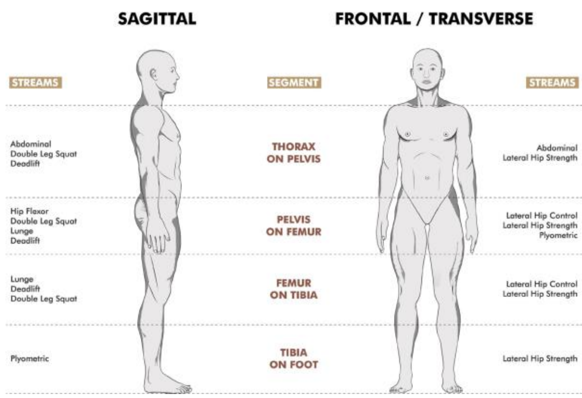


Figure 3 Level 1: intersegmental control and strength rehabilitation streams (the figure identifies the plane of intersegmental control each stream influenced).

King et al., 2018

"Rehabilitation focused on intersegmental control" – technique and movement skill

Multiplanar movements (such as change of direction tasks) and high speed running have been reported to be provocative for individuals with athletic groin pain

*But are not commonly employed as outcome measures

205 patients with 'athletic groin pain' showed positive results: :

- Improved adductor muscle strength
- Quantified changes to biomechanics during athletic tasks (cutting performance)
- Improved HAGOS scores

***150 subjects were able to achieve pain free return to participation (73.9%)**

King et al., 2018

Technique and movement skill

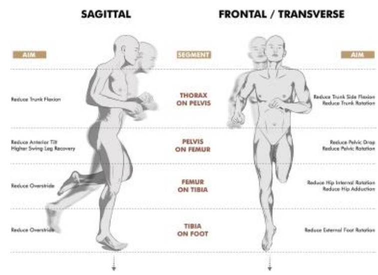


Figure 4 Level 2: segmental control focus of linear running drills (the figure demonstrates the intersegmental control the drills targeted).

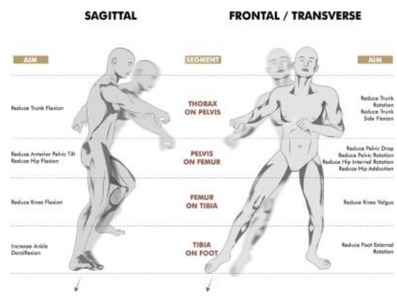


Figure 5 Intersegmental control focus of multidirectional drills (the figure demonstrates the intersegmental control the drills targeted).

King et al., 2018

A philosophy relevant to the high performance setting –

"This model allows for rehabilitation interventions to be thoroughly devised around the functional restrictions and limitations of the presenting athlete, and is not based on patho-anatomical findings alone"

King et al., 2018

We respect the (ongoing) role of motor control exercises

The presence of pain alters factors such as muscle recruitment and motor pattern, and are well established in the literature for a host of presentations other than the hip and groin:

- *Low back pain*
- *SIJ pain, dysfunction*
- *Patellofemoral pain*
- *Following acute injury (ankle, knee)*
- *'Shoulder' pathology*

Hodges & Richardson, 1996
Shadmehr et al., 2012
Cowan et al., 2003

A situation to avoid if a 'return to performance' is the goal: If 'control' becomes all-consuming and at the expense of other biomotor abilities

"Taking the smallest muscle involved and training it at 10% of its MVC with every effort to turn off everything else with the view that this muscle is inordinately important"

Dr Anthony Shield

2. Force application

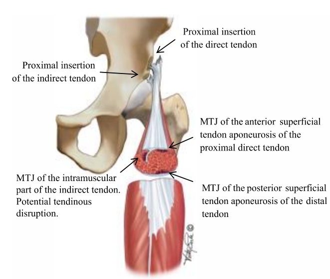
Tenets of Force application

- Commence developing the force-generating capacity locally as early as is clinically reasonable
- Strengthening away from the site of injury/ pathology should always continue
- Respect range of motion deficits and do not add additional load at the expense of movement quality (it is often better to use an alternative exercise)
- Shorter range of motion, bilateral compound lifts are a 'safe' starting point
- If unable to perform a Good Morning, probably not appropriate to be squatting under load

If we consider architecture:
Where exactly do we intend to bring about positive adapta

semsa

- Contractile unit:
  Fascicle length, cross sectional area, pennation angle
- Musculotendinous junction:
  MTJ integrity, shear stress dispersion
- Elastic elements in parallel with the contractile unit:
  Epi-muscular and intra-muscular connective tissue network
- Elastic elements in-series with the contractile unit:
  Tendon, inter-muscular connective tissue network



***The nervous system is another topic altogether**

Strengthening also offsets the effects of global detraining

Detraining (def.):

'partial or complete loss of training-induced anatomical, physiological and performance adaptations as a consequence of training reduction or cessation'

Short term global detraining (within 4 weeks) results in reductions to:

1. Whole-body maximal strength: 6 to 9%
2. Whole-body power output: 14 to 17%
3. Muscle fibre cross sectional area (CSA)
4. Average EMG activity
5. Capillary density
6. Oxidative enzyme activity
7. Glycogen synthase activity
8. Mitochondrial ATP production

***The functional consequences of these changes, on top of pathology, can be disastrous**

Izquierdro et al., 2007
Mujika & Padilla, 2000
Mujika et al., 1996

Architectural considerations: Inducing tissue changes

- Loadings >80% are most effective at inducing trophic/ anabolic changes to architecture – therefore once clinically appropriate (and to unaffected areas), the stimulus needs to be progressed beyond low load prescriptions.

- If the threshold of intensity is too low – favorable transitions may not occur or are less timely (seen with relative intensities < 40%)

***Away from pathology – do not be afraid to load the tissue intensely**

Have we addressed the entire spectrum of what the tissue will be required to do (and withstand) during match play?

- Is the intention cross sectional area (sarcomeres in-parallel) ?
- Is the intenstion fascicle length (sarcomeres in-series) ?
- Is it both?

Fry et al., 2004
Goldspink & Harridge, 2003
Wilson et al., 2012

Architectural considerations: Tissue gradients about the hip, pelvis and spine.

- Within muscles:
  Early histological analysis of deeper compared to more superficial fibres within the same muscle highlight a prevailing tissue gradient
- The distribution/ arrangement of deeper fibers is more suited to stabilization
- The distribution/ arrangement of superficial fibers is more suited to greater gross torque generating capacity
- This gradient also seems to exist between muscles

Therefore these multiple functions need to be addressed, and it is also intuitive if we expect to develop proficiency during high-level tasks that demand both stability and propulsion/ positive work

Retchford et al., 2013
Astrand et al., 2003
Malisoux et al., 2007

Complementary programming of compound lifts and isolation exercises

Compound lifts are highly useful, but also consider that:

- Architectural adaptations from complex movements may take slightly longer, and therefore there can be delayed hypertrophic changes during early exposures – the earliest improvements to 'strength' are primarily due to neural adaptations
- Simpler auxiliary exercises cause early gains in strength and accompanied hypertrophy – 'tissue-building' exercises
- Use isolation training with large volume load for faster increases in hypertrophy

NB: We are not advocating body-building type training, but identify where everything fits in an overall rehabilitation plan

Stone et al., 2007
Sale et al., 2003
Chilibeck et al., 1998

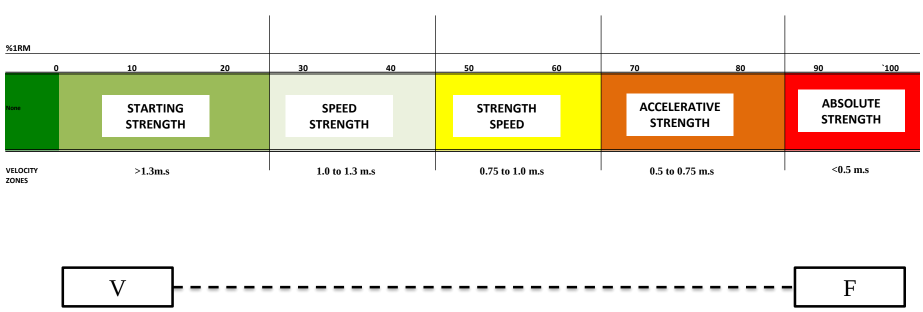
Complementary programming of compound lifts and isolation exercises

There are also region-specific architectural responses –

- Compound lifts display more uniform trophic response along entire fiber/ MTU length
- Isolation training (or contraction-phase specific loading) shows more targeted hypertrophy at either the distal or proximal fibre pole pending site of force application and attenuation

Stone et al., 2007
Sale et al., 2003
Chilibeck et al., 1998

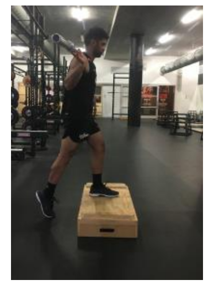
Is it good enough to just be retraining 'strength' ?



Suchomel et al., 2016
Haff & Nimphius, 2012

Factors that determine ‘strength’ during a task

1. Motor unit recruitment
2. Motor unit activation frequency (rate coding)
3. Motor unit synchronization
4. Neuromuscular activation patterns (intramuscular activation)
5. Muscle action patterns (intermuscular activation)
6. Use of elastic energy and reflexes (stretch-shortening cycle)
7. Neural inhibition vs excitation
8. Muscle fibre population
9. Muscle cross sectional area (CSA)
10. Biomechanical factors and technique
11. Anthropometric factors (most related to movement performance)



Stone et al., 2007
Malisoux et al., 2007

‘Strengthening’ during rehabilitation – we have choices?

Common starting position:
CG pull from 15cm blocks

Vertical thrust or ‘Jump shrug’

CG pull to extension

CG pull to high position

CG pull to hip or CG deadlift

V

F

Suchomel et al., 2016
Haff & Nimphius, 2012

What is our approach to 'strengthening' and why? Force: velocity considerations.

Approach	Isometric peak F	1RM	Iso peak RFD	Dynamic peak RFD	Peak power	Maximal velocity
Isometric	++++	+++	++	+	+	+
Heavy resistance	+++	++++	++	++	++	++
Speed-strength resistance	+	++	+++	++++	++++	+++
Intentionally slow/ TUT focus	+++	++	?	+	+	+ or -

Stone et al., 2007

What is our approach to 'strengthening' and why? Architectural and neurological adaptations.

Approach	Hypertrophy	II/I CSA ratios	Neurology
Isometric	+	+	+++
Heavy resistance	++++	++	+
Speed-strength resistance	+	+++	++++
Intentionally slow/ TUT focus	++	+	++

Stone et al., 2007

There are mechanical consequences to our loading prescriptions: exercises won't always 'look' the same

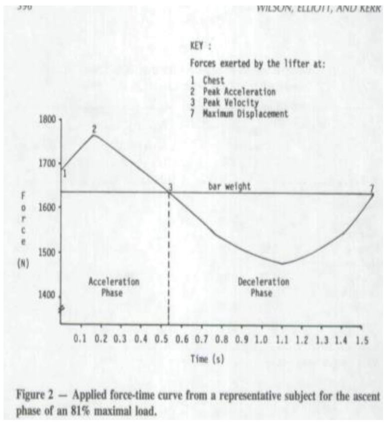


Figure 2 — Applied force-time curve from a representative subject for the ascent phase of an 81% maximal load.

Loading at 81% of maximum

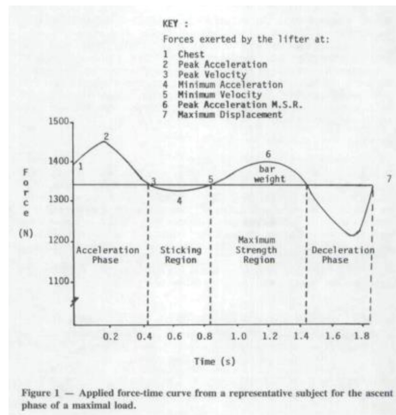


Figure 1 — Applied force-time curve from a representative subject for the ascent phase of a maximal load.

Maximal and near-maximal loading

Wilson et al., 1989

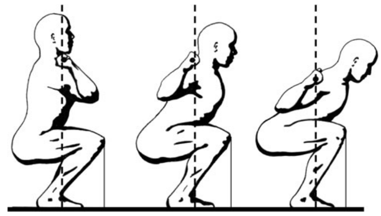
Squatting in the context of hip and groin pain

Why is it that we look to squatting motions so often?

- One method to increase maximal lower extremity strength/ force-generating capacity
- Improvements to power-based attributes
- Improvements to functions needed for sport (sprinting, jumping, COD)
- Improves running economy
- A valid and reliable measure of strength and function to track over time
- Effective in rehabilitation plans
- Erector spinae, quadriceps, hamstring, gluteal and triceps surae muscle groups all contribute to successful execution of a squat
  (NB: more than 200 muscles are recruited in the execution of a single repetition)
- The mass of the bar applies force to the body in all planes (sagittal, coronal, transverse)

Glassbrook et al., 2017
Hartman et al., 2013
McCaw & Melrose, 1999

‘Strengthening’ – we have choices



For example – IF we are wanting to squat them, what do we prescribe?

- *High bar back squat (HBBS)*
- *Low bar back squat (LBBS)*
- *Front squat*
- *Bulgarian split squat*
- *Pin squat (‘Bottom-up’, concentric-only squatting)*
- *Shortened range squatting (1/2, 1/4 squats)*
- *Cossack squat*

Different movement strategies according to:
1. **Joint angles**
2. **Vertical ground reaction forces**
3. **Activity of key muscles**

(*Load lifted*)
(Movement speed)
(*Emphasized contractile mode*)

Glassbrook et al., 2017
Hartman et al., 2013
McCaw & Melrose, 1999

Other joint contributions to the mechanical conditions of the hip ?
Mobility can be the elephant in the room.

Subjects with greater dynamic hip internal rotation and medial knee displacement were significantly more restricted during an ankle dorsiflexion lunge test.

“Regardless of bar position, the back-squat requires an adequate range of motion at the hip, knee, and ankle joints.”

Rehabilitation provides an opportunity to address concomitant restrictions and movement aberrations

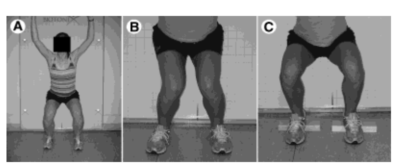


Fig 1. (A) Control subject during the overhead squat task. The mid-patella stays over the foot during the squat. (B) MKD subject during the overhead squat. The mid-patella is medial to great toe. (C) MKD subject performing the overhead squat on the heel lift (2×4 wooden block). MKD is corrected and mid-patella stays over the foot during the squat.

Glassbrook et al., 2018
Bell et al., 2008

Exercise prescription – where are we, and why are we there?

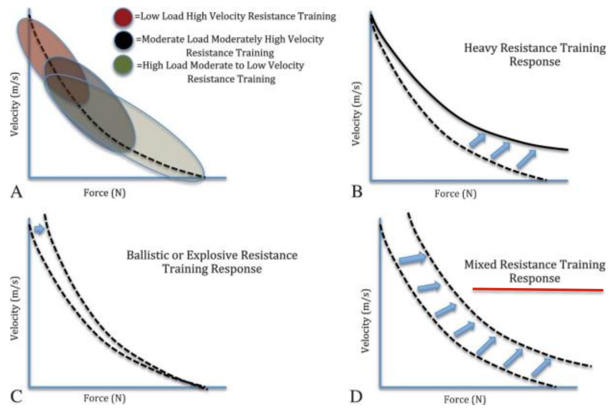


Figure 6. Potential training interventions which impact the force-velocity curve.

*Classic load-velocity or force-velocity curve was proposed as early as 1938 (Hill)

Haff & Nimphius, 2012
Hakkinen & Keskinen, 1989
Edman, 2003

Typical gym-based rehabilitation session structure

Preparation: motor control and activation series of exercises, mobility drills

Power-based or time-dependent motion(s)

Force-based motion(s)

*Exercises with the largest neurological demand are reserved earlier in the session

'Special' strength for sport, or additional unilateral exercises

Specific auxiliary or accessory loading
*could be for other areas;
Calf, hamstrings, e.spinae

3. Intermediate preparatory phase

Why do we do have an intermediate preparatory phase?

- The gap between earlier rehabilitation and field-based rehab is very large in terms of the rate of loading throughout the lower limb
- Gross force generating capacity in controlled conditions does not mean we are effective during dynamic force application; we need to redevelop this attribute
- We need to spend longer developing the different capacities that will permit a successful return to running and more advanced ballistic actions
- Developing elastic functions of the MTU takes time, even if the elastic tissues have not been injured!

Intermediate preparatory phase

Tenets of the intermediate preparatory phase

1. **Successful** force application in more than one condition and position
2. Graduated exposure to load absorption in more than one position and plane*
3. Introductory plyometric exercises:
   Propulsive drills: Concentrically-biased
   Locomotive drills: Short amplitude, low force, low velocity
4. Locomotive capacity building:
   Prowler > Sled > Farmer's walks
5. Basic running prep and technical drills (Eg. Triple extension-flexion; 'Wall series') – this may be an opportune time
6. Do not overlook multi-axial loading and rotational drills with force application and load absorption (*this needs to be rehabilitated prior to multi-directional running)

***NB: Concurrently develop vertical and horizontal profile**

Locomotive capacity building precedes high-end running

- Varied foot strike to deliberately alter position of load absorption, and the position of force application
- In football players –
  Highly variable running speeds and mechanics;
  Therefore prescribe across the spectrum
- Drills from Position A are more related to the horizontal vector
- Drills from position B are more related to the vertical vector
- Once integrating drills for true speed – combined vector

  (*without restriction –
  and we want this condition to be uncontrolled once we are there)

Position A

Position B

4. Field-based rehabilitation

semsa

What do we do during field-based rehab?

- More advanced plyometric training and running drills
- Graduated running program specific to the presentation/ player
  (*not necessarily the pathology)
- Integration of skill-based retraining throughout
- More advanced prowler and sled prescriptions

Utilize the force-generating and force-absorbing abilities we have previously worked on to now permit efficiency during the entire SSC, *which is what is required during 'normal' function

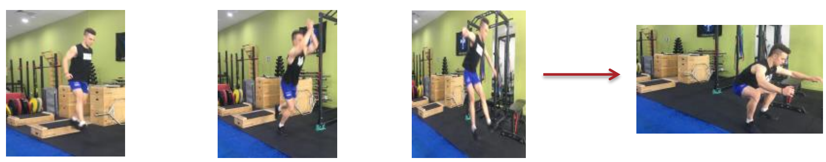
Rehabilitating ballistic actions

- Selection of plyometric training according to pattern of motion expressed during competition, or to develop a wanted adaptation

- Basic classification according to wanted transfer effect:

  Locomotive drills *are more related to improving maximum velocity or speed*

  Propulsive drills *are more related to accelerative attributes or starting acceleration*



Plyometric exercises and the adductor muscles

In addition to the positive effects to global athletic attributes –

- Plyometrics are also shown to have a significant effect on the extent of preparatory adductor muscle activity, and a positive ratio of adductor: abductor coactivation

- It is likely that this is one preparatory motor strategy to optimize joint position for successful load absorption and generation of positive work

Predominantly:
- ***Split squat jumping progressions***
- ***Lateral, rotational jumping***
- ***Drop jumping progressions***

Chimera et al., 2004
Stone et al., 2007
Seiberl et al., 2015

An example of progressing (over time) locomotive plyometric drills:

A. Rhythmic submaximal skip bounding for 20m, walk recovery: **vertical focus**

B. Rhythmic submaximal skip bounding for 30m, walk recovery: **horizontal focus**

C. Bounding (combined vector) for 30m, 90-120s recovery

D. Single leg bounding (combined vector) for 15m, 120s recovery

Rehabilitating plyometric muscle actions: Continuum approach to prescription

Lower relative stress on the entire MTU

Concentrically-biased, more limited range of motion (Force application)

Re-development of force absorption

Small amplitude, low force rhythmic SSC drills (*usually distal focus)

Basic recoil energetics and utilization of strain energy for positive work

Rhythmic and locomotive plyometric drills
(*Maximal velocity training)

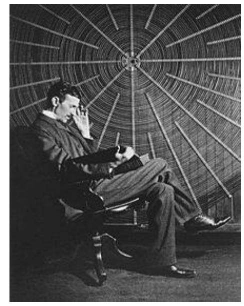
Accelerative and propulsive plyometric drills
(*Accelerative attributes)

Greater relative stress on the entire MTU

*Successful implementation emphasises controlled frequency and volumes initially, a necessity during staged rehabilitation following injury
*Try not to 'get lost' in the process

Running qualities and capacities – more choices?

- *Speed endurance*
- *Maximal aerobic speed*
- *Repeat-sprint ability (RSA)*
- *Acceleration*
- *Deceleration*
- *Maximal velocity training*
- *Economy and technical aspects of running*
- *Combative endurance / contacts*
- *Change of direction (COD)*
- *Reactive agility*
- *Multidirectional running*



How do you know what to prescribe and plan? (Needs analysis)

What information do we have from MOI or predisposing factors?

General requirements of the hip muscles during straight line running

Actions of the hip muscles can be broadly considered according to:

Stance actions	**Alternating hip flexion-extension actions**

***At face value, what does this tell us about what we need to address, during running, and also strengthening?**

Gazendam & Hof, 2007
Anderson et al., 1997
Nene et al., 2004

General stance actions of the hip muscles during running

Stance actions

- Initial burst that is synchronized with 'extensors':
  Gluteals, distal quadriceps, calf muscles
- With this simultaneous action and the segment positioned in relative flexion at the hip, knee and ankle;
  the leg becomes an 'elastic element' in-series
- During initial stance, the segment is compressed by the weight of the system and the downward velocity of the trunk
- This is followed by extension actions at all of these joints, which utilizes the stored strain energy (stretch-shortening cycle)

Gazendam & Hof, 2007
Anderson et al., 1997
Nene et al., 2004

General swing actions of the hip muscles during running

Alternating flexion-extension actions

- Alternate hip flexion is achieved by combined action of psoas, iliacus, rec fem and 'superficial adductors'.
- Combined flexor actions occur around the instant of maximal hip flexion, and also at maximal hip extension
- NB: Gluteal musculature participate in both stance actions and propulsive actions (***Implications for rehab**)

Gazendam & Hof, 2007
Anderson et al., 1997
Nene et al., 2004

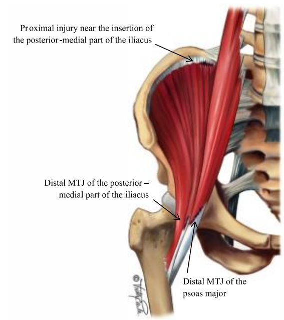
Requirements of faster running

- With faster running, there is a larger angular movement at the hip that needs to occur in a shorter time

  ('higher angular acceleration' = 'higher demand for hip flexion torque')

  (*Implications for rehab – ***train hip flexor capacity***)

- (*And remember that the swing phase, in which these muscles do most of their work, becomes longer with increased speed



Andersson et al., 1997
Preece et al., 2016
Franz et al., 2009
Saunders et al., 2005
Hamner et al., 2010
Riley et al., 2010

Requirements of faster running

With rising running speed (1):

- Concurrent mechanical changes are seen at neighboring structures to achieve a kinematic outcome

  Eg. The degree of 'hip extension' observed during faster running is the result of the combined motion at the lumbar spine, pelvis and hip (rather than the hip joint alone)

- Up-regulated activity in abdominal muscles and lumbar multifidus (superficial) accompany the increases to lumbo-pelvic motion

- The relative duration of EMG bursts for the hip flexors (PS, IL, 'superficial adductors') increase with speed

- Very strong braking requirements for the hip flexors/ proximal quadriceps in stance

Andersson et al., 1997
Preece et al., 2016
Franz et al., 2009
Saunders et al., 2005
Hamner et al., 2010
Riley et al., 2010

Requirements of faster running

With rising running speed (2):

- Significantly longer ground contact times with increasing distance
- Larger reductions in GRF in the horizontal than vertical direction
- Increased decrements to vertical stiffness increased with sprint distance
- Acute decrements to global leg stiffness property more pronounced with longer trials
- Mechanical alterations occur earlier during longer running trials

Girard et al., 2016
Preece et al., 2016
Franz et al., 2009
Saunders et al., 2005
Hamner et al., 2010
Andersson et al., 1997

Requirements of faster running

With rising running speed (3):

- Significantly higher loading rate (BW s^{-1}) in injured versus noninjured male novice runners, at multiple running speeds (9km/hr, 10km/hr)
- Force contributions for some of the adductor muscles only becomes prominent once running beyond 3.0 m/s (such as Adductors Magnus)
- Iliacus and Psoas activity increases significantly with rising speed; by 4-fold even when progressing along the range from 2 to 4.5 m/s
- Very high activity of the deep stabilizers (QF), which may be synergistic for superficial hip muscles and hamstring function

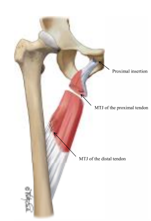


FIGURE 6 Anatomical illustration of the three most common adductor longus injury locations. MTJ, musculo-tendinous junction; BTJ, bone-tendon junction

Bredeweg et al., 2013
Gazendam & Hof, 2007
Semciw et al., 2015
Andersson et al., 1997

Parameters of running workload to plan and graduate quantitatively throughout rehab:

1. Absolute volume or distance covered during straight line running
2. Running volume at two 'high-speed' running band widths (18-24km/hr, >24km/hr)
3. Distance covered multi-directional running rehab
4. Intensity of running during multi-directional rehab
5. Workload and intensity during uncontrolled running conditions (football drills)

In the context of the:

a) Current training week

b) Preceding 2, 3 and 4 training weeks

c) More chronic training 'completeness' (previous months, pre season)

King et al., 2018

Keep in mind that quantification is useful – but it is part of the puzzle and not the answer

Some useful areas of qualitative analysis:

- Running gait (intra- and inter-session)
- Kicking tolerance and performance (efficiency, penetration, decision-making)
- Other areas of the body – hamstrings, rectus femoris, calf muscles, lower back, upper limb once contact training begins to be reintroduced
- Psychosocial factors are paramount in a high performance setting
- An acute: chronic workload ratio will not tell you more than what the acute: chronic workload ration is

Typical field- or track-based session structure

Dynamic mobility, low level SSC and technical drills, phase-builds, low level craft, low level MD/ 'off center' drills

Accelerative and velocity-based running and plyometric prescriptions

Reactive agility, COD and multi-planar plyometric prescriptions

*More pronounced neural demand earlier in session

High-end endurance:
Speed endurance, power endurance

Special endurance – volume

Locomotive capacity building or
specific overload of lower level plyometrics while fatigued

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