BASIC SCIENCE OF THE SKELETAL MUSCLES

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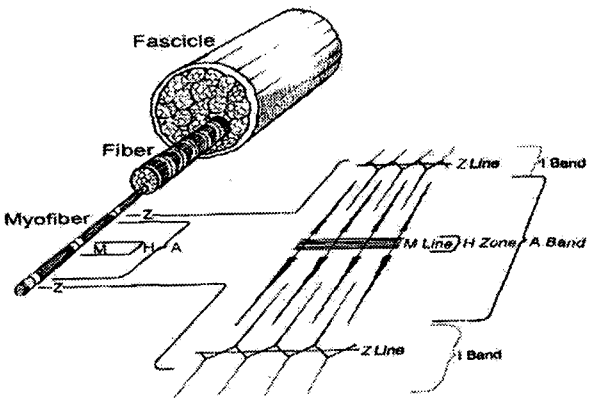
Introduction

-40%~45% of total B.W.
-Consist of m.cells. organized network of nerve, blood vessel & extracellular connective tissue.
-Function
-Support & protect the structure against injury
-Generate force producing joint movement & locomotion
-Maintain posture, stabilize joints & generate heat



Schematic drawing of the structural design of human skeletal muscle.

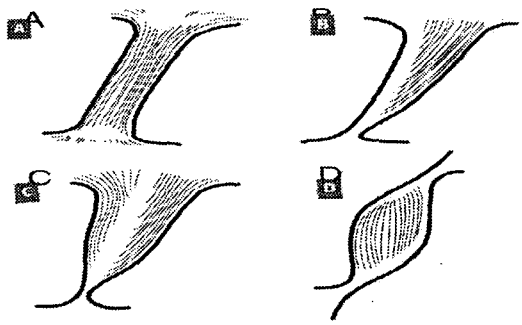
Gross Structure

-Originate from bone or dense CT(connective tissue) & tendon of origin pass distally to a tendon of insertion.
-muscle tendon unit cross one or more joint

one joint muscle	two joint muscle (phasic)
close to bone decreased speed of contraction increase strength	superficial to skin greater speed of shortening greater capacity for length change
soleus	gastrocnemius rectus femorris

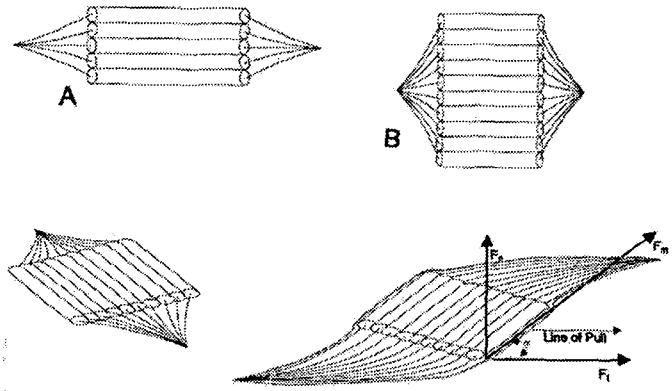
structure

muscle fiber - basic structural unit of skeletal muscle
sarmomere - smallest contractile unit of fiber
fascicle - small bundle of muscle fiber
fiber arrangement
1) fusiform - great ROM 2) parallel -powerful 3) unipennate
4) bipennate 5) multipennate



Muscle fiber architecture. A, Parallel. B, Unipennate. C, Bipennate. D, Fusiform.

Fiber arrangement in muscle is an important determinant of it' s functional and contractile properties (length and force)



The effects of muscle architecture on force development and length change. **Top**, the length of A is twice that of B; the cross-sectional area of A equals that of B; the maximum force of A is one-half that of B and the maximum length change of A is twice that of B. **Bottom left**, The force is diminished only by a small factor when fibers are arranged in a pennate fashion. **Bottom right**, The effect of fiber angle pennation on whole-muscle force. (a = angle of pennation ; Fm = muscle force, Fn = normal component; Ft = tangential component.

In tendon transfer of another muscle tendon unit, transferred muscle has a tendon with suitable size and length.

Myofibrillar proteins

−4 major proteins

1. myosin(55%)
2. actin(20%)
3. tropomyosin(7%)
4. troponin(2%)

Ultra - structure

−banded arrangement of skeletal muscle is due to the repetition of dark and light bands.

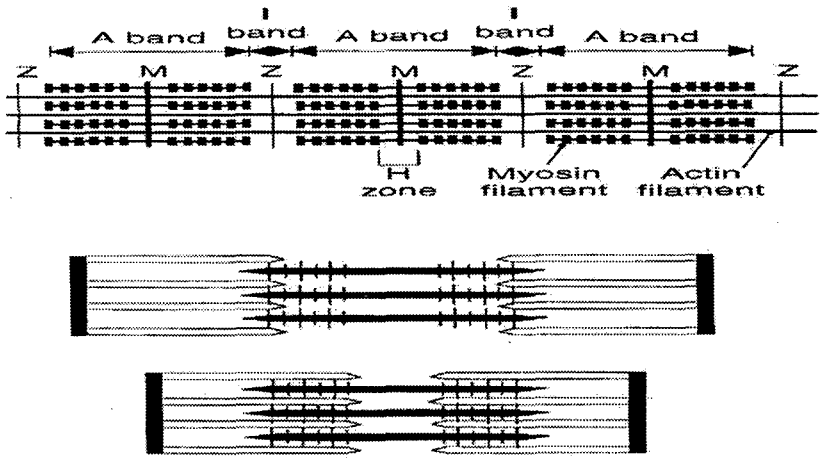
−dark bands : thick filament, myosin ; A band

−light bands : thin filament, actin ; I band

H zone in anisotropic band

Z line in isotropic band

—sarcomere : basic unit of skeletal muscle between Z line



Schematic drawing indicating the sliding of thick and thin filaments that occurs when a muscle is stretched. Note the constancy of the lengths of the thick and thin filaments

Guiding hypothesis for muscle shortening call for the cross - bridges from the thick filament to reach out and attach to the thin filament by hydrolysis of ATP and calcium.

Motor unit

single alpha motoneron axon and muscle fiber it' s innervate

Muscles fiber types differences

Table 1
Characteristics of Human Skeletal Muscle Fiber Types

	Type I	Type IIA	Type IIB
Other Names	Red, slow twitch (ST) Slow oxidative (SO)	White, fast twitch (FT) Fast oxidative glycolytic (FOG)	Fast glycolytic (FG)
Speed of contraction	Slow	Fast	Fast
Strength of contraction	Low	High	High
Fatigability	Fatigue-resistant	Fatigable	Most fatigable
Aerobic capacity	High	Medium	Low
Anaerobic capacity	Low	Medium	High
Motor unit size	Small	Larger	Largest
Capillary density	High	High	Low

Orthopaedic Basic Science : American Academy of Orthopaedic Surgeons

Physiology of muscle cell activity

electrical impulse for axon
motor end plate
↓
chemical transmission at the synapse
↓
electrical potential in muscle membrane
↓
transverse tubule
↓
calcium release for sarcoplasmic reticulum
↓
bind thin filament
↓
confimatory change between thick and thin filament by hydrolysis of ATP
↓
cross bridge cycle
↓
transport of cacium into longitudinal tubule

Correlation of fiber type with performance

Endurance athletes (eg. distant runner) has significant higher percentage of type I fiber	non endurance athletes (eg. sprinter) has significant percentage of type II fiber

(Gollnick, 1972; Thorstensson; 1976)

Adaptability of fiber types

-plasticity of skeletal muscle under physiologic overloading result in adaptation of all component of motor unit
-physiologic overload including exercise training, hypergravity stress, cross reinnervation, electrical stimulation, tyrotoxicosis. compensation

hypertrophy

Training effect on muscles

Endurance training (aerobic training)

−Endurance excercise → activation of large m. groups
→ generate high metabolic overload.
→ adaptation of resperatory & circulatory transport and enzymatic capacity of muscle

−Endurance training can double the oxidative capacity of skeletal muscle, a change in the percentage of type I & II fiber and marked increase m. capillary density & mitochondria (Saltin & Gollnick, 1972)

Anaerobic(Sprint or power) training

−exercise of a high intensity that last a few seconds to 2 min require metabolic support from anaerobic pathways(anaerobic glycolysis).

−several adaptations are increased stored phosphagens, increased enzyme controlling glycolysis such as phosphofructokinase and succinate DHase in fast-twitch muscle fibers.

Strenth training

−high force low repetition training result in an increase in m. strength & cross-section area due to m. hypertrophy (increase size, increase contractile protein, esp. myosin) and alteration of CNS firing of motor neuron

Muscle injury and Repair

−regeneration begin with the satellite cell activated with a host growth factor and cytokine.

−proliferation of satellite cell transformed into myotube & m. fiber.

−m. laceration by sharp trauma
; healed by dense CT scarring which was seen with a few muscle fiber

; in midbelly laceration, distal isolated m. fragnent was denervated from motor poont

; 40% of mean grip strength was recovered when repairing laceration at the proximal muscle by tendon graft (Garrett, 1984)

—m. contusion by sports

; inflammation reactive & hematoma leading scar formation with dense CT follows regeneration of muscle

; In mobilized muscle, greater inflamation, more scar formation, faster recovery of tensile strength

; sever trauma to muscle injury may result in bone formation (myositis ossifications) at periosteum. bone or CT (D/D osteogenic sarcoma).

Indirect muscle strain injury

—complete m. tears

- failure occurs within the m. fiber in a few millimeter of myotendinous junction because the terminal sarcomere near the myotendious junction are stiffer than the middle sarcomere of m. fiber
- m. strain occur in the setting of powerful eccentric m. activity (eg. quadriceps)

—incomplete m. tear

- common in myotendinous junction
- frequent in hamstring. rectus femrris. gastrocnemius which cross 2 joints (extensive lenghth muscle)

—m. cramps

- common in gastrocnemius complex, hamstring, abdominal m. during exercise
- onset follows contraction of shorten muscle
- origination for single fascilation spread throughout muscle arized f가m hyper excitable motoneuron in the spinal cord
- related with electrolyte imbalance (excessive sweating , decrease sodium), dehydration & m. fatigue

Tx.

interrupted by forceful streching of involved m. or activation of antagonistic muscle
correction of electrolyte balance
quimine sulfate, chloroquine phosphate are beneficial

Immobilization & Disuse

-prolonged immobilization change in m. size, structure, physiological properties & metabolic properties
-muscle atrophy & wt loss in early phase is loss of strength, easy fatigability with decrease an aerobic metabolic pathway
-immobilization in a stretched muscle position leads to a less pronounced changes
-The rate of protein synthesis in muscle decrease within hours of the initiation of immobilization due to decreased insulin sensitivity and increase corticosteroid.

Muscle stretching & viscoelasticity

-efficacy of stretching in injury prevention and rehabilitation or in the enhancement of performance are well known.
-chronic stretching in growth
-acute stretching for increased ROM leading stress relaxation by viscoelastic properties of CT and decreased stiffness.
-temperature effect: cold muscle is stiffer than warm muscle.
-common stretching routines usually advocate slow static stretching of the muscle tendon unit.