Sarcopenia and Osteopenia in Athletes with Acute and Chonic ACL Deficiency

Christos K. Yiannakopoulos, MD

Orthopaedic Surgeon

Athens, Greece

ACL Biomechanics

- ACL prevents anterior tibial translation

ACL Tear : A Silent Epidemic

ACL Tear Incidence (USA)

30/100.000/ year = 75.000/year

Reconstructions (USA)

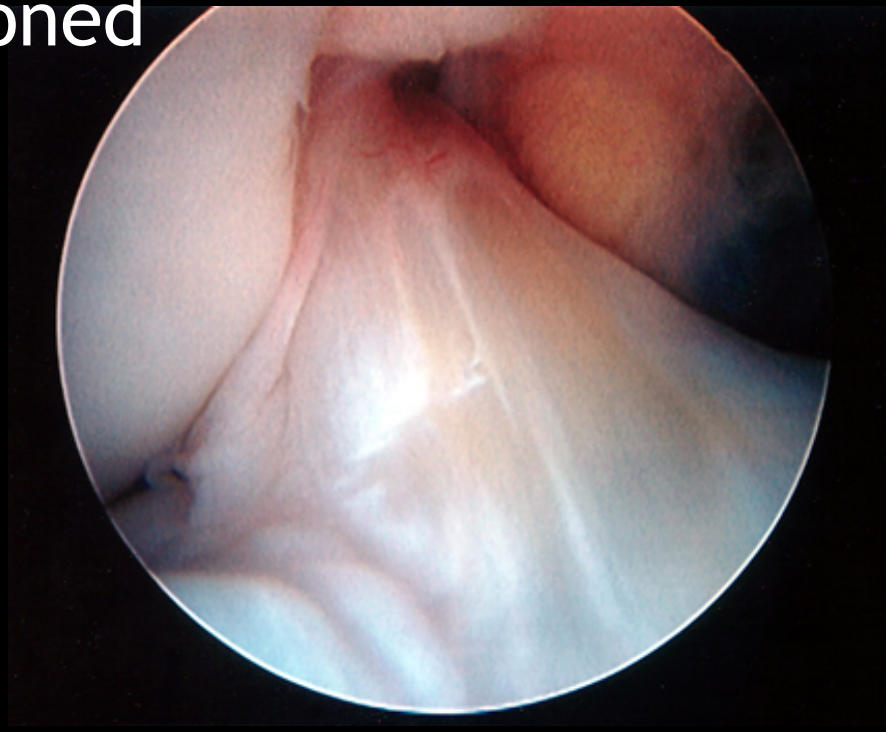
105.000/year

Success Rate 85%

15000 failures/year

Epidemiology

- Increasing incidence
- Females > males
- Combined injuries common
- Conditioned vs. unconditioned



What happens after ACL injury?

A patient with acute ACL rupture may in the following years:

- cope with the injury
- adapt to it
- or become non-coper, a patient group which necessitates ACL reconstruction.

ACL deficient patients

17% functional copers

45% adapters

38% non-copers

Button K et al. Classification of functional recovery of anterior cruciate ligament copers, non-copers, and adapters. Br J Sports Med. 2006; 40(10):853-859.

Although many patients cope with the injury only 5% of those with acute ACL injury involved in high demand activities return to the pre-injury level

Button K, van Deursen R, Price P. Classification of functional recovery of anterior cruciate ligament copers, non-copers, and adapters. Br J Sports Med. 2006; 40(10):853-859.

ACL rupture leads to:

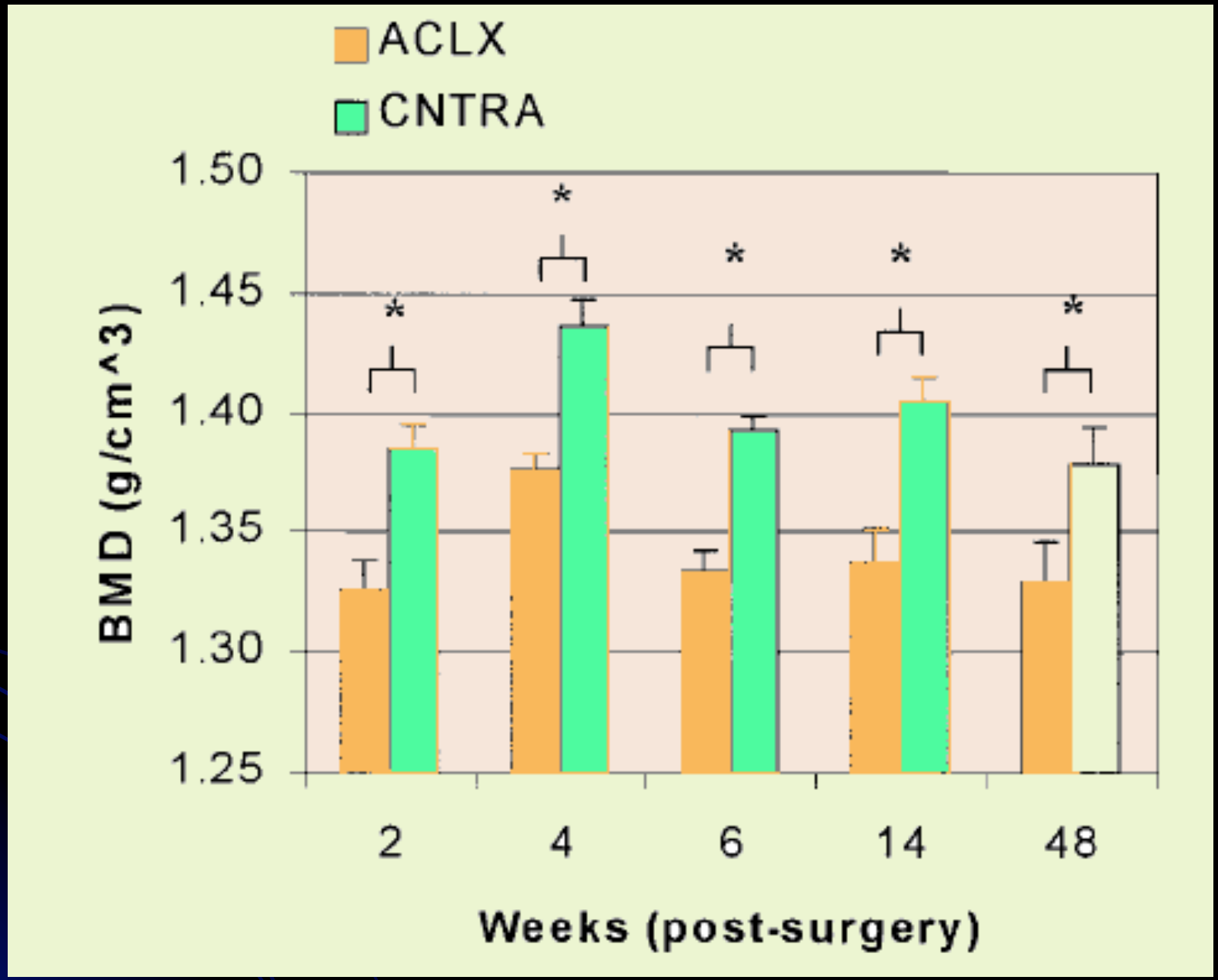
- Increased laxity
- Proprioception deficit
- Decreased muscle strength
- Sarcopenia
- Osteopenia
- Increased incidence of secondary injuries
- Secondary osteoarthritis

The loss of knee stability elicits a cascade of events leading to loss of anatomical and functional integrity in the tissues in and around the knee joint eventually leading to loss of function and knee osteoarthritis.

Currently ACL reconstruction does not:

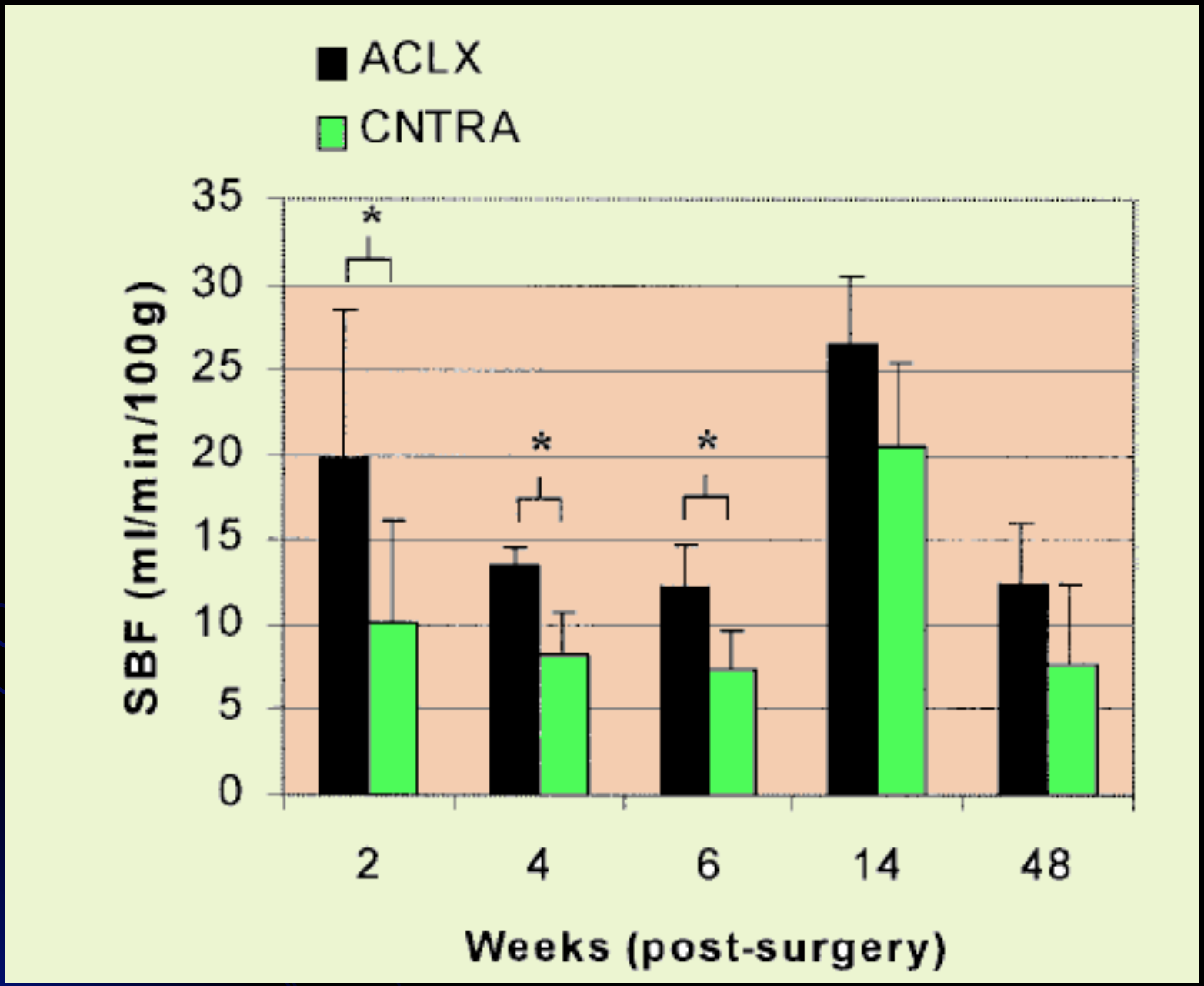
1) Restore normal proprioception of the ACL
2) Reproduce the multi-stranded structure of the ACL
3) Restore normal knee joint kinematics
4) Preserve the articular integrity of the knee joint

Early decrease and anatomical heterogeneity in the BMD around the ACL deficient knee has been reported both in animals and humans.



Shymkiw, 2001

Standardized blood flows of ACLX and Cntra limbs



Shymkiw, 2001

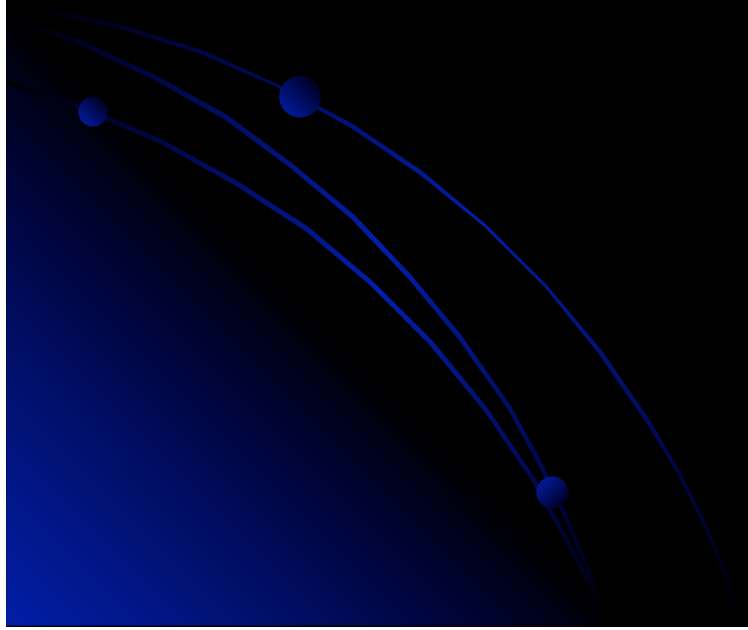
ACL rupture increases blood flow and may stimulate osteoclasts to increase bone resorption, which is more pronounced in the metabolically more active cancellous bone.

Shymkiw RC et al. Physiological and mechanical adaptation of periarticular cancellous bone after joint ligament injury. J Appl Physiol. 2001;90:1083-1087.

Bone loss in patients with ACL tear treated conservatively is minor (2-3%) but after surgical reconstruction bone loss is greater than 15-20% with limited recovery.

[Rittweger, 2005]

BMD is further reduced
following ACL reconstruction



- MCL and ACL injuries treated operatively
- All patients were immobilized for 6-7 weeks postoperatively
- DEXA at various sites in the lower extremities
- On avg. 10 years after the injury

Kannus P et al. A cruciate ligament injury produces considerable, permanent osteoporosis in the affected knee. J Bone Miner Res 1992; 7:1429-1434.

- MCL-operated patients did not have side-to-side difference in bone density unlike ACL-operated patients.

- The average bone loss in the injured limb was 6% in the distal femur, 9% in the patella, and 3.3% in the proximal tibia.

- A positive association between bone density and functional knee scores was found.

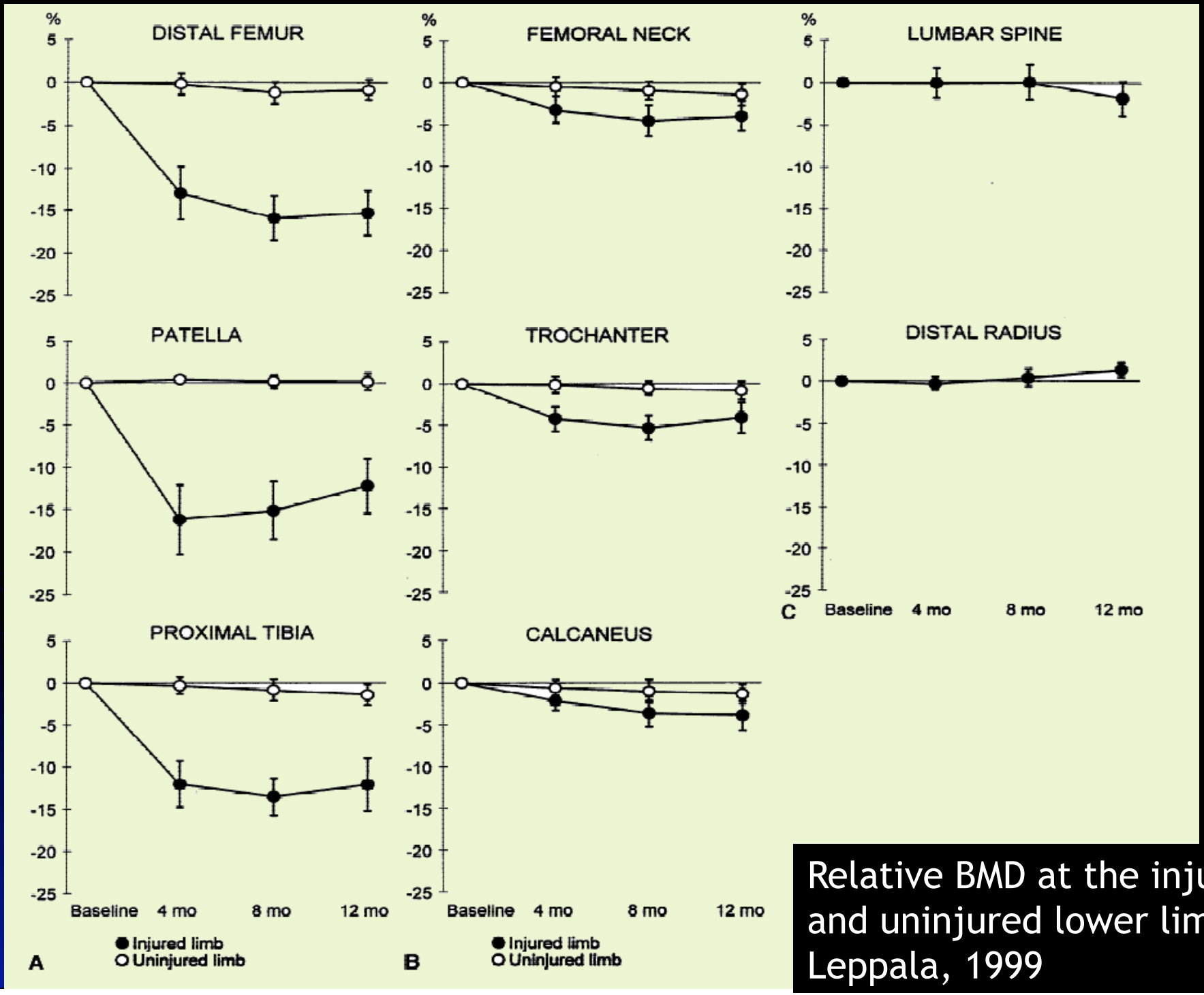
Kannus P, Sievanen H, Jarvinen M, Heinonen A, Oja P, Vuori I. A cruciate ligament injury produces considerable, permanent osteoporosis in the affected knee. J Bone Miner Res 1992; 7:1429-1434.

- 1-year prospective follow-up study
- ACL-deficient patients treated surgically or conservatively
- DEXA
- BMD of the injured extremity and the lumbar spine

Leppälä J et al. Effect of anterior cruciate ligament injury of the knee on bone mineral density of the spine and affected lower extremity: a prospective one-year follow-Up study. Calcif Tissue Int. 1999; 64:357-63.

- Surgical treatment results in significant bone loss in the affected knee.
- Bone loss is less significant at the patella and the proximal tibia.

Leppälä J et al. Effect of anterior cruciate ligament injury of the knee on bone mineral density of the spine and affected lower extremity: a prospective one-year follow-Up study. Calcif Tissue Int. 1999; 64:357-63.



Relative BMD at the injured and uninjured lower limbs, Leppala, 1999

The early loss of bone mass, in conjunction with vascular changes throughout the joint, may initiate damage and adaptation in the articular cartilage.

Osteopenia following ACL injury - 1

i) immobilization and loss of function

ii) reduced activity and bone loading

iii) muscle atrophy and reduced bone loading

iv) increased laxity, altered kinematics and gait adaptation

Osteopenia following ACL injury - 2

v) increased local blood flow and bone turnover especially on the cancellous bone

vi) overloading of the uninjured limb

vii) harvesting of autologous tendon grafts with inability of the muscles to exert their action on the bone

viii) surgically removed bone for tunnel drilling.

EVALUATION OF THE EFFECT OF ACUTE AND CHRONIC ACL TEARS ON THE CALCANEUS USING ULTRASOUND DENSITOMETRY

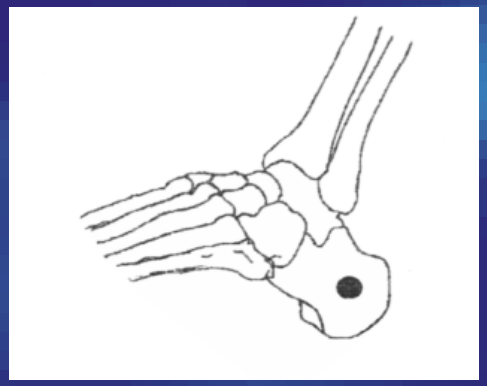
C.K. Yiannakopoulos, E. Antonogiannakis,
G. Trovas, G. P. Lyritis

Laboratory for the Research of the Musculoskeletal System,
University of Athens

2nd Orthopaedic Department, Athens General Army Hospital

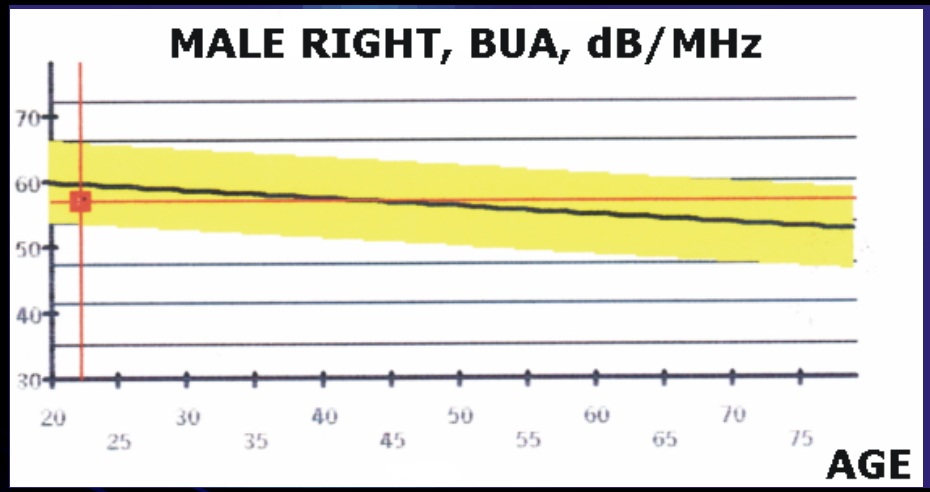
Patients - Methods

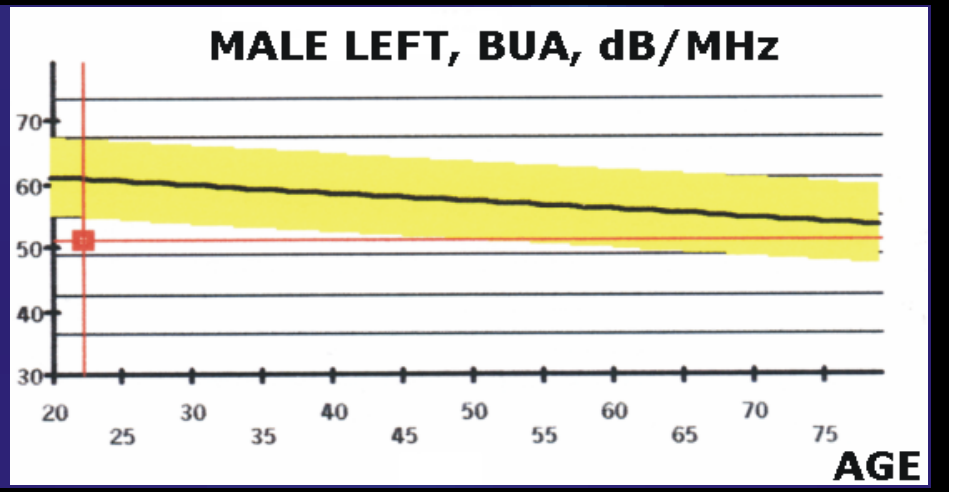
- ✓ 32 young male patients
- ✓ 13 acute and 19 chronic tears
- ✓ Lysholm, Tegner και IKDC scores
- ✓ QUS



- ✓ speed of sound, SOS
- ✓ broadband ultrasound attenuation, BUA
- ✓ both calcanei

Broadband Ultrasound Attenuation, BUA





Results

Acute Tears

	SOS m/sec	BUA dB/mHz
injured	1555.109±22.71	56.14±3.85
normal	1549.976±15.99	54.86±5.52

p=0.017

Results

Chronic Tears

	SOS m/sec	BUA dB/mHz
injured	1534.208±39.41	51.41±3.66
normal	1563.126±12.84	58.13±4.55

p=0.00012

Sarcopenia

Sarcopenia

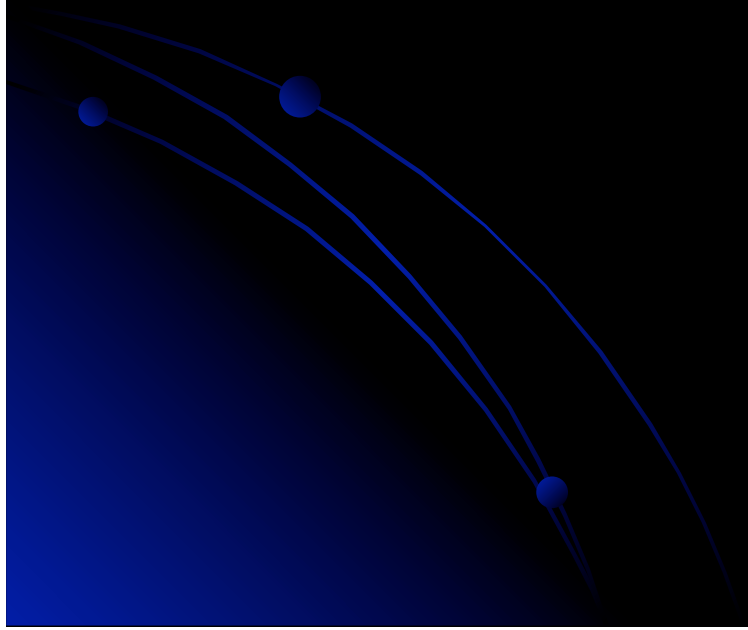
Loss of skeletal muscle mass and strength with aging or injury.

A key factor in the process of disablement.

Sarcopenia is associated with:

- Decreased lower extremity performance
- Functional impairment
- Falls
- Physical disability
- Frailty

Humans lose about 20–40% of both skeletal muscle mass and strength from 20 to 80 years of age.



Pathogenesis of sarcopenia

Multifactorial

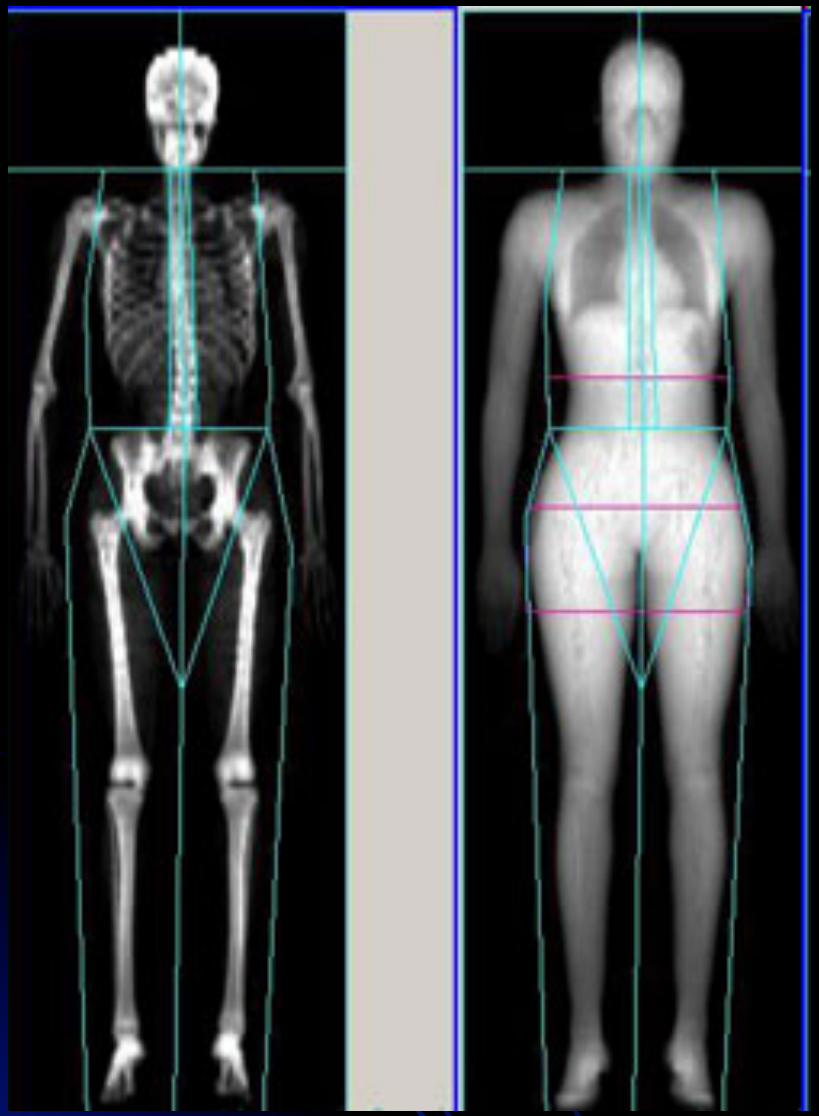
Attributed to:

- Undernutrition
- Oxidative stress
- Inflammations
- Endocrine changes
- Inactivity
- Early growth

Appendicular lean mass as determined by:

- DEXA scanning
- Skeletal muscle index [bioelectrical impedance analysis]
- Muscle CSA

DEXA scans

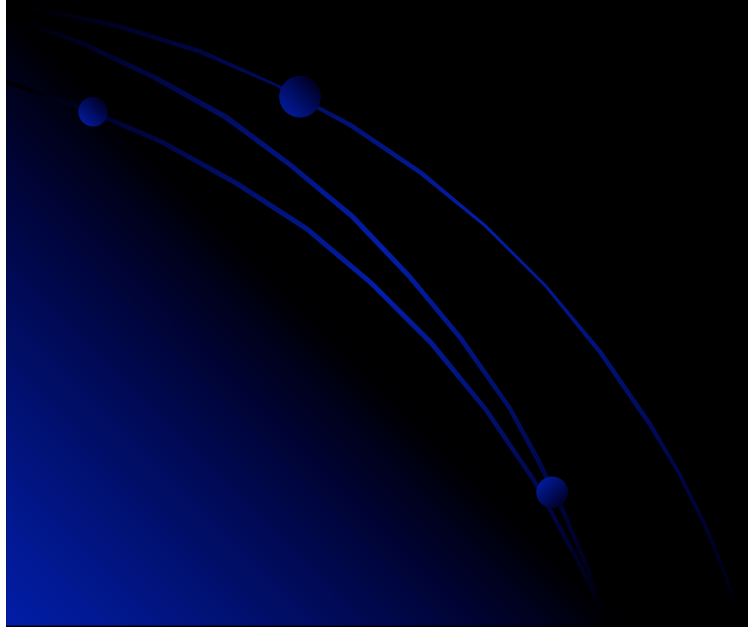


body composition assessment for the entire body

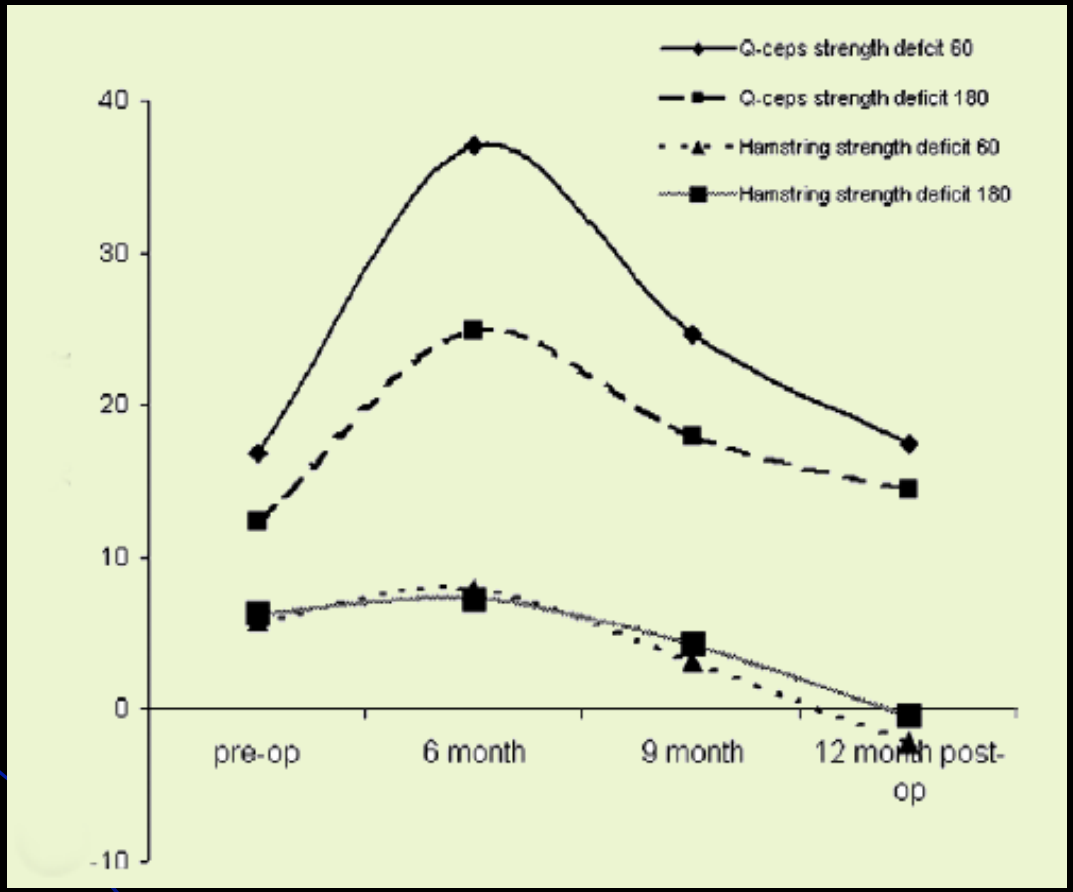
"compartment analysis"

SMM (skeletal muscle mass) index(kg/m2)
<2 SD below mean or <5.45 for women / <7.26 for men

Patients still have permanent muscle weakness and functional deficits after ACL reconstruction



Quadriceps strength deficit vs time after ACL reconstruction



Considerably increased after ACL reconstruction, and strength is regained after 6 months.
A persistent deficit is seen compared with preoperatively.

The underlying mechanism of quadriceps weakness in patients with ACL deficiency is loss of proprioceptive feedback from ACL mechanoreceptors.

The hamstring muscles are ACL agonists preventing anterior tibial translation while the quadriceps acts as antagonist to the ACL assisting tibial translation.

[Konishi]

Osteopenia and Sarcopenia in Acute and Chronic ACL injury.

A peripheral quantitative computed tomography study.

C. Yiannakopoulos et al.

11 patients with acute ACL injury

14 patients with chronic ACL injury

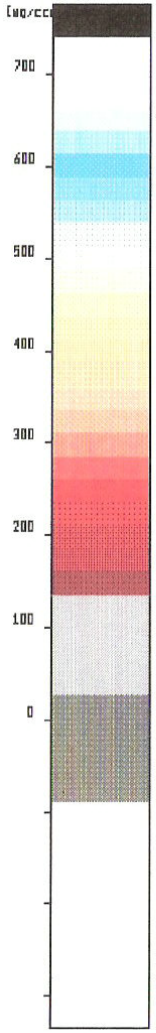

XCT 3000

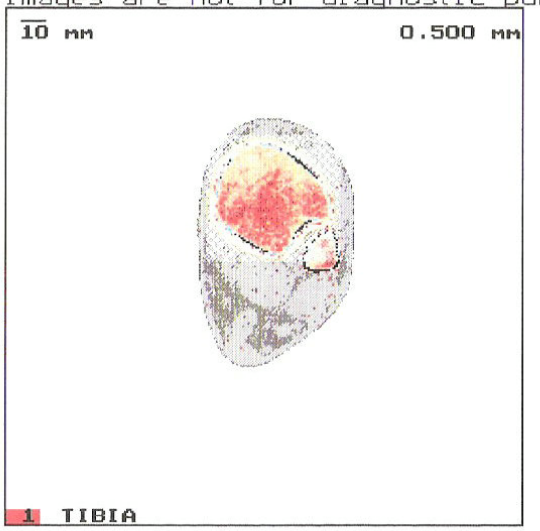
17.01.2005 16:27 STRATEC XCT-3000 pQCT ™ 5.50 D

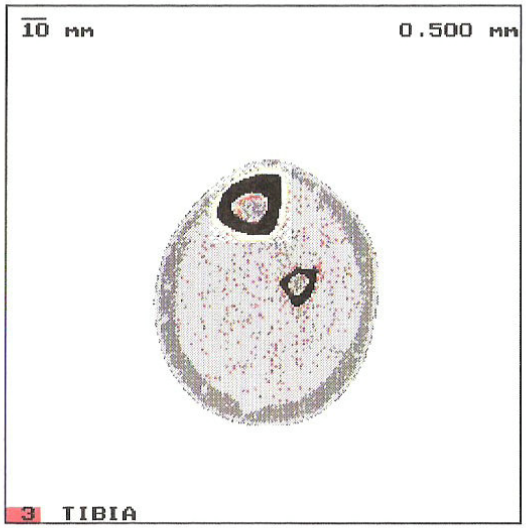
Name : DRIVAKOS GEORGIOS
CT No. : 0020820R Slice: 4/ 6
Birth : 29.04.1985 Pat.#:20496

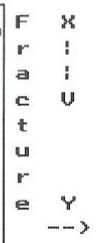
Object length : 440.0 mm female
Scan date : 02.11.2004 Age : 19

Images are not for diagnostic purposes









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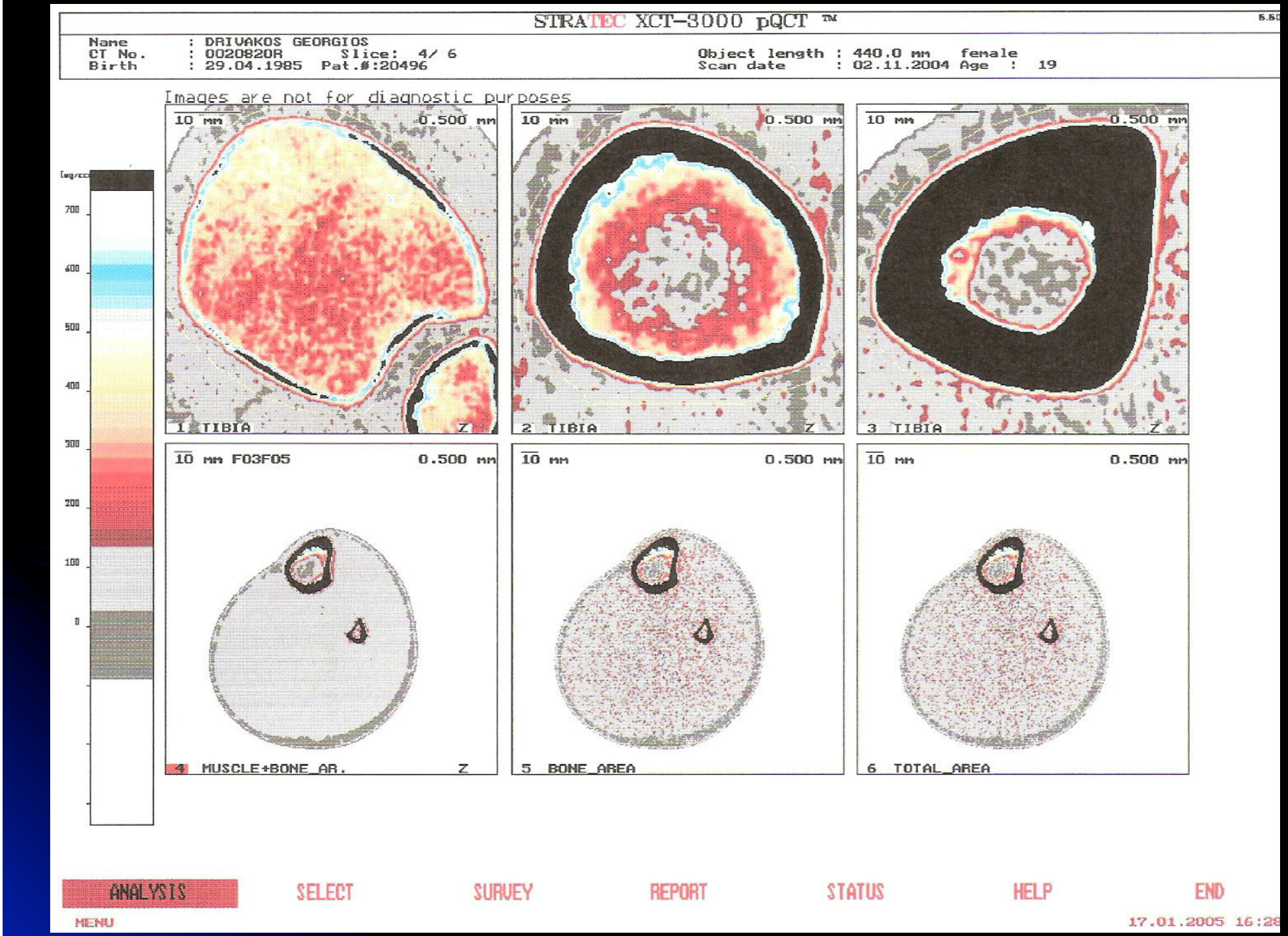
Mass1	5.11 g/cm	Mass2	3.35 g/cm	Mass3	4.37 g/cm
		SSIPOL2	2151.34 mm^3	SSIPOL3	2245.91 mm^3
TotArea1	1432.00 mm^2	TotArea2	611.50 mm^2	TotArea3	498.75 mm^2
TotDen1	357.15 mg/cm^3	CrtDen2	1070.05 mg/cm^3	CrtDen3	1137.86 mg/cm^3
TrbDen1	304.12 mg/cm^3	CrtArea2	205.25 mm^2	CrtArea3	353.75 mm^2
Bending Test Length	200.00 mm	Fracture Load X	4811.38 N	Mass1/Mass3 Ratio	1.17
Bone Ultimate Strength	180.00 MPa	Fracture Load Y	4861.87 N	CrtArea2/TotArea1 Area Ratio	14.33 %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Reduction of Bone and Muscle Loss

- Doxycycline
- Biphosphonates (risedronate)
- Calcitonin
- Diacerhein
- Immediate mobilization
- Proprioception training

Conclusions

In animals and humans following an ACL injury considerable posttraumatic osteopenia and sarcopenia develops quickly regardless of the preventive and rehabilitative measures taken

Conclusions

Subsequent attempts by the bone to recover lost bone mass not only may be ineffective, but may also exacerbate cartilage changes by altering mechanical properties of the subjacent subchondral plate.

Osteopenia in the cancellous bone and altered joint loading and knee kinematics may be also an important link in the pathogenesis of posttraumatic osteoarthritis.

Predisposing Factors for Females

- Narrower femoral notch- no difference btw males and females-smaller (decreased cross-sectional area) and weaker ACL
- Notch width of less than 0.2-predisposition to ACL injuries
- Greater pelvic width, increased external rotation (ER) at the knee, and greater genu valgum which may be due to the increase in tibial ER.- structural differences lead to different movement patterns which may place women at a higher risk for injury than males

Mechanics of Females vs Males

- Knee flexor moments during landing from a jump that were three times less than those of males (decreased knee flexion angles)
- Greater ground reaction force vertical loading rates and increased anterior translation of the tibia both occur at low knee flexion angles (0-40 degrees) which causes shear forces on the ACL. The increased stress on the ACL creates greater chance for an ACL injury in female athletes.
- Females have been shown to land with greater femoral internal rotation and tibial ER causing valgus stress on the knee -increase the load on the ACL five times compared to when the knee is aligned in the frontal plane
- Less knee flexion and greater knee valgus during side-cutting and cross-cutting tasks

ACL Tx

- Pt selection
- Operative vs. Non-operative
  - Demand level
  - Modify lifestyle
  - ndent
  - ons

Figure 7: ©1999.Terry Boles

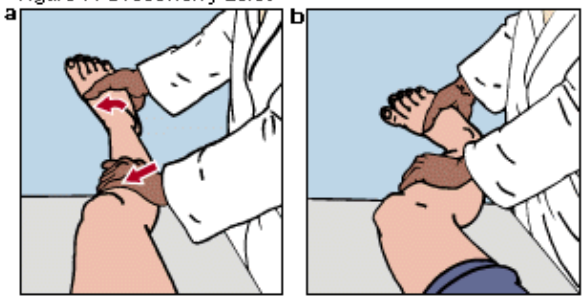


Figure 7. For the pivot-shift test, apply internal rotation and valgus forces to the nearly fully extended knee (a). If the anterior ACL is torn, the tibia will sublux slightly antero-laterally. As the knee is then flexed to about 40° (b), the iliotibial band changes from a knee extensor to a flexor and reduces the subluxed tibia, sometimes with an audible clunk—a positive test for an ACL tear. A positive test should not be repeated because of risk to the meniscus.

Who is a candidate for ACL reconstruction?

- Young; athlete
- Symptoms of instability & pain
- Risk of further meniscal & articular cartilage injury
- Presence of degenerative changes

Nonsurgical treatment for ACL deficiency

- Sedentary patients; knees with advanced degenerative changes
- Functional bracing
- Rehab: full ROM, closed kinetic chain strengthening, focus on hamstrings (quads & gastroc), proprioceptive re-ed
- Behavior modification

Non-operative

- Acutely – splint & crutches
- Early active ROM
- Closed chain WB to strengthen
- Avoid high risk
- Functional bracing controversial

Prevention

- Mechanoreceptors deep in ACL tissue that serve a sensory role through communication with the neuromuscular system to provide proprioceptive feedback during training and competition
- Trained individuals (increased exposure) have a significantly decreased incidence of ACL injuries 88% difference compared to the control group with 1263 high school athletes participating in the study
- PEP available that address proper technique, strengthening, proprioception, and neuromuscular training

Programm of prevention

- Adequate warming up
- Isometric strengthening of the quadriceps
- Streching of the quadriceps and hamstrings
- Ice packs after any vigorous training

Considerable posttraumatic osteopenia at the affected bone sites occurs quickly regardless of appropriate preventive and rehabilitative actions, and the time needed for steady-state and recovery will be long.

Sievanen H, Kannus P, Heinonen A, Oja P, Vuori I. Bone mineral density and muscle strength of lower extremities after long-term strength training, subsequent knee ligament injury and rehabilitation: a unique 2-year follow-up of a 26-year-old female student. Bone. 1994;15(1):85-90.

The posttraumatic decrease in the BMD of the injured knee is rapid and corresponds to approximately 2 SD (approximately 20%) observed in the age- and sex-matched population.

Sievanen H, Kannus P, Heinonen A, Oja P, Vuori I. Bone mineral density and muscle strength of lower extremities after long-term strength training, subsequent knee ligament injury and rehabilitation: a unique 2-year follow-up of a 26-year-old female student. Bone. 1994;15(1):85-90.

Mechanism / Hx

- Usually noncontact
- Change direction
- Stop / jump
- Audible “pop”
- Instability
- Swelling

Treatment Options

- Conservative
  - Isolated injury
  - Older age group
  - Willingness to accept activity limitations.
  - KT 2000 SSD < 5mm
- Surgical
  - Associated meniscal + ligament injury
  - Younger patients
  - High performing athletes
  - KT 2000 > 5mm

Loss of periarticular cancellous bone at the knee joint is important because altered joint stresses are induced.

Increased stiffness of the subchondral bone leads up to 50% compressive stress elevations in the overlying deep hyaline cartilage layer.

Brown TD, Radin EL, Martin RB, Burr DB. Finite element studies of some juxtarticular stress changes due to localized subchondral stiffening. J Biomech. 1984;17(1):11-24.

In another study, bilateral BMD measurements of the proximal tibia and the calcaneus using DPA were performed before surgery and 4, 12, and 24 months after ACL reconstruction using the autogenous patellar tendon. Despite significant improvements in the functional knee scores during the first year after surgery there was significant decline in the BMD of the proximal tibia of the operated leg, whereas there was no change in the calcaneus and contralateral leg. Two years after the operation the BMD of the medial tibia has returned to near normal levels unlike the lateral tibia where BMD remained significantly lower.

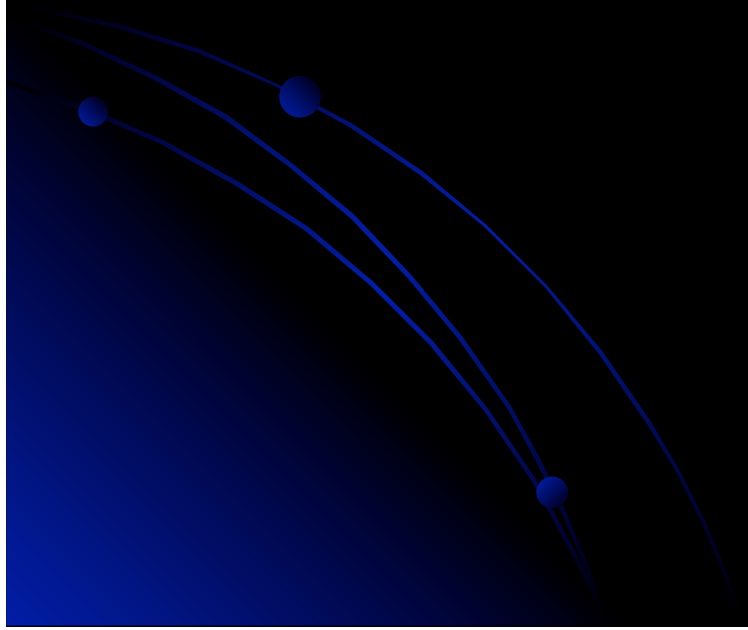
Zerahn

BMD at distant sites after ACL reconstruction may also decrease.

Between 6 and 32 months following ACL reconstruction BMD reduction is in the trochanteric region 6.6%, while on the entire hip it is 4%.

Reiman MP, Rogers ME, Manske RC. Interlimb differences in lower extremity bone mineral density following ante cruciate ligament reconstruction. J Orthop Sports Phys Ther. 2006;36:837-844.

BMD of the calcaneus may remain unaffected after ACL deficiency or reconstruction [Kannus 1992 == Zerahn] or may decrease bilaterally. [Ejerhed === Kartus1998]



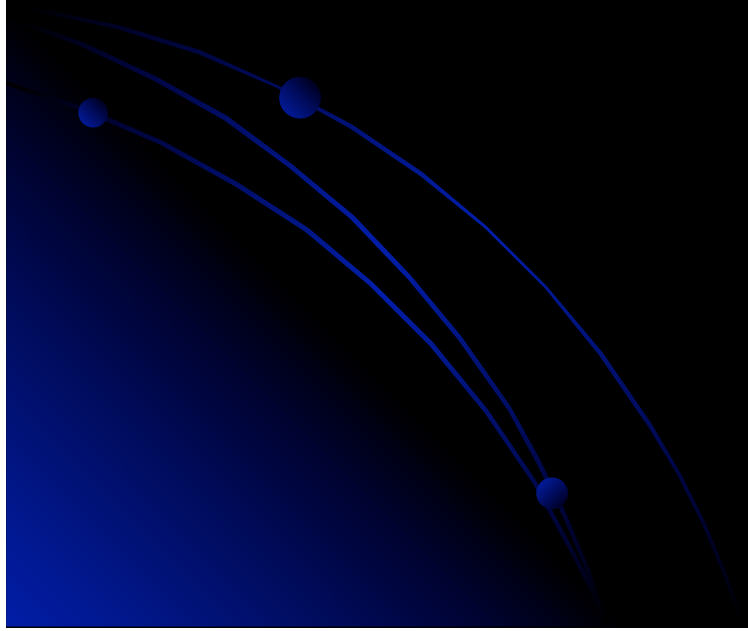
In another study bone mineral areal mass (BMA) in the calcaneus of male patients with unilateral ACL injury was measured before and after reconstruction.

BMA at a mean of 24 months after surgery was significantly lower on the injured side compared with the normal one.[Kartus 1998]

No correlation has been shown between calcaneal BMD and the time since injury.[Ejerhed = Zerahn]

Osteopenia Definition

Low skeletal muscle strength
is predictive of disability and mortality.



Age-related changes in skeletal muscle

- Decrease in muscle cross-sectional area
- Loss of muscle fibers
- Fiber atrophy
- Decrease in muscle strength

Mechanism of Injury

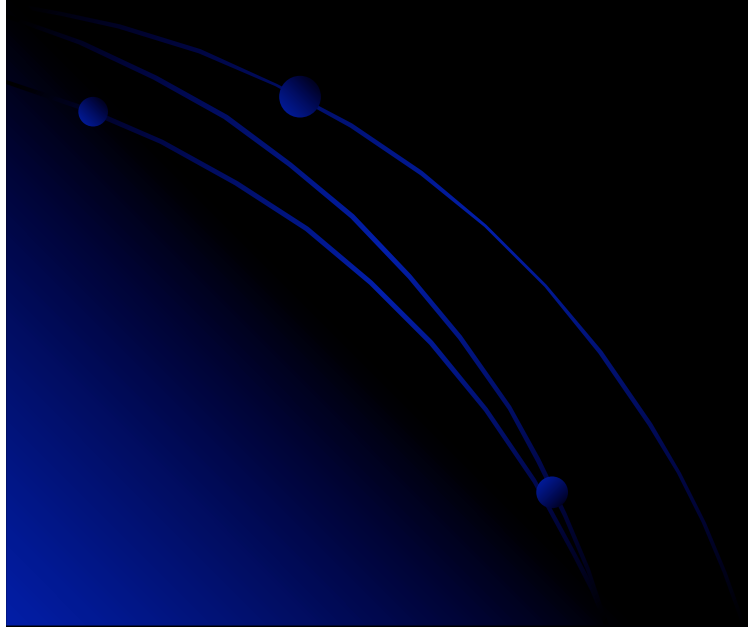
- Non Contact (80%): Internal Rotation
- Contact (20%): Valgus - External Rotation
- In children avulsion fractures

  (IR, hyperflexion or -extension)

Weakness and functional deficits may be permanent and persist after ACL reconstruction.

Keays SL et al. Strength and function before and after anterior cruciate ligament reconstruction. Clin Orthop. 2000; 373:174-83

Several authors performed BMD measurements in humans after ACL injury or reconstruction.



- Quadriceps strength deficit is related to the ACL injury and is increased by ACL reconstruction.

- Even 1 year after ACL reconstruction, a quadriceps strength deficit of almost 20% persists.

- Flexion strength is within the normal range before and after surgery.

De Jong et al., 2007

Active patients with chronic instability as a result of an ACL rupture have a more stable knee and a better functional outcome after ligament reconstruction when compared with the preoperative situation.

The involved leg exhibits a persisting deficit compared with the uninvolved leg even after intensive coordinated military rehabilitation.

De Jong et al., 2007