



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

BMST4004

Muscle Healing

Trawsnewid Addysg; Trawsnewid Bywydau
Transforming Education; Transforming Lives



www.uwtsd.ac.uk

Muscle Healing

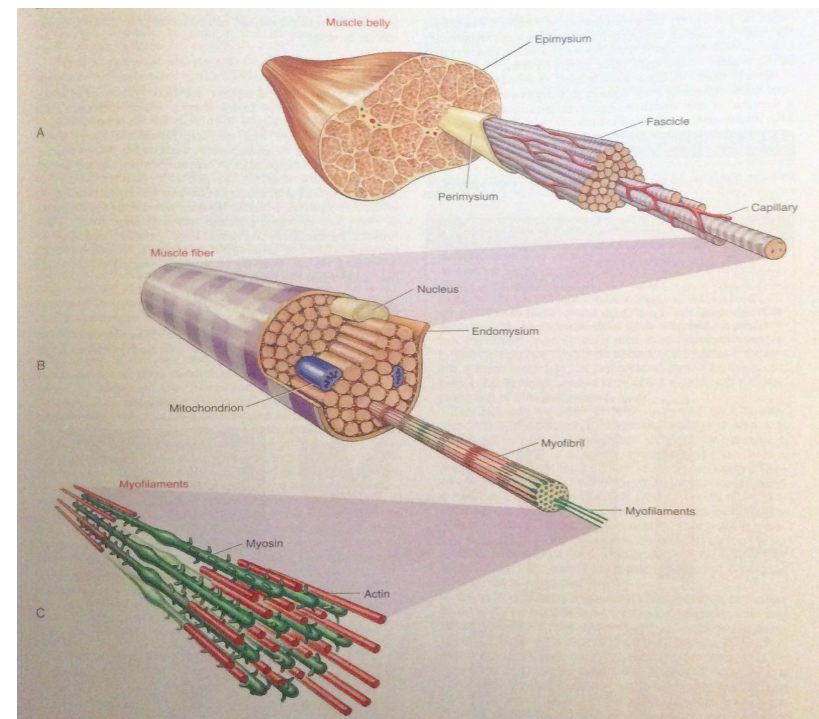
LEARNING OBJECTIVES

To be able to:

- **Explain common mechanisms of muscle injuries**
- **Describe grade and severity of muscle injury**
- **Understand the regenerative capacity of muscle tissue**
- **Discuss the application of rehabilitation and recovery from muscle injury**

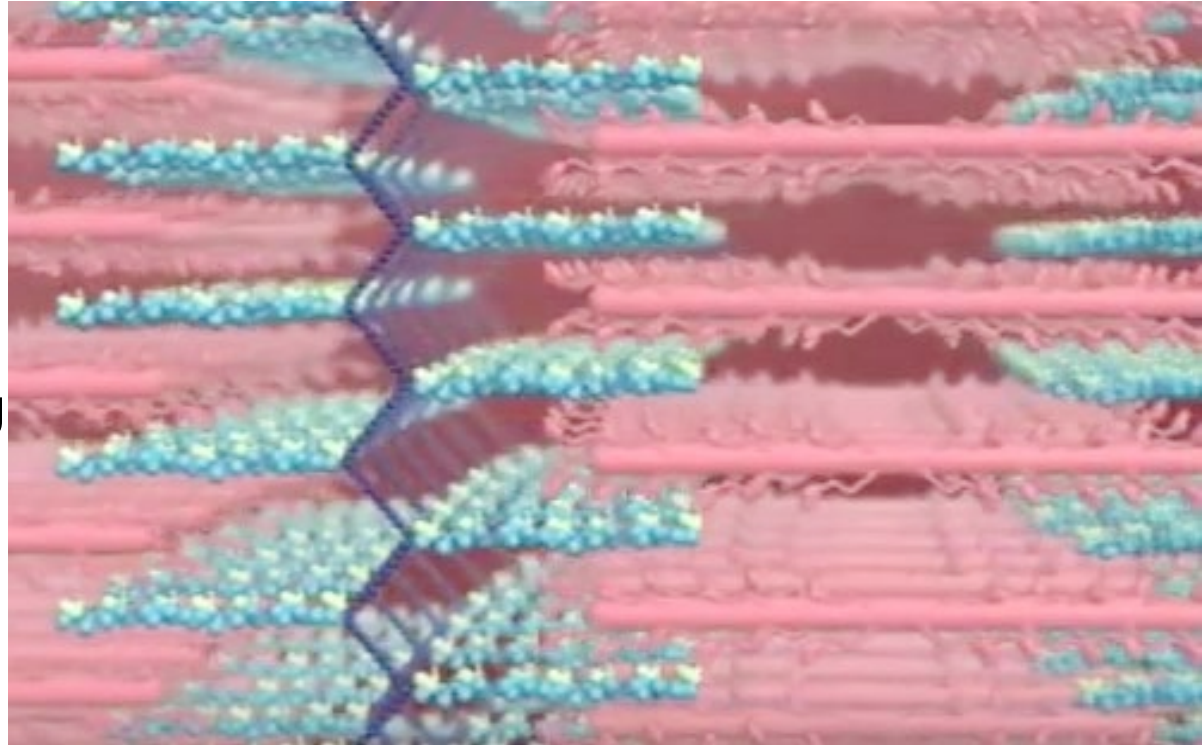
Muscle architecture

- Largest organ
- Types – skeletal, smooth, cardiac
- Total weight
 - MALES 40%
 - FEMALES 23%
- Myofibrils – CABLE LIKE STRUCTURES
- Sacromeres
 - INDIVIDUAL CONTRACTILE UNITS
 - PRODUCE FORCE TO BE ABLE TO MOVE



Sacromere

- Actin and myosin
- Cross bridges
- Contractile
- Sacroplasm
- Huxleys sliding filament



Fibre types

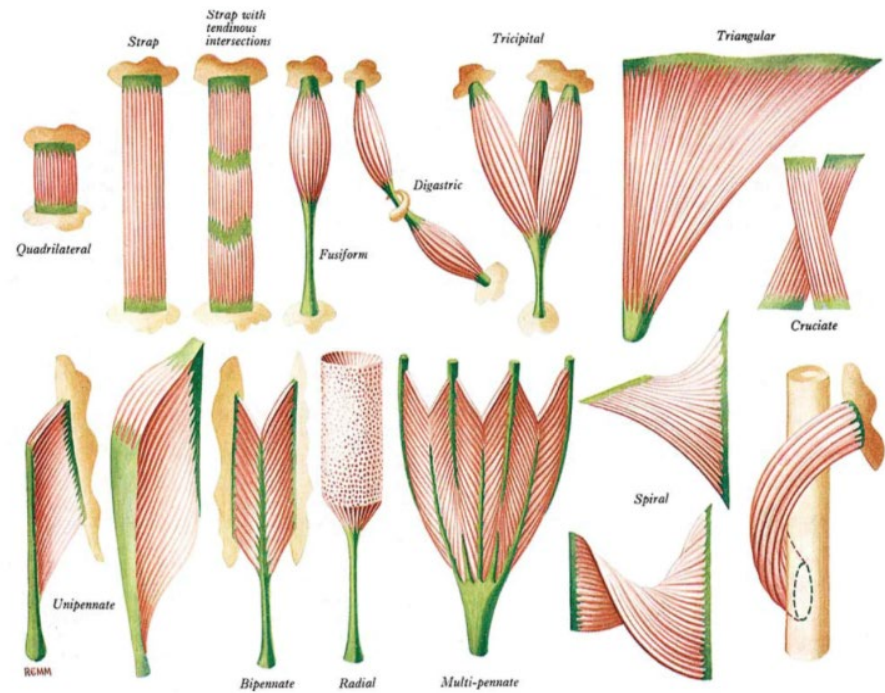
- Type I / TYPE Iia/ type Iib
 - TYPE I – SLOW TWITCH, HIGH AEROBIC CAPACITY, SPEED OF CONTRACTION (110MS), LOW SACROPLASMIC DEVELOPMENT, 10-180 FIBRES PER MOTOR UNIT.
 - TYPE IIA – FAST TWITCH, MODERATE AEROBIC CAPACITY, SPEED OF CONTRACTION (50MS), HIGH SACROPLASMIC DEVELOPMENT, 300-800 FIBRES PER MOTOR UNIT.
 - TYPE IIB – FAST TWITCH, LOW AEROBIC CAPACITY, SPEED OF CONTRACTION (50MS), HIGH SACROPLASMIC DEVELOPMENT, 300-800 FIBRES PER MOTOR UNIT.
- Factors influencing fibre type – GENETICS, TRAINING TYPES (ENDURANCE/PLYO), AGING
- Generally recruitment follows slow to fast.....

Muscle architecture

Majority of muscles in body are pennate and generate More force than their fusiform cousins

Physiologic cross-sectional area (PCSA) and pennation angle determine the amount of force transmitted through M-T complex

Pennation angle refers to angle of orientation between the muscle fibres and tendon



Muscle architecture

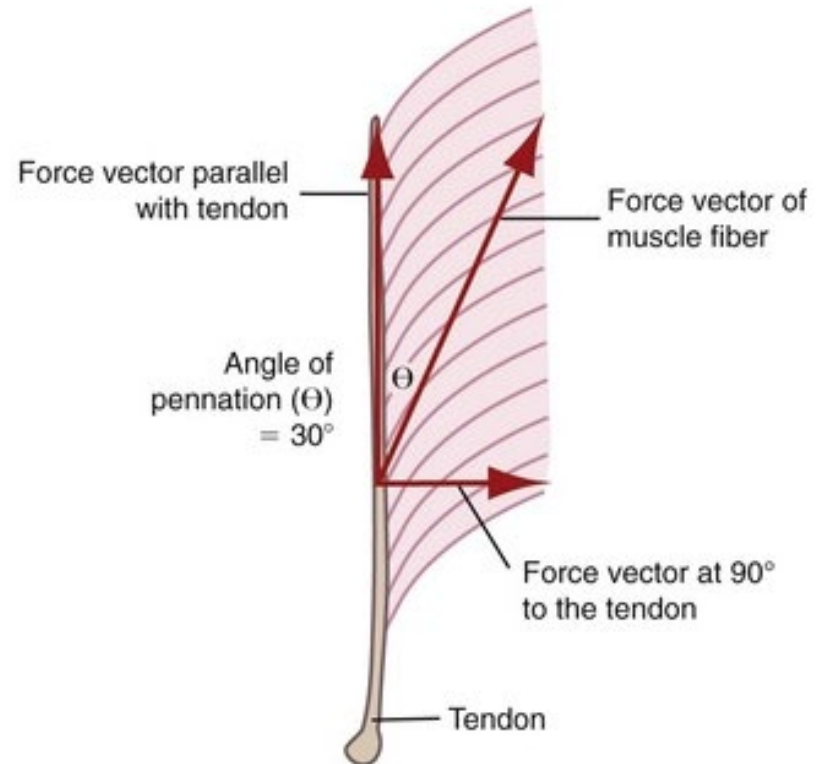
The high PCSA allows for pennate muscles to transmit high forces

If the muscle was directly below the tendon 100% of the force would be transmitted

In the example of Gastrocnemius 86% of the force is transmitted through the achilles tendon

You can workout force vectors by using cosine

The conundrum = PCSA v Angle of Pennation



Length-tension in muscles

Passive Length Tension (PLT)

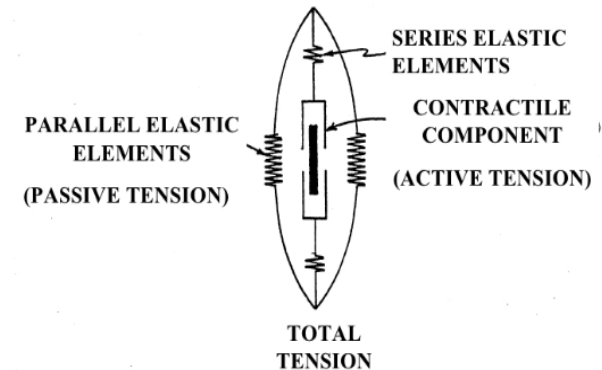
Two components involved

- Series elastic components (titin)
- Parallel elastic components (perimysium, epimysium)

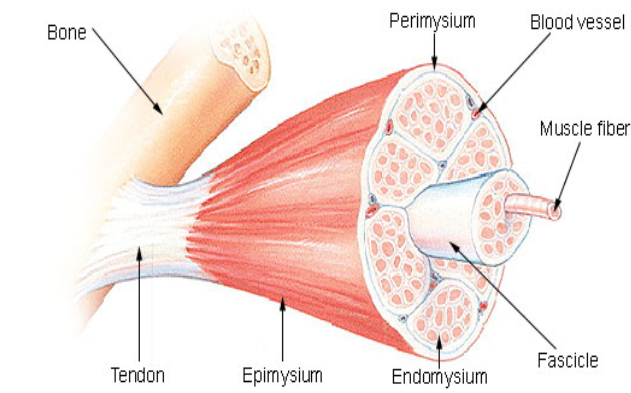
Assists with Movement/Stability

PLT

- slow adaptability
- significant lengthening required
- Ability to store energy (plyos)



Structure of a Skeletal Muscle



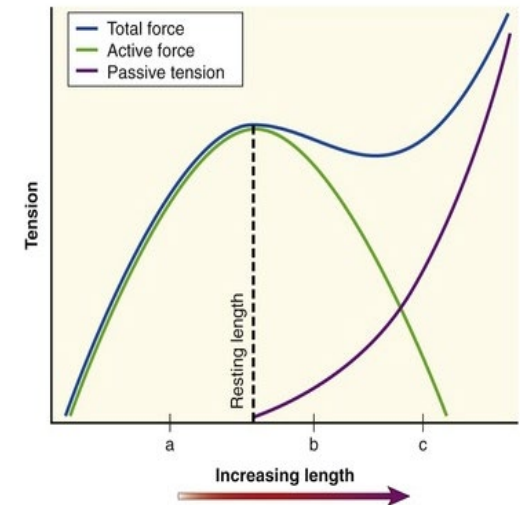
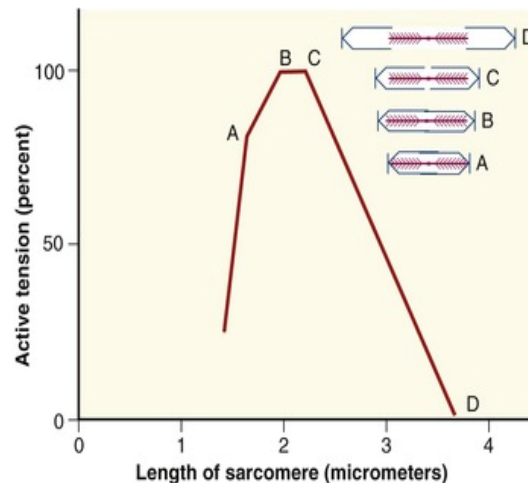
Length-tension in muscles

Active Length Tension (ALT)

Muscle Length is changed by active contraction or passive elongation – alters the overlap between Actin & Myosin

As the muscle length the number of potential cross bridges reduces

PLT and ALT allows for functional versatility (force & length)



Types of contraction

Concentric (lower force)

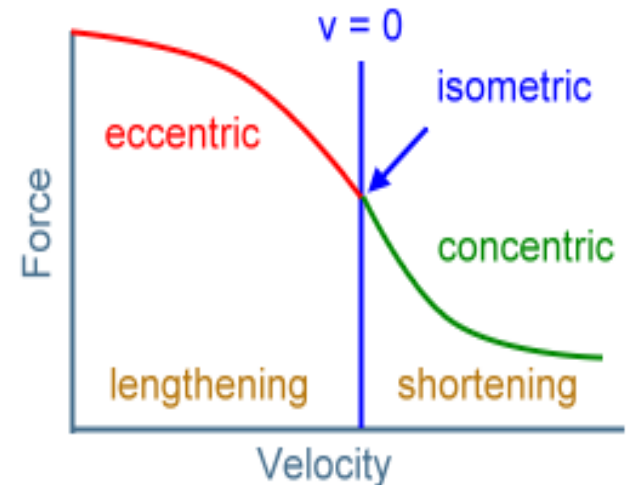
- Force produced inversely proportional to velocity of shortening muscle. High speed leads to low cross bridge formation

Isometric

- Muscle produces most amount of cross bridges

Eccentric (higher force)

- Greater force on cross bridges as pulled apart/ reattached
- Rapid reattachment phase
- PLT produced by the series and parallel elastic properties allows force to be stored and transmitted



Force-Velocity Curve of a Muscle

Skeletal muscle

FATIGUE

ATP provides the energy for the muscle contraction

As stimulus continues the body's ability to replenish ATP results in twitch responses becoming weaker, eventually hitting zero.

Other possible causes are thought to be:

Reduced excitability at neuromuscular junction

Reduced excitability at sarcolemma

Reduced blood flow and O_2

Reduced availability of intra-cellular calcium

Eventually leads to reduced co-ordination and increased injury risk.

Skeletal muscle

ADAPTATION

Lengthening

- With MT unit stretching:
- Addition of sarcomeres to muscle fibres
- In region on myotendinous junction

Strengthening

- Max strength achieved between 20-30yrs
- Cross-sectional area of muscle is greatest
- Resistance training increases myofibrillar diameter

Cross-sectional Area

- female is 75% of male
- Response to resistance training in males via hypertrophy
- Whilst strength gains in females due to increased fibre recruitment

Skeletal muscle

IMMOBILISATION

Marked reductions in muscle strength and atrophy

Loss of strength can be 3-6% per day in the first week

Predominance toward higher proportion of Type II fibres

If immobilised in shortened position then protein degradation is promoted

Resistive exercise can reverse the effects of chronic immobilisation of a limb.

Low intensity and long duration exercise important during the early phases.

Skeletal muscle

ATROPHY

- Atrophy (CSA) rate normally at 50% of the strength loss of the muscle
- CSA reduced due to protein degradation
- Can be prevented by placing muscles under some passive tension
- Isometric activity can maintain of the Type II fibres and can safely reduced atrophic factors

Skeletal muscle

HYPERTROPHY

- Hypertrophy is enlargement of muscle fibres within the muscle: NOT more fibres being created
- Also neurological adaption: recruitment of motor units and synchronisation of muscle activation
- Direct relationship between muscle cross-sectional area and strength

MUSCLE INJURIES

CLASSIFICATIONS AND TYPES

- Contusion – Heavy compressive load usually by direct blow
- Muscle Strain – Excessive load leading leading to overstrain of myofibrils, hence potential strain or possible rupture
- Laceration – epidermal breakage (only 10% of all muscle injuries)

MUSCLE INJURIES

CONTUSIONS

- Intramuscular Contusion
 - Blood pools within intact muscle fascia and increase intramuscular pressure
 - P1 ++ on passive stretch
- Intermuscular Contusion
 - Bleeding from the damaged blood vessels in the muscle
 - Fascia surrounding muscle is also torn so blood can move out of compartment into surrounding area
 - Point tender over area of damage with Bruising +++

MUSCLE INJURIES

MUSCLE STRAINS

Table 2 Classification of acute muscle disorders and injuries

A. Indirect muscle disorder/injury	Functional muscle disorder	Type 1: Overexertion-related muscle disorder	Type 1A: Fatigue-induced muscle disorder
		Type 2: Neuromuscular muscle disorder	Type 1B: Delayed-onset muscle soreness (DOMS)
	Structural muscle injury	Type 3: Partial muscle tear	Type 2A: Spine-related neuromuscular Muscle disorder
		Type 4: (Sub)total tear	Type 2B: Muscle-related neuromuscular Muscle disorder
B. Direct muscle injury			Type 3A: Minor partial muscle tear
			Type 3B: Moderate partial muscle tear
			Subtotal or complete muscle tear
			Tendinous avulsion
		Contusion	
		Laceration	

MUSCLE INJURIES

MUSCLE STRAINS

Table 3 Comprehensive muscle injury classification: type-specific definitions and clinical presentations

Type	Classification	Definition	Symptoms	Clinical signs	Location	Ultrasound/MRI
1A	Fatigue-induced muscle disorder	Circumscribed longitudinal increase of muscle tone (muscle firmness) due to overexertion, change of playing surface or change in training patterns	Aching muscle firmness. Increasing with continued activity. Can provoke pain at rest. During or after activity	Dull, diffuse, tolerable pain in involved muscles, circumscribed increase of tone. Athlete reports of 'muscle tightness'	Focal involvement up to entire length of muscle	Negative
1B	Delayed-onset muscle soreness (DOMS)	More generalised muscle pain following unaccustomed, eccentric deceleration movements.	Acute inflammatory pain. Pain at rest. Hours after activity	Oedematous swelling, stiff muscles. Limited range of motion of adjacent joints. Pain on isometric contraction. Therapeutic stretching leads to relief	Mostly entire muscle or muscle group	Negative or oedema only
2A	Spine-related neuromuscular muscle disorder	Circumscribed longitudinal increase of muscle tone (muscle firmness) due to functional or structural spinal/lumbopelvic disorder.	Aching muscle firmness. Increasing with continued activity. No pain at rest	Circumscribed longitudinal increase of muscle tone. Discrete oedema between muscle and fascia. Occasional skin sensitivity, defensive reaction on muscle stretching. Pressure pain	Muscle bundle or larger muscle group along entire length of muscle	Negative or oedema only
2B	Muscle-related neuromuscular muscle disorder	Circumscribed (spindle-shaped) area of increased muscle tone (muscle firmness). May result from dysfunctional neuromuscular control such as reciprocal inhibition	Aching, gradually increasing muscle firmness and tension. Cramp-like pain	Circumscribed (spindle-shaped) area of increased muscle tone, oedematous swelling. Therapeutic stretching leads to relief. Pressure pain	Mostly along the entire length of the muscle belly	Negative or oedema only

MUSCLE INJURIES

3A	Minor partial muscle tear	Tear with a maximum diameter of less than muscle fascicle/bundle.	Sharp, needle-like or stabbing pain at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain	Well-defined localised pain. Probably palpable defect in fibre structure within a firm muscle band. Stretch-induced pain aggravation	Primarily muscle-tendon junction	Positive for fibre disruption on high resolution MRI*. Intramuscular haematoma
3B	Moderate partial muscle tear	Tear with a diameter of greater than a fascicle/bundle	Stabbing, sharp pain, often noticeable tearing at time of injury. Athlete often experiences a 'snap' followed by a sudden onset of localised pain. Possible fall of athlete	Well-defined localised pain. Palpable defect in muscle structure, often haematoma, fascial injury Stretch-induced pain aggravation	Primarily muscle-tendon junction	Positive for significant fibre disruption, probably including some retraction. With fascial injury and intermuscular haematoma
4	(Sub)total muscle tear/tendinous avulsion	Tear involving the subtotal/complete muscle diameter/tendinous injury involving the bone-tendon junction	Dull pain at time of injury. Noticeable tearing. Athlete experiences a 'snap' followed by a sudden onset of localised pain. Often fall	Large defect in muscle, haematoma, palpable gap, haematoma, muscle retraction, pain with movement, loss of function, haematoma	Primarily muscle-tendon junction or Bone-tendon junction	Subtotal/complete discontinuity of muscle/tendon. Possible wavy tendon morphology and retraction. With fascial injury and intermuscular haematoma
Contusion	Direct injury	Direct muscle trauma, caused by blunt external force. Leading to diffuse or circumscribed haematoma within the muscle causing pain and loss of motion	Dull pain at time of injury, possibly increasing due to increasing haematoma. Athlete often reports definite external mechanism	Dull, diffuse pain, haematoma, pain on movement, swelling, decreased range of motion, tenderness to palpation depending on the severity of impact. Athlete may be able to continue sport activity rather than in indirect structural injury	Any muscle, mostly vastus intermedius and rectus femoris	Diffuse or circumscribed haematoma in varying dimensions

MUSCLE INJURIES

MUSCLE STRAINS

When muscle-tendon-bone units are pulled to failure, tears could occur at:

- Bone-tendon junctions
- Muscle Belly
- Myotendinous junction (McMaster 1933)
- Myotendinous junction (Garrett et al, 1988)
- Within muscle cell approx 0.5mm from myotendinous junction (Tidball & Chan, 1989)

MUSCLE INJURIES

SKELETAL MUSCLE REPAIR

- Healthy skeletal muscle has substantial ability to repair itself
- Muscle regeneration
 - Sateillite Cells
 - Fuse with adjacent myofibres to repair and regenerate muscle tissue
 - Restore and replace muscle cells routinely damaged by activity (Caplan et al, 1988)
 - Replace injured muscle tissue with new muscle tissue
 - When the mass of damaged muscle is larger than 3 g (0.1 oz) muscle healing occurs through scar tissue and goes through the normal healing sequence

MUSCLE INJURIES

REGENERATION OF CONTRACILE ELEMENTS

- Regeneration similar regardless of mechanism (contusion or strain)
- Activation of satellite cells that are normally passive and are found in between the basal lamina and the sarcolemma
- More satellite cells in Type I fibres
- Satellite cells are self-proliferating
- Disruption of basal lamina activates satellite cells mitosis
- Blood vessel disruption

MUSCLE INJURIES

REGENERATION OF CONTRACILE ELEMENTS

- Trauma or strain (satellite cell activated: aka Myofibroblasts)
- Muscle fibres that are torn RETRACT
- Gap is formed
- At the ends in tact sarcomeres HYPERCONTRACT
- Myoblasts attracted to the ends of the basal lamina, fuse and grow into the gap.
- Scar tissue laid down in the gap

MUSCLE INJURIES

REGENERATION OF CONTRACILE ELEMENTS

- Myotubes mature in to myofibres (14/7) and reunite?
- Mini-musculotendinous junction where myotubes attach to scar tissue?
- Immobilisation increases 'interlacing' of myotubes with granulation/scar tissue (Lehto et al 1985)
- Scar tissue decreases over months, may bring myofibres edges together (fuse?)
- Aarimaa et al (2004) maintaining close proximity of muscle fibres after injury sign. reduced presence of new junctions. Fibre regeneration is greatly enhanced , notable improvement of tissue strength

MUSCLE INJURIES

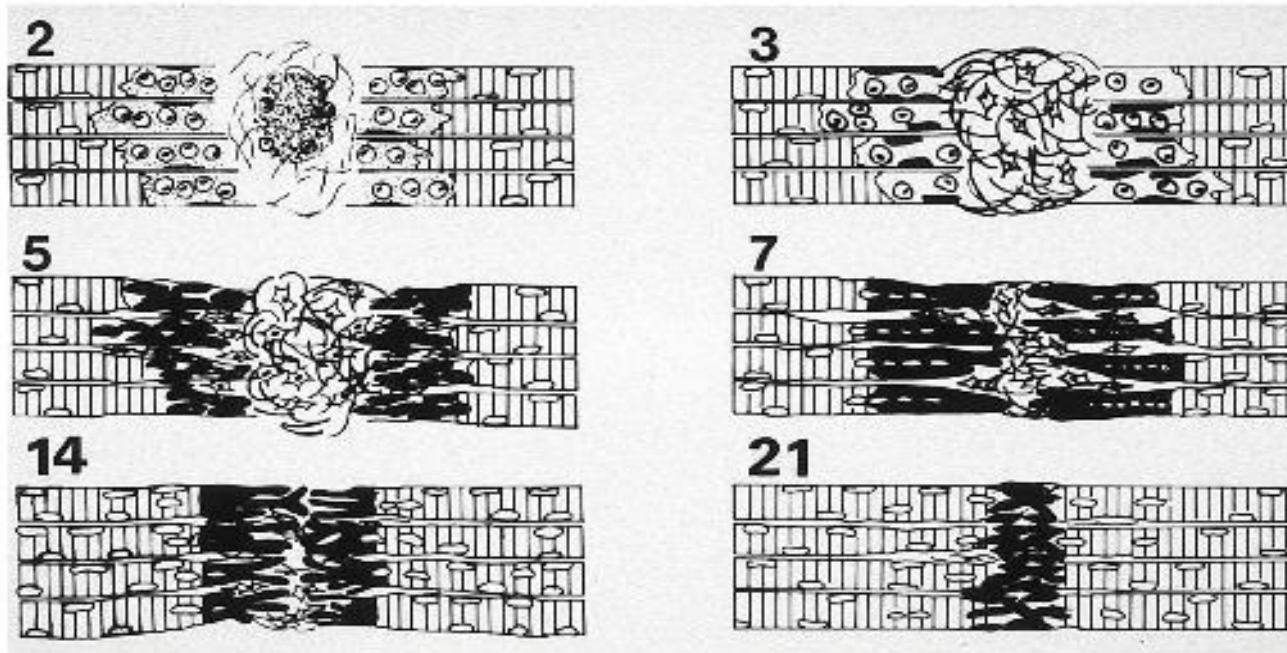


Figure 2. A schematic illustration of the healing skeletal muscle. Day 2: the necrotized parts of the transected myofibers are being removed by macrophages while, concomitantly, the formation of the connective tissue scar by fibroblasts has begun in the central zone (CZ). Day 3: satellite cells have 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.

Jarvinen *et al.*(2005).
Muscle injuries
biology and
treatment. *The
American
Journal of
Sports Medicine*,
33, 5, pg. 747

MUSCLE INJURIES

Time	Activity
6/24	Fragmentation of injured fibres begin Macrophages appear
1-4/7	Fibroblasts appear At 2d macrophages become most dominant inflammatory cell (removal of necrotic tissue)
7/7	5-7/7 number of leucocytes and macrophages decreases considerably 7/7 myotubes have grown in between damaged basal laminae, new basal lamina is apparent Collagen/scar tissue is seen in large muscle injuries in the central zone in between basal lamina
8-11/7	Tensile strength reaches near normal
10/7	Large numbers of phagocytes : primary macrophages are seen at the injury site
14/7	Maturation of myotubes into myofibres complete
18/7	Cross-striated muscle fibres appear
6/52 – 6/12	Contraction ability is 90% of normal , scar tissue volume decreases, myofibres may fuse

HEALING: SKELETAL MUSCLE

MOBILISE EARLY

- Strengthen tissue more quickly
- May prevent myofibrils from joining
- More scar tissue in the gap
- Mini-musculotendinous jt: predispose to recurring injury
- Scar tissue reduces extensibility of muscle

IMMOBILISE EARLY

- Limit scar tissue formation
- Regenerating myofibrils penetrate more easily
- Normal muscle performance restored
- Potential for atrophy

Rehabilitation Implications

- Don't stretch for first 7-10/7
- Immobilise in shortened position to encourage myotubes infill.
- Ice and compress (15-20mins every 30-60mins)
- Continue with intermittent ice for 6 hours
- When ready (pain free)
 - Isomet
 - Concentric
 - Eccentric
- Maintain CV fitness without compromising the injury
- Ensure biomechanical factors are worked on during initial phases as allowed
- BEWARE of Myositis Ossificans – Bone growth in muscle tissue

SUMMARY

- Classification of muscle injuries
- HUGE regenerative capacity if managed well
- DO NOT STRETCH INJURED TISSUE
- Mobilise to pain free limits
- Be aware of complications