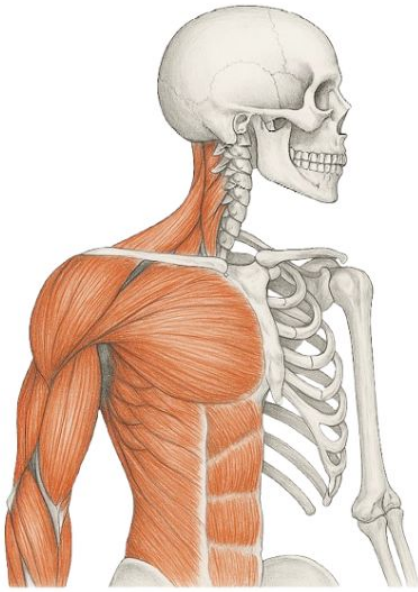
RECURSO EDUCATIVO: MANUAL

KINESIOLOGY

Sports Sciences Degree



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KINESIOLOGY

Kinesiology

Sport Sciences Degree

Universidad de Málaga, 2025

A la Educación Pública por permitir que la magia del conocimiento prevalezca sobre todo lo demás

“Puedes enseñar una lección un día; pero si puedes enseñar creando curiosidad, el aprendizaje será un proceso para toda la vida”

Clay P. Bedford

ÍNDICE

RESUMEN 11
BACKGROUND 12
BONE COMPOSITION AND STRUCTURE 17
BIOMECHANICAL PROPERTIES OF BONE 20
SURGICAL EFFECTS 26
STRESS RAISERS 33
DEGENERATIVE CHANGES IN BONE ASSOCIATED WITH AGING 35
COMPOSITION AND STRUCTURE OF ARTICULAR CARTILAGE 40
BIOMECHANICAL BEHAVIOR OF LUBRICATION OF ARTICULAR CARTILAGE 43
WEAR OF ARTICULAR CARTILAGE 45
HYPOTHESIS ON BIOMECHANICS OF ARTICULAR DEGENERATION 47
EXERCISE FOR CARTILAGE WEAR 49
COMPOSITION AND STRUCTURE OF TENDONS 52
COMPOSITION AND STRUCTURE OF LIGAMENTS 55
BIOMECHANICAL PROPERTIES OF TENDONS AND LIGAMENTS 57
FACTORS THAT AFFECT THE BIOMECHANICAL PROPERTIES OF TENDONS AND LIGAMENTS 58
COMPOSITION AND STRUCTURE OF SKELETAL MUSCLE 70
MOLECULAR BASIS OF MUSCLE CONTRACTION 72
MECHANISM OF MUSCLE CONTRACTION 74
FORCE PRODUCTION IN MUSCLE 76
MUSCLE FIBER DIFFERENTIATION 78
MUSCLE REMODELING 80
BIOMECHANICS OF PERIPHERAL NERVES AND SPINAL NERVE ROOTS 84
ANATOMY AND PHYSIOLOGY OF SPINAL NERVE ROOTS 89
BIOMECHANICAL BEHAVIOUR OF PERIPHERAL NERVES AND SPINAL NERVE ROOTS 91
NERVE INJURY AND PAIN 93
FUNCTIONAL INDEPENDENCE: A LIFELONG GOAL 99
THEORIES OF HUMAN DEVELOPMENT 102
MOTOR DEVELOPMENT AND MOTOR CONTROL 104
BODY SYSTEMS CHANGES 107
LOCOMOTION PATTERNS ALONG THE LIFESPAN 110
PREHENSION 112

CONCEPTUAL INTRODUCTION 115
HEALTHY BEHAVIOR 116
FITNESS PRINCIPLES 118
CARDIORESPIRATORY FITNESS, MUSCULAR FITNESS, AND FLEXIBILITY 121
BODY COMPOSITION, NUTRITION, AND WEIGHT MANAGEMENT 123
STRESS AND DISEASE 126
SUBSTANCE USE AND ABUSE 127
REASONS FOR EXERCISE 130
TYPES OF EXERCISE 133
TYPES OF ENDURANCE 137
EXECUTION OF EXERCISE 140
EXERCISE TECHNIQUE 142
EXERCISE PROGRAM DESIGN 144
HIP JOINT COMPLEX 148
HIP JOINT TESTS 150
KNEE JOINT COMPLEX 155
KNEE JOINT TESTS 157
ANKLE JOINT COMPLEX 161
ANKLE JOINT TESTS 162
FOOT JOINT TESTS 167
SHOULDER JOINT COMPLEX 171
SHOULDER JOINT TESTS 173
ELBOW JOINT COMPLEX 180
ELBOW JOINT TESTS 181
WRIST AND HAND JOINT COMPLEX 185
GRIPS 187
BIOMECHANICS OF THROWING 192
GLOSSARY OF TERMS 198
BIBLIOGRAPHIC REFERENCES 199

RESUMEN

En este libro se intenta dar respuesta a la necesidad de los estudiantes del Grado Internacional en Ciencias de la Actividad Física y el Deporte de la Universidad de Málaga, de tener un manual para la asignatura Kinesiología, impartida en lengua inglesa, motivo por el que este manual está escrito en dicha lengua de aquí en adelante.

El libro agrupa el contenido de esta asignatura tanto en su sección teórica como práctica, en las que se tratan contenidos relacionados con la composición, estructura y biomecánica de los tejidos, humanos, aludiendo al hueso, el cartílago, los tendones y los ligamentos, así como los nervios periféricos y las raíces nerviosas.

En todos esos capítulos, se hace referencia tanto a la histología como a la fisiología, nombrando las posibles lesiones que pueden ocurrir en cada tejido, así como el procedimiento a seguir tanto para su prevención usando ejercicio como para su tratamiento, derivando a profesionales sanitarios regulados.

Por otro lado, se habla de independencia funcional, pasando desde las teorías del desarrollo humano, hasta los signos de alarma del desarrollo motor. Además, se habla de los cambios producidos en los distintos sistemas corporales debido al envejecimiento, aludiendo por supuesto a los cambios en los patrones de movimiento. Acompañando a esta sección, aparece un capítulo dedicado a la diferenciación entre la terminología wellness y fitness, haciendo referencia al efecto de estos sobre los distintos sistemas del cuerpo humano: cardiorrespiratorio, musculoesquelético, genitourinario, inmunitario y nervioso. Para terminar la sección teórica, se dedica un capítulo a los principios del entrenamiento de fuerza, partiendo de la base de los tipos de ejercicio de fuerza y la fisiología de los diversos tipos de esfuerzo, para continuar con la técnica y la ejecución, terminando con el diseño de programas de ejercicio.

En la sección práctica, se hace una introducción anatómica y funcional de cada articulación, con recuerdo de las funciones de los músculos periarticulares. Además, se incluyen lecciones sobre biomecánica articular, con pruebas funcionales orientadas a detectar problemas o desequilibrios en el control motor y los patrones de movimiento, con el objetivo de pautar ejercicios que puedan ayudar a mejorar el rendimiento deportivo.

Palabras clave: biomechanics; strength; motor control; movement; training.

BACKGROUND

Kinesiology

The term “Kinesiology” has its origin in two Greek words: ***kinesis***, which means movement, and ***-logía***, which means science. So, this term alludes to the study of the functionality and quality of human body movements.

Considering this broad meaning, the term Kinesiology could be understood as a multivariable term, including six subdisciplines:

- Motor Learning: several processes that need to be practiced to produce stable adaptations in relation to the capacity to perform effective actions.
- Motor Development: a sequential and dynamic process through which humans acquire motor skills, trying to reach functional independence. This process is accompanied by the maturation of the nervous system, and it is produced during childhood.
- Pedagogy: science that studies education.
- Exercise Physiology: science that studies the behavior and the responsiveness of the organism during exercise, conducting a deep analysis of different biomarkers.
- Exercise Psychology: science that studies the behavior and mental health of athletes, as well as the relevance of motivation in sport performance.
- Biomechanics: the science that studies the movement of living things, analyzing how forces can create motion. This science provides essential knowledge about the most effective and safe motion patterns, the most adequate equipment for each sport, and exercises to optimize motor performance.

Exercise performance

The term “Exercise Performance” is defined as the junction of efforts performed by an athlete trying to achieve specific goals in a predetermined time frame.

Considering this definition, it is necessary to talk about effective movement such as the ability to develop a sports gesture in the minimum time possible and expending the minimum quantity of energy possible.

In the sports context, it is very relevant to design evaluation protocols to detect issues in the execution of sports movements, prevent injuries, and enhance exercise performance to achieve better results in competitions. Nevertheless, the development of assessment protocols is only the first step in this process, because it is necessary to apply correct clinical reasoning to relate the observed findings during the evaluation with the cause and use this data to determine the best exercise protocol to correct the problems and/or improve the outcomes.

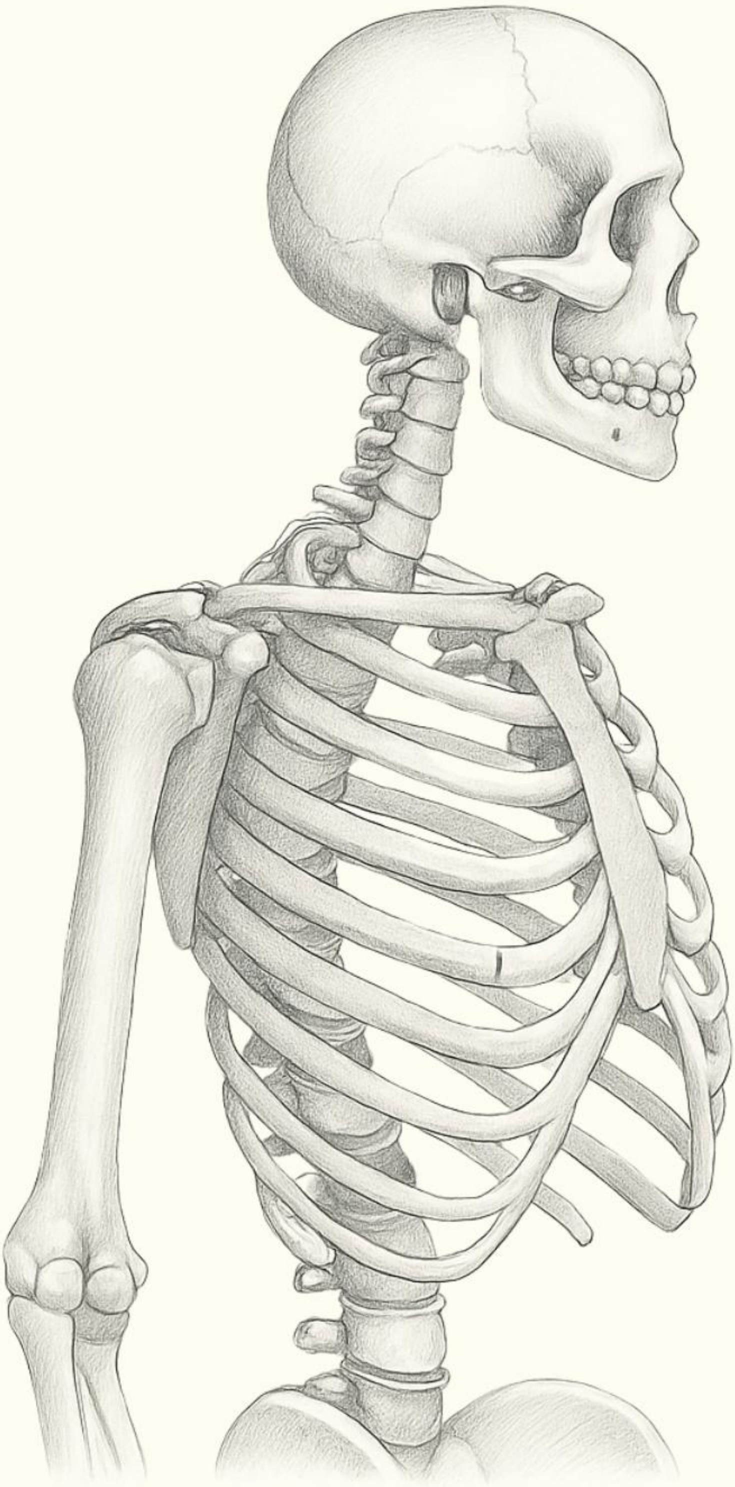
Human movement

The human body could be understood as a living machine that is subjected to forces causing movements. For the analysis of these processes, it is need to differentiate some relevant couple of concepts:

- Static vs dynamic: static is usually explained as the state of the objects at rest, but it also refers to motion when it is constant, while dynamic alludes to the motion when it is subjected to an acceleration produced by internal or external forces.
- Kinetics vs kinematics: kinetics involves the study of the forces that produce the movement, while kinematics is based on the complex analysis of the motion including time, space, position of the body segments, activation of the muscles,...

THEORETICAL SECTION

1



BONE COMPOSITION AND STRUCTURE

BONE COMPOSITION AND STRUCTURE

Bone tissue

Taking into account the basic histology, bone tissue is a specialized connective tissue whose principal characteristic is that it presents a mineralized extracellular matrix.

This tissue has three main properties:

- Hardness
- Strength
- High tensile and compressive resistance.

These three properties allow bone tissue to fulfill four essential functions for life:

- Body support, that is a mechanical function
- Organ protection
- Calcium deposit, that is a metabolic function (99% of the body's calcium stores are found in the bone)
- Blood cell formation occurs in the bone marrow.

However, the most important aim of bone tissue is to keep the body in constant remodeling throughout life, which makes it a dynamic tissue.

Gross organization of bone

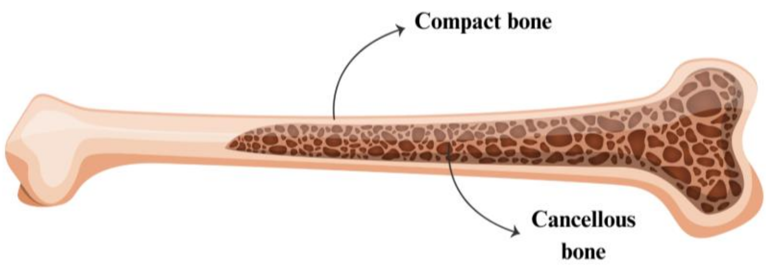


Figure 1. Gross organization of bone

Bone tissue can be structured depending on its macroscopic organization in compact and cancellous bone.

- Compact bone is dense, solid, and without cavities. It corresponds to the outer layer.

- Cancellous, trabecular or spongy bone is composed by a fine network-like trabeculae whose spaces are occupied by bone marrow.

These two types of bone tissue can be found in different proportions depending on the type and the part of each type of bone. In long bones we differentiate three parts: the epiphysis, that is made up of cancellous bone surrounded by a fine layer of compact bone; the metaphysis, made up of hyaline cartilage when we are children and becomes the epiphyseal line in adulthood; and the diaphysis, a compact bone cylinder with an internal cavity called "medullary cavity". Short flat bones are made up of cancellous bone surrounded by a fine layer of compact bone.

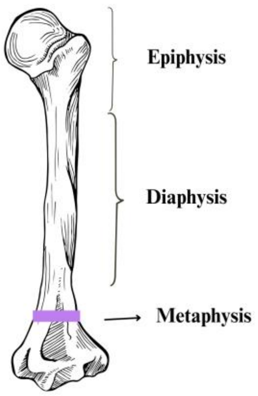


Figure 2. Parts of the long bones

Bone facing

There are two layers covering the bone, the periosteum and endosteum.

- Periosteum is a layer of dense connective tissue that covers the external surfaces of the bone and contains osteoprogenitor cells, osteoblasts, and bone lining cells.
- Endosteum is a fine layer that covers the internal surfaces and contains osteoprogenitor cells.

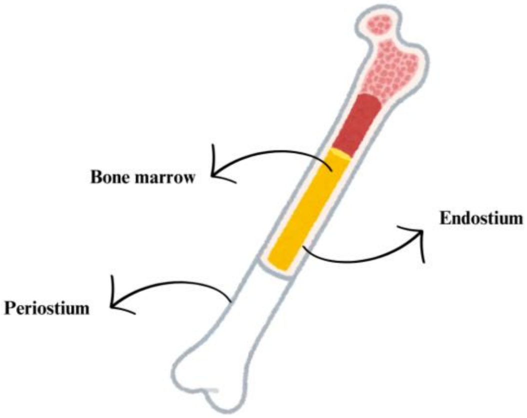


Figure 3. Covering layers of the bone

Bone tissue components

There are two main components forming the bone tissue: the extracellular matrix and the cells.

The extracellular matrix is mineralized, and the mineral is calcium phosphate in the form of hydroxyapatite crystals. This matrix is formed by fibers and ground substance.

There are five types of bone cells:

- Osteoprogenitor or osteogenic cells, the precursors to the rest of cells (more specialized). These cells throughout the process of mitosis and differentiation become osteoblasts.
- Osteoblasts are responsible for synthesizing the cell matrix.
- Bone lining cells, the inactivating form of the osteoblasts.
- Osteocytes are osteoblasts that become trapped in the matrix.
- Osteoclasts, responsible for bone resorption, break down the matrix to release calcium and phosphate.

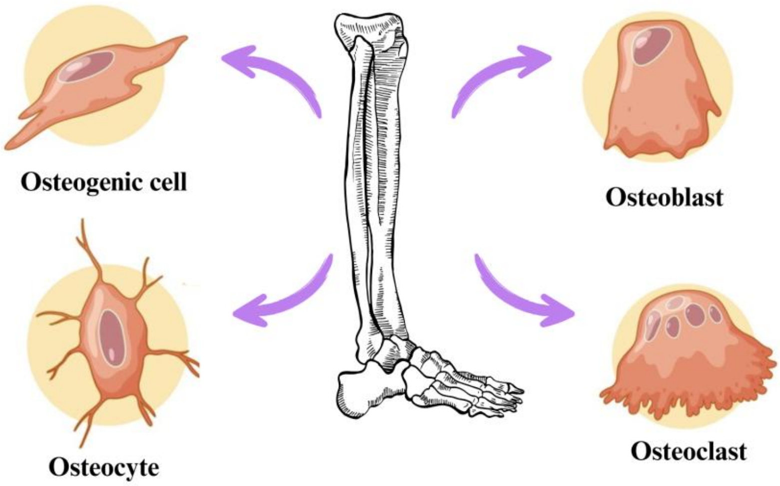


Figure 4. Types of bone cells.

These types of cells do not have the same origin. Osteoprogenitor cells, osteoblasts, bone lining cells, and osteocytes come from the osteoblastic lineage and have a mesenchymal origin, whereas osteoclasts come from the osteoclastic lineage and have a hematopoietic origin.

BIOMECHANICAL PROPERTIES OF BONE

Hierarchical structure of bone

In order to understand the biomechanical properties of bone, it is necessary to take into account the different structural levels because each of these hierarchical levels has an influence on the biomechanical properties and characteristics of bone. We will start describing the macroscopic level down to the microscopic and molecular level (Caeiro et al., 2013). The whole bone is formed by two main types of bone tissue: cortical bone and trabecular bone.

1. Cortical bone or compact bone: as we have mentioned before, this bone tissue is located in the outer layer and carries most of the load.
2. Trabecular bone or cancellous bone: this bone tissue is inside the bone and it is more porous. One of its functions is to absorb the forces.
3. Individual osteons: structural units of cortical tissue that are organised in the form of cylinders and contain canals called Haversian canals.
4. Individual trabeculae: rod-shaped structure that forms a network. Although this bone tissue has no Haversian canal, it does have osteocytes.
5. Lamellae are present in the compact bone and cancellous bone. The lamellae have osteocytes trapped in the matrix.
6. Haversian canal: cortical bone structure that are central canals found in each osteon. In the Haversian canal is located the osteocytes. In the center of the Haversian canal, we can find nerves and blood vessels that supply the tissue. Surrounding the canal are concentric lamellae, which are layers of bone matrix containing osteocytes trapped within.
7. Collagen fibres: The bone is made up of collagen fibers type I.
8. Collagen molecule: the collagen fibres are divided into collagen molecules formed by amino acids. They are the result of the union of a triple helix of this material.
9. Hydroxyapatite crystals: They are located in the gaps of the matrix.

Each component of the bone provides different biomechanical properties to the bone, which, when configured together, will cause the whole bone to present different characteristics in relation to each individual component.

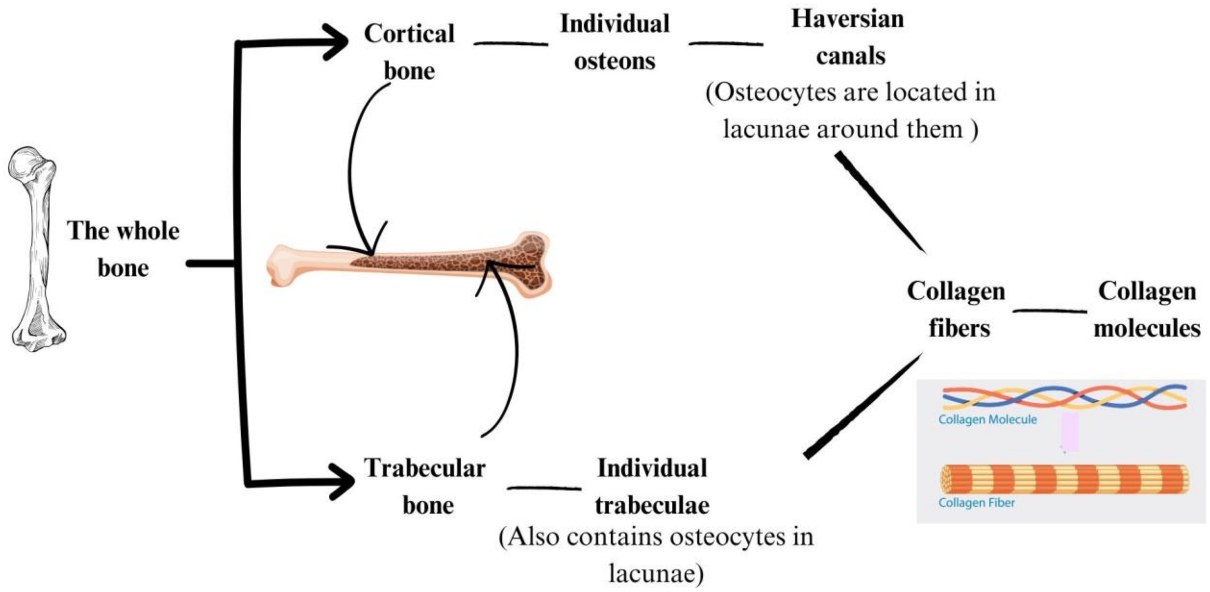


Figure 5. Structural levels of the bone.

Biomechanics of the entire structure

We highlight three main features:

- Greater resistance to compression than to traction.
- Weakness against shear forces.
- The flexural resistance will depend on the stiffness and the magnitude of the fracture load threshold.

By taking these properties, we could understand that in sports we find headlines such as “Krohn-Dell suffers an avulsion fracture of the lower pole of the patella”, which is explained by the first property.

Moreover, these bone properties mean that when fractures occur (some later than others), they have a different fracture line, establishing the following force-fracture relationship:

- Traction with transverse fractures.
- Compression with oblique fractures.
- Bending or flexión with “butterfly fractures”.
- Torsion with spiral fractures.

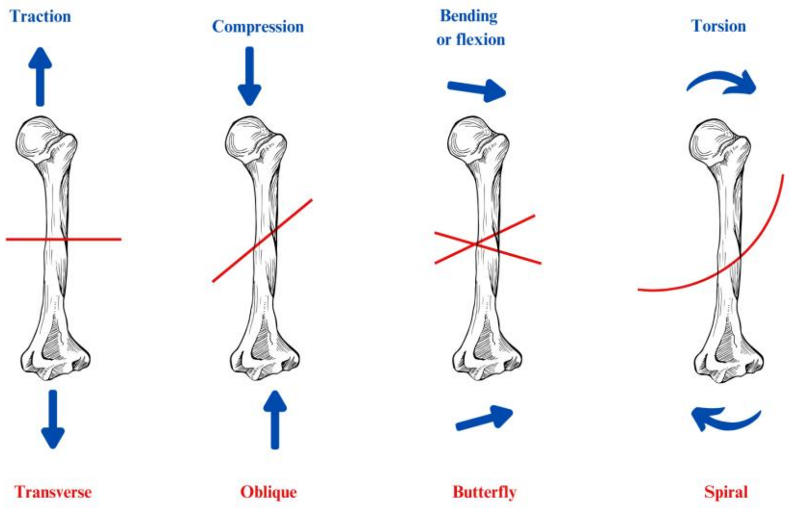


Figure 6. Force-fracture relationship.

Biomechanics of tissue components

The compact or cortical bone presents greater resistance to compression than to traction, and a huge weakness against torsion. It presents a similarity with the whole bone due to the fact that the strength values of compact bone represent 60% of the resistance of the whole bone.

The cancellous bone has a higher resistance to compression than traction, like the compact. Nonetheless, the most notable characteristic of this type of bone is that the trabeculae are able to reorient depending on the loads to which they are subjected more frequently.

These differences result in distinct curves, as observed in the graph. The cortical bone can withstand significant loads without deforming; however, it fractures under minimal deformation. In contrast, cancellous bone deforms under relatively small loads but can endure substantial deformations without breaking.

Biomechanics of osteons and individual trabeculae

At the smallest level we find:

- The longitudinal lamellae of the osteons presents greater resistance to traction and torsion, while the transverse ones have greater strength against compression, shear forces and flexion. This makes the distribution of the lamellae different in each area of the body depending on the loads that it supports.

- Besides, regarding the individual trabeculae, these have a smallest longitudinal modulus of elasticity compared to that of osteons of cortical bone.

Trabecular bone deforms when it is subjected to increasing loads until it fails and the consequent fracture occurs.

Biomechanics of molecular components

When we talk about molecular components we refer to collagen fibres and hydroxyapatite crystals (the microscopic structures).

Collagen fibers

When collagen fibres are subjected to tensile stress, an initial linear strain occurs in all fibres. However, from a point called “critical strain”, heterogeneous deformation is observed. It is believed that this occurs because, from this point onwards, there is a change in the mineral composition of the collagen fibres.

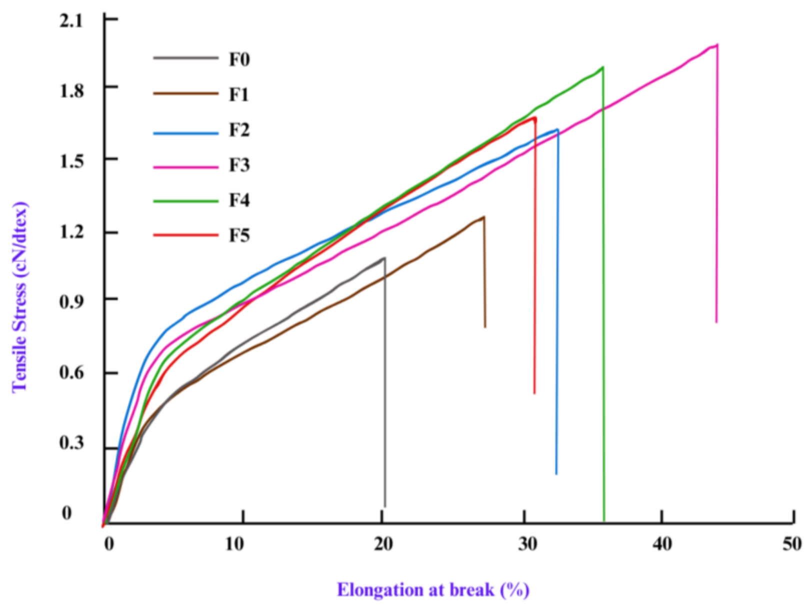


Figure 7. Stress-deformation curve of the collagen fibers.

Hydroxyapatite crystals

In relation with the hydroxyapatite crystals, they show greater hardness and elasticity on their basal faces (flat surfaces) compared to their lateral faces (the edges). However, the lateral faces are more resistant to damage, making these crystals highly tolerant to microfractures (Caeiro et al., 2013).

Joints

Joints have a fundamental role in kinesiology, they are not only the union between bones but also responsible for allowing movement. Their study is key to understanding human biomechanics, preventing injuries and maximizing sport performance. That's why we will delve into their components, classifications and key concepts.

The joint is an anatomic structure that connects two (e.g. humeroulnar joint) or more (e.g. radiocarpal joint) bones , allowing movement and providing support and stability.

We can establish two different classifications. According to their mobility and components.

According to mobility.

- Synarthrodial: without mobility.
- Amphiarthrodial: little movement.
- Diarthrodial: great range of motion
- Diarthroamphiarthrodia: mix of Diarthrodial and Amphiarthrodial

According to components:

- Membranous: joints where the connective tissue is membranous, such as suture of a baby's skull (as we grow this tissue ossify turning into bone)
- Cartilaginous: joints where bones are connected by cartilage. These are: synchondrosis (hyaline cartilage) and symphysis (fibrocartilage).
- Synovial: joints surrounded by a synovial capsule filled with synovial fluid. They are the most mobile joints.
- Bone (synostosis): joints can ossify completely becoming a bony connection without movement, Such as femoral metaphysis.

	SYNARTHRODIA	AMPYARTHRODIA	DIARTHRODIA
MEMBRANOUS	Suture (cranium) Gomphosis (tooth)	Syndesmosis (ulna and radius)	---------
CARTILAGINOUS	Synchondrosis (growth plate)	Symphisis (vertebrae)	---------
SYNOVIAL	---------	---------	Throclea (elbow) Throcoid (atlas-axis) Condylia (wrist) Reciprocal engagement (carpo-metacarpal) Enarthrodia (shoulder) Arthrodia (acromioclavicular)
BONE	Synostosis (femoral metaphysis)	---------	---------

Figure 8. Joints' classification.

SURGICAL EFFECTS

When we talk about the side effects of surgery on the bone, we are going to look at different types of bone injuries with their causes and types of management, finally focusing on the surgical approach and seeing its effects.

Fractures

According to the World Health Organization, fractures are defined as total or partial breakage of the bone, and there are two main types of fractures.

- Open fractures, when the bone pokes through the skin and can be seen, or deep wound exposes the bone.
- Closed fractures, when the bone is broken but the skin remains intact.

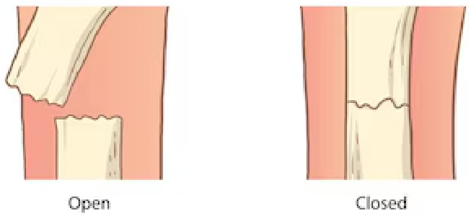


Figure 9. Open and closed fractures.

Most common types of fractures

If we base it on the way in which the fracture line is produced, we find a much broader division:

- Green stem, it is an incomplete fracture very typical in children, in which a portion of the bone breaks, causing the other side to bend. For example, imagine you have a green, flexible branch from a tree. If you try to bend it, it doesn't break completely as a dry branch would, but it does break a little on one side while the other side just bends. That's where the name green stem comes from.
- Transverse, when the break occurs in a straight line through the bone.
- Spiral, when the break is diagonal across the bone.

- Compression, in which the bone is crushed, causing the broken bone to become wider or flatter.
- Comminuted when the break occurs in three or more pieces, and fragments are present at the fracture site.
- Segmental, in which the same bone is fractured in two places, leaving a “floating” segment.

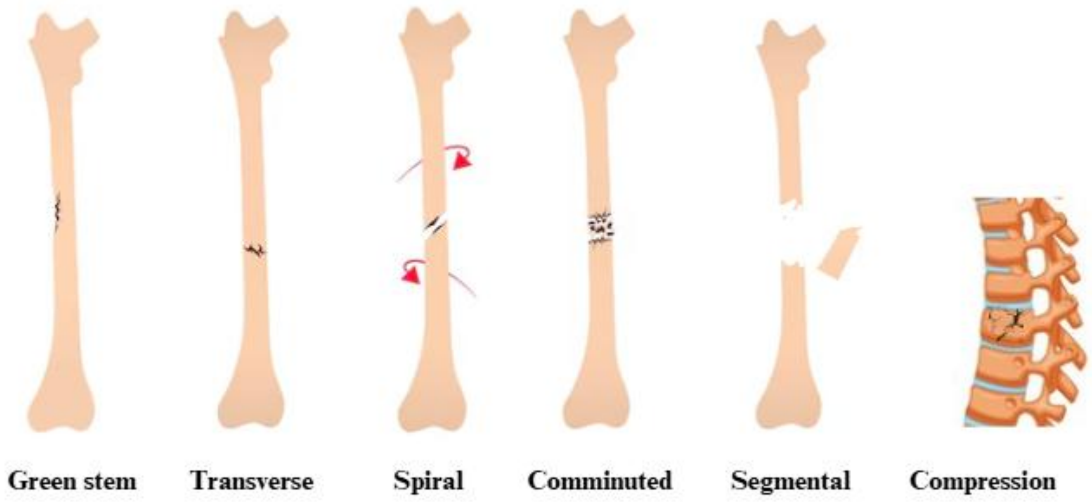


Figure 10. The most common type of fractures.

Etiology of fractures

When we talk about the etiology of fractures, we want to talk about the causes of this type of injury.

Generally, fractures occurs when there is more force applied to the bone then the bone can withstand, but in these terms, we could differentiate three main causes:

- Traumatic fractures, what are those that are caused by falls or direct hits.
- Stress fractures, when we subject an area to overuse or repetitive movements.
- Disease fractures, usually generated by osteoporosis or bone cancer, which weaken the bones making them more prone to breakage.

Symptoms and diagnosis of fractures

When diagnosing a fracture, doctors rely on a double diagnosis: clinical diagnosis and imaging diagnosis.

Clinical diagnosis

In the first instance, a clinical diagnosis is based on the symptoms, which often include sudden pain, difficulty to move the injured area and surrounding areas, swelling, obvious deformity and warmth or redness.

Imaging diagnosis

Nonetheless, this clinical diagnosis must always be confirmed by an imaging test, be it radiography, magnetic resonance imaging or computed tomography.

Management of fractures

Once the diagnosis is carried out, it is necessary to go on to the treatment, which only presents two options: conservative treatment and/or surgical treatment.

Conservative treatment

Conservative management in which an immobilization is performed with a plaster to keep the fragments aligned and promote the consolidation of the fracture.

Surgical treatment

In some cases, it is necessary to bet on surgical treatment, and even, use internal or external fixation devices (plates, nails or rods) are used to hold the bone fragments in place while they weld.

Bone deformities

Another common pathology of the bone is bone deformity, which are atypical, structural deviation or distortion of bone shape from its normal alignment, length, and size, that could be congenital or acquired.

Symptoms

Its main symptoms are pain, discomfort, difficulty moving, problems in development and growth, and different pathologies or injuries because of misalignment.

Usually, doctors try to solve the problem with orthopaedic devices such as splints but in most cases, they end up in surgery.

Most common types of bone deformities

The most common types of bone deformities are three:

- Bone dysplasias, that are alterations in the formation of bone tissue, that causes an absence or less growth in a bone than the physiological.
- Bone misalignments, that are alterations of the mechanical axes of the body due to discrepancies or abnormal rotations that cause loss of intrinsic stability of the skeleton.
- Bone malformations, that are abnormal developments of bone either in shape, union with other bones or internally in terms of bone density.

Diagnosis and treatment of bone deformities

Regarding the diagnosis, it is characterized by:

- Visually obvious deformity.
- Abnormal movement patterns
- Associated symptoms or other injuries such as joint dislocations or repeated fractures.
- Clear deformity detected at imaging tests.

In terms of treatment there are different options like splints, that we have already said, that don't usually solve the problem; cuts into the bone and placement of plates to realign; bone grafts to supply the absences of these; or metal rods and tensioners to guide growth.

Osteoporosis

To continue with bone diseases, we need to talk about osteoporosis, that is a disease characterized by a decrease in bone density due to the loss of normal bone tissue. This pathology causes a decrease in the resistance of the bone against load or trauma, with the consequent appearance of fractures.

This pathology could be caused by menopause, alcoholism, some drugs, rheumatic, endocrine or inflammatory disease, or even natural loss of bone mass typical of aging.

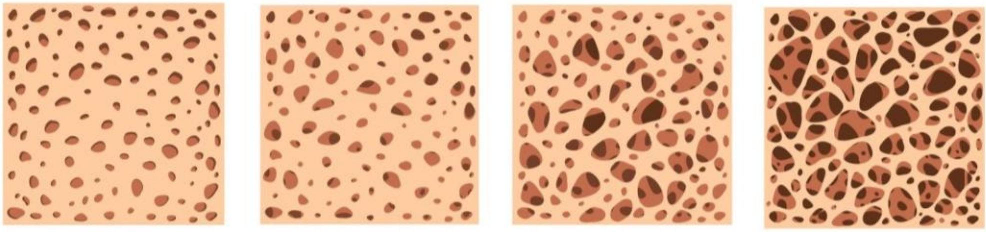


Figure 11. Degrees of severity in the loss of bone density.

Symptoms, diagnosis, and treatment

Osteoporosis is considered a "silent disease" because it does not cause greater symptoms until the person starts to deal with fractures such as vertebrae, hip, and wrist fractures.

The diagnosis is given by a densitometry with values less than two and a half in T-score.

Regarding the treatment, it is multifactorial, such as:

- Dietary modifications, increasing calcium intake.
- Use of antiresorptive, bone forming, or mixed action drugs.
- Surgery, in case of fracture.
- The global treatment is exercise.

Exercise in osteoporosis

We have to consider some different key points when we are working with people who suffer from osteoporosis (García-Gomariz et al., 2019):

- Plan a multi-component exercise program that includes endurance, strength, and balance training, with progressive loads based on the theoretical maximum resistance.
- Include medium-high impact exercise, taking into account the individual state of each person and avoiding generic group workouts.
- If there is a history of osteoporotic fracture, we should start with very low loads, between six and eight repetitions, and a large number of series, to get strength and avoid muscular fatigue, trying to avoid fracture recurrence.

Bone cancer

Bone cancer is considered one of the worst bone pathologies. It means an uncontrolled multiplication of abnormal bone cells.

The most common bone cancers are osteosarcoma, chondrosarcoma and Ewing's sarcoma, generally presented as metastasis, and whose main symptom is severe pain.

The diagnosis is given by a biopsy.

Treatment of bone cancer

The treatment of bone cancer has three main points:

- Surgery that may include amputation of the affected limb.
- Chemotherapy and radiotherapy to shrink the tumour.
- Exercise as an adjuvant before, during and after the treatment.

In cancer patients we have to include aerobic and strength training, functional exercises according to their motivations, because these people usually deal with depression. Also, we need to focus on toning of the residual limb to improve healing, strength and the possibility of walking with prosthesis. And exercise during the chemotherapy period with direct supervision, in mixed units of cardio-oncological rehabilitation (Garcia et al., 2020). .

Side effects of surgical approach

As we have already seen, the surgical approach is sometimes essential, but it brings with it several side effects for the bone like following:

- Malunion, that is a deformity, or the fracture heals in the wrong position or is displaced.
- Interruption of bone growth. If we are in the presence of a bone deformity that affects both ends of the bones, there is a risk that the normal development of that bone would be affected.
- Persistent bone or bone marrow infection. It means that a bacteria enters and infects the bone or the bone marrow, and patients need to be treated with antibiotics.

- Rejection of bone grafts or metal elements, with the harmful consequences that it could bring.
- Sudeck's syndrome**,** which is a chronic pain disorder that affects the tissues around the injury.

STRESS RAISERS

When we talk about stress raisers, we mean a "type of tension caused by a concentration of stress in localized regions of the cortical bone and can cause catastrophic failures rather than stress fractures" (Yoo et al., 2021).

Mechanical stress

The mechanical stress, that is defined as the force divided by the area of tissue subjected to said force. There are five types of mechanical stress:

- Traction.
- Compression.
- Shear.
- Torsion.
- Bending or flexion.

In terms of training, the key point is to create stress to generate adaptations but without reaching the maximum umbral of adaptation, avoiding injuries.

Hormone stress

Another great stress raiser is hormone stress, which is a derangement in normal blood hormone concentrations. Hormones that could affect bone are:

- Growth hormone.
- Thyroid Hormones.
- Sex hormones such as estrogens, progesterone, and testosterone.
- Insulin.
- Insulin-like growth factors.
- Cortisol.
- Parathyroid hormone.
- Calcitonin.

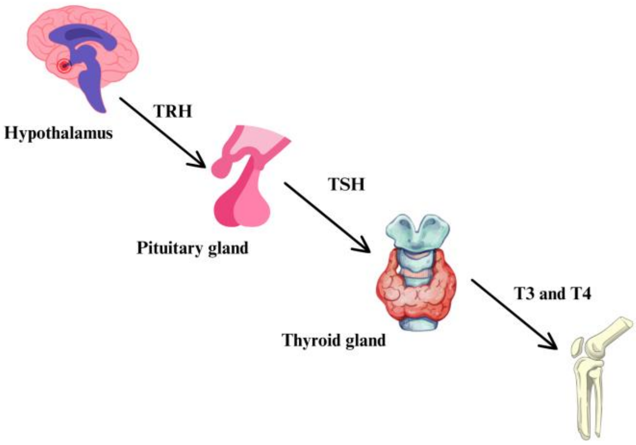


Figure 12. Production of thyroid hormones.

Psychosocial stress

Moreover, we have psychosocial stress, which is a cumulative physiological response to environmental, social, and psychological stressors, and can be divided into:

- Social strain.
- Social support.
- Social functioning.

This stressor could cause a loss of bone mass density (Follis et al., 2019).

DEGENERATIVE CHANGES IN BONE ASSOCIATED WITH AGING

In addition to the stress raisers, we have to deal with the degenerative changes in bone associated with aging.

Aging

Aging can be defined as the physiological process that begins at conception and causes changes in the characteristics of the species through the life cycle.

It is considered a major risk factor in the loss of bone mass and quality, increasing the incidence of fractures (Portal-Núñez et al., 2012).

Furthermore, aging affects metabolism, causing:

- The poorest quality of collagen fibers
- Lower ability to repair microfractures
- Relative increase in bone resorption vs bone forming

Histological changes in bone tissue

In addition, aging causes histological changes in bone tissue like:

- An increase in the relationship: osteoclasts-osteoblasts.
- A greater loss in cancellous bone than in cortical bone, decreasing the number of trabeculae and trabecular connectivity
- An increase in the diameter of the periosteum to maintain mechanical properties.
- A decrease in angiogenesis.

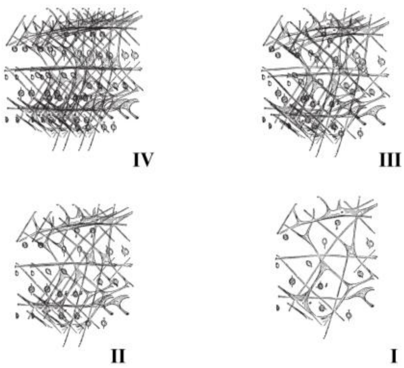


Figure 13. Loss of bone density.

Changes in osteoblastic function

Aging causes changes in osteoblastic function, too. We can observe:

- Drastic reduction of bone-forming surfaces.

- Abnormalities in the growth and/or function of bone-forming cells.
- Decreasing of osteocalcin.
- Acceleration of osteoblastic maturation, provoking shorter cell half-life.
- Decreasing of telomerase in somatic cells, causing a decrease of proliferation and differentiation of osteoblasts.

Oxidative stress in osteopenia

Finally, one of the main degenerative changes is the oxidative stress in osteopenia, that can cause:

- Imbalance in the level of oxidizing and deoxidizing agents.
- Excessive production of reactive oxygen species, promoting cell damage and apoptosis of osteoblasts and osteocytes.
- Alteration of various molecules that inhibit the action of osteogenic factors.

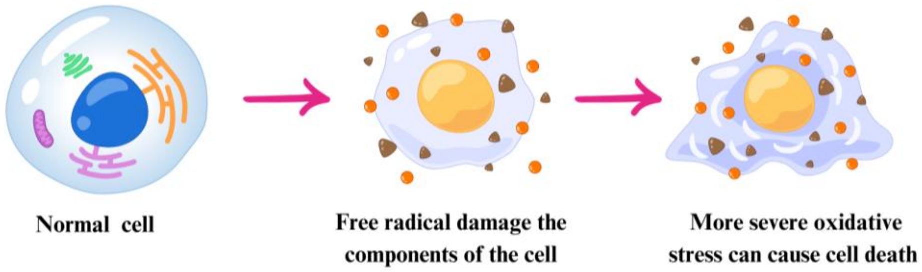


Figure 14. Oxidative stress in osteopenia.

What can we do against these changes? At those ages, is this useful?

Firstly, we need to create exercise programmes related to the objectives of the elderly, focusing on functional exercises and establishing different strategies to increase adherence.

If you need to keep in mind three sentences, they should be:

- “Walking is not enough”
- “Physical or mental disability does not equal no solution”
- “Educational is equal or more important than the exercise that is done”

The physical activity has multiple benefits at any stage of life, but the conclusions of scientific papers about the effects of exercise in aging are:

- Increase in bone mass density and decrease in osteoporosis.
- Significative outcomes in balance and muscle strength.
- Decrease in falls and of course, decrease in fractures.
- Maintenance of skeletal integrity.
- In case of fracture, better recovery.
- Balance hormonal levels.
- Increase in quality of life.
- Fewer hospitalizations, supporting the fact that exercise is highly cost-effective.

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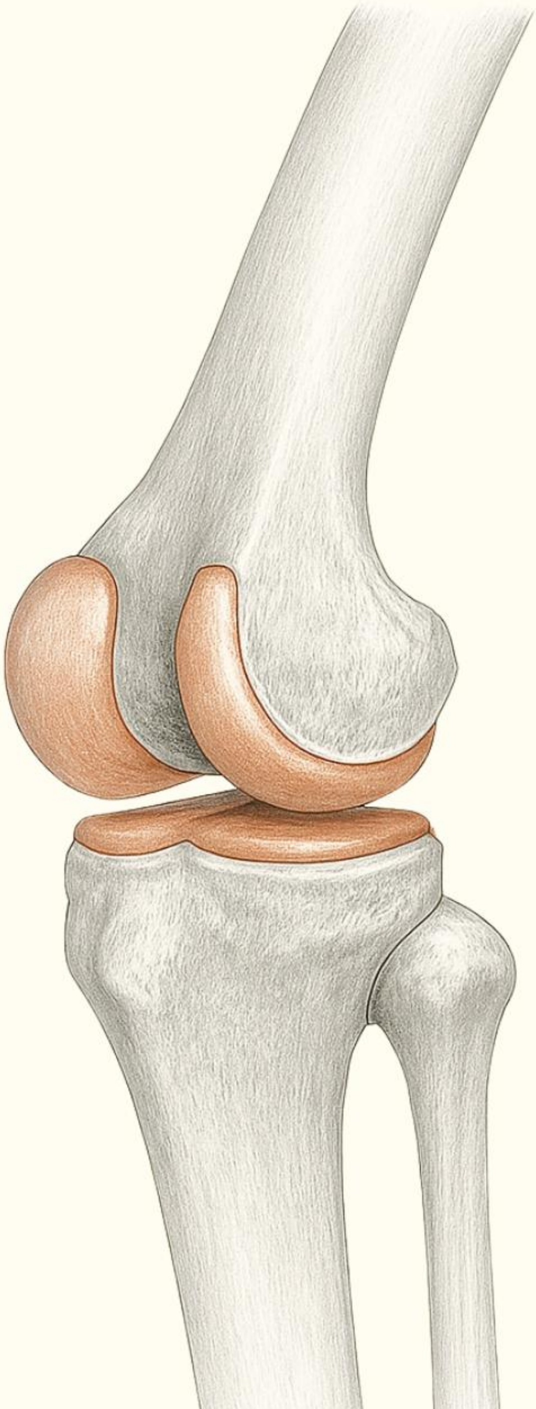

BIOMECHANICS OF ARTICULAR CARTILAGE

COMPOSITION AND STRUCTURE OF ARTICULAR CARTILAGE

Cartilage

The cartilage is a white, solid, resistant and elastic connective tissue, specialized in the support and movement of the body. One of the characteristics that make this tissue different from others is that it doesn't contain vessels and nerves; but instead, it is nourished by adjacent structures. Its functions are:

- To allow movements of bones in joints
- To be flexible but strong framework of some organs
- To be the mold on which long bones are formed

Types of cartilage

In our body, we can find three different types of cartilages, according to their components and the organization of them.

Hyaline cartilage (articular cartilage)

- It is the most abundant type of cartilage in our body.
- It has few cells and fibers.
- It is surrounded by perichondrium.

Elastic cartilage

- It presents numerous and large chondrocytes.
- It has predominance of elastic fibers.
- It is surrounded by perichondrium.

Fibrous cartilage

- It has intermediate characteristics between dense connective tissue and hyaline cartilage.
- It has the chondrocytes in a row.
- Type of fibers: collagen I and II.
- It isn´t surrounded by perichondrium.

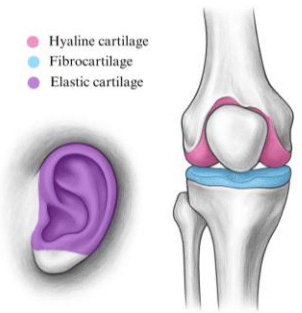

Figure 15. Types of cartilages in the body.

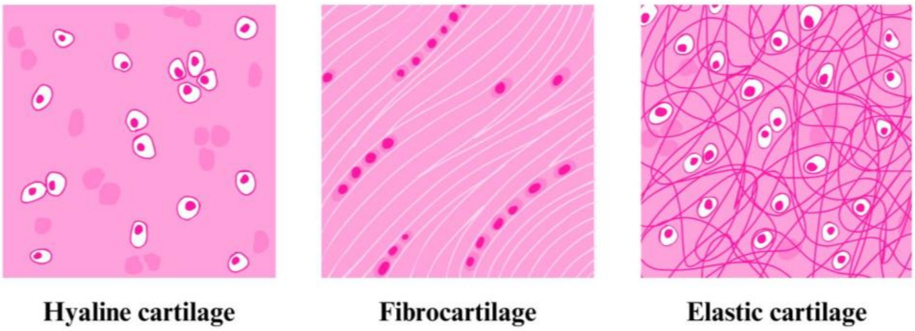

Figure 16. Hyaline, fibrous, and elastic cartilage.

Components of articular cartilage

As articular cartilage is the most abundant in our body, we are going to focus on this type. This type of cartilage is formed by three components: the extracellular matrix, perichondrium and cells.

- Extracellular matrix is formed by fibers and ground substance.
- Perichondrium is a connective tissue that surrounds and nourishes cartilage.
- Cells that form the articular cartilage tissue are chondrogenic cells, chondroblasts and chondrocytes

All these cells have a mesenchymal origin. Chondrogenic cells are differentiated stem cells located in the internal face of the perichondrium and are present from fetal life to puberty. When these cells suffer a process of mitosis and differentiation, they become chondroblasts, which are active young cells responsible for the extracellular matrix synthesis. These cells suffer a process of mitosis becoming chondrocytes, mature cells with the function of extracellular matrix maintenance. Both chondroblasts and chondrocytes are located in lacuna or chondroplasty.

Structure of articular cartilage

Once it is known the composition of the articular cartilage, it is time to know the structure.

Articular cartilage is structured in four layers, from the most superficial one to the deepest we can find:

- Surface zone: It is the layer in which we can find elongated chondrocytes and collagen fibers arranged parallel to the surface.
- Intermediate zone: Where there are also chondrocytes but arranged without any order
- Deep zone: With chondrocytes arranged in linear isogenous groups and collagen fibers perpendicular to the surface.
- Calcified zone: It is a calcified matrix as her name says.

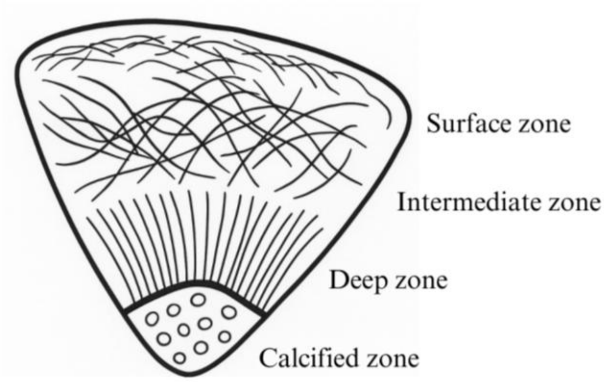

Figure 17. Structure of articular cartilage.

Localization of hyaline cartilage

Hyaline cartilage could be found in different parts of the body depending on the life stage. When a fetus is born, all the skeleton is formed by hyaline cartilage. In childhood and adolescence hyaline cartilage is present in the growth plates, where the bones grow. In adulthood, when the bones are completely formed, we find hyaline cartilage in nasal septum, larynx, trachea and bronchi, costal cartilages, and in the surface of mobile joints like knee, ankle or hip.

BIOMECHANICAL BEHAVIOR OF LUBRICATION OF ARTICULAR CARTILAGE

Lubrication of the articular cartilage

Lubrication is the process by which friction between two moving parts is reduced by introducing a fluid to separate the two contact surfaces. There are two mechanisms by which the articular cartilage lubricates (Nancy Stella Landínez-Parra et al., 2011):

- Barrier lubrication, in which a glycoprotein called lubricin is absorbed as a monolayer for each articular surface.
- Film-fluid lubrication, that generates a greater separation of the surfaces and supports the load.

Film-fluid lubrication of the articular cartilage

The film-fluid lubrication could be further divided into two subtypes:

- Hydrodynamic lubrication, in which load bearing surfaces slide against each other forming a fluid conversion and generating a real separation of the surfaces. It is the type of lubrication used to hold continuous loads.
- Film-press lubrication, in which articular surfaces move perpendicular to each other generating a viscous resistance of the fluid that acts preventing its escape from the space. This allows cartilage to support high loads for a short duration.

"Mixed lubrication" of the articular cartilage

These two types of lubrication mentioned before are not exclusive, generally several mechanisms are produced with the predominance of one. This is the so-called "mixed lubrication". In this way, in the low contact areas there is a predominance of film-fluid lubrication, while in areas of greater friction, the barrier lubrication is the type that dominates.

Viscoelastic response

This lubrication is important because cartilage is a tissue with special characteristics, specifically, it is a viscoelastic tissue.

Viscoelasticity is a type of behaviour exhibited by certain materials that present both viscous and elastic properties when deformed, i. e. the tissue is adapted to the shape of the load (viscous), but once the load disappear, becomes to the initial shape (elastic).

Thanks to this property, cartilage is capable of undergoing a constant load, responding with rapid initial deformation that becomes slow and progressive over time.

So, we can say that cartilage behaves like a hybrid between liquid and solid (Rodríguez-Camacho & Correa-Mesa, 2018).

WEAR OF ARTICULAR CARTILAGE

Wear of articular cartilage

Articular cartilage has some particular characteristics, like the absence of vascularization, the reason why this tissue is very susceptible to wear.

Wear is an imbalance between synthesis and degradation processes in the extracellular matrix, leading to a progressive loss of cartilage tissue.

We should always keep in mind that load and movement are the main requirements for the development, renewal and maintenance of cartilage and joint integrity.

However, if we subject the cartilage to constant load, it will produce a reduction in cartilage thickness but when we stop the activity, it produces a joint discharge and the hydrostatic pressure is re-established. So we need to find the perfect balance when we prescribe exercise to our clients (Camarero-Espinosa et al., 2016).

Factors contributing to wear

There are also other factors that contribute to wear of articular cartilage:

- Overweight: It produces an increase of the force through the joint inducing cartilage rupture, and of course, due to its relationship with the adipose tissue, this tissue acts like a systemic factor that accelerates cartilage rupture.
- Aging: In bone tissue, there are changes in cell function that hinder tissue maintenance. Moreover, when we are older, the wear surface increases.
- Overuse: Minor repetitive loads cause deformity of the tissue with the consequent cell death without enough regeneration, producing a tissue collapse.

Types of cartilage injuries

The wear of the articular cartilage can have different levels of severity, that is the reason why we can differentiate different injuries:

- Chondropathy: Caused by an overuse with minor repetitive trauma, sustained increased pressure of the cartilage or direct trauma. In this pathology, there is an interruption of nutrition from synovial fluid and a posterior destruction of the cartilage.
- Osteochondritis: caused by a gradual wear aggravated by excessive loads, decrease of viscosity of the synovial fluid, or local cartilage injury. This degeneration starts by a modification of the intercellular cement (chondromalacia) to continue with a loss of

connection between collagen fibers (fibrillation) and finally, cartilage erodes away exposing subchondral bone.

- Osteochondritis Dissecans: caused by a degeneration of the central zone of the cartilage. This fact produces a proliferation of the perichondrium that generates a peripheral ring of thickened cartilage; this cartilage suffers an ossification and detaches giving rise to the so-called “articular mice”.

HYPOTHESIS ON BIOMECHANICS OF ARTICULAR DEGENERATION

Patellar chondropathy

As we already know, cartilage degeneration is not only produced by aging, so researchers have hypothesized about the biomechanical component of this injury.

So, we are going to focus on patellar chondropathy because it is the most prevalent injury of the articular cartilage.

First of all, we need to know that patella orientation and position is a determining factor in the genesis of inadequate cartilage compression, and this position is given by the action of different static and dynamic elements or stabilizers.

Among static stabilizers we find:

- Patellofemoral congruence: both articular surfaces must fit each other
- Medial and lateral retinacles
- Patellofemoral ligaments
- Patellar tendon

Among dynamic stabilizers, we have:

- Cuadriceps (the most important ones), especially the vastus medialis.
- “Goose foot” (in spanish “*pata de ganso”*)
- Femoral biceps

These elements must work together for the correct functioning of the extensor apparatus, and if there is an imbalance, it could cause an injury.

Etiopathogenic factors

So, studying these elements, researchers have established three etiopathogenic factors in relation to cartilage degeneration:

- An abnormal patellofemoral morphology. During fetal life, it is possible that there is a patella dislocation, causing a lack of influence on the external condyle, and this will be flat and small.

- The malalignment of the extensor apparatus. This fact would be due to the defect of static stabilizers such as laxity of internal wing, hypertension of external wing, angle Q greater than twenty or a high patella. Also, we can find a defect of dynamic stabilizers like the atrophy of the vastus medialis. Moreover, there are congenital defects like genu recurvatum, genu valgum and femoral or tibial torsion.
- Traumas. Both direct trauma in which a fall is produced with patellar contact, or indirect trauma by a mechanism or flexion plus external rotation, causing a patella subluxation.

In general, we can establish a linear development from patellar imbalance, going by hyperpression, subluxation and luxation, causing chondromalacia and ultimately reaching osteoarthritis (Díaz-Mohedo, 2015).

Osteoarthritis should not be confused with the Spanish word “artritis”, because in English osteoarthritis is equal to the Spanish word “artrosis”.

EXERCISE FOR CARTILAGE WEAR

Exercise to prevent cartilage damage

Scientific evidence says that:

- Physical exercise helps to lose weight, and improve the function of the muscle and ligaments, thus preventing wear of articular cartilage.
- Exercise promotes the growth of muscle fiber volume, helping to discharge the joint.
- Physical activity regulates the load in the joint, helping to balance in the chondroblasts and chondrocyte's function.

So, exercise is highly beneficial to the patients, but we need to take into account the following key points before training them:

- An individualized evaluation of the etiopathogenic biomechanical factors is necessary.
- It is important to generate variability in sports gestures to avoid overuse by repetition.
- Avoid impact gestures with high load only until reaching a high level of physical conditioning.

Exercise training methods for osteoarthritis

There are some different types of exercise to be used having a client with osteoarthritis:

- Joint activity training. Based on joint mobility to avoid stiffness, and active mobility to alleviate tissue adhesion, improve blood circulation, accelerate metabolism, eliminate swelling and pain, and regulate chondrogenic function.
- Aerobic exercise. It improves symptoms like swelling and limited mobility and promotes heart and lung function. However, it is unclear the type of aerobic exercise that is more beneficial for cartilage, because swimming and cycling help to avoid high joint loads; but the impacts of running promote the repair.
- Aquatic exercise therapy. It promotes blood circulation, relieves tissue adhesion and reduces the pressure on joints. Moreover, the low water pressure can promote cartilage self-repair, but more research is needed.
- Muscle strength training. We can bet on multipoint intermittent isometric training, that improves muscle strength and function without pain; or isotonic, that is not recommended for acute inflammation phase (Xiao, 2020).

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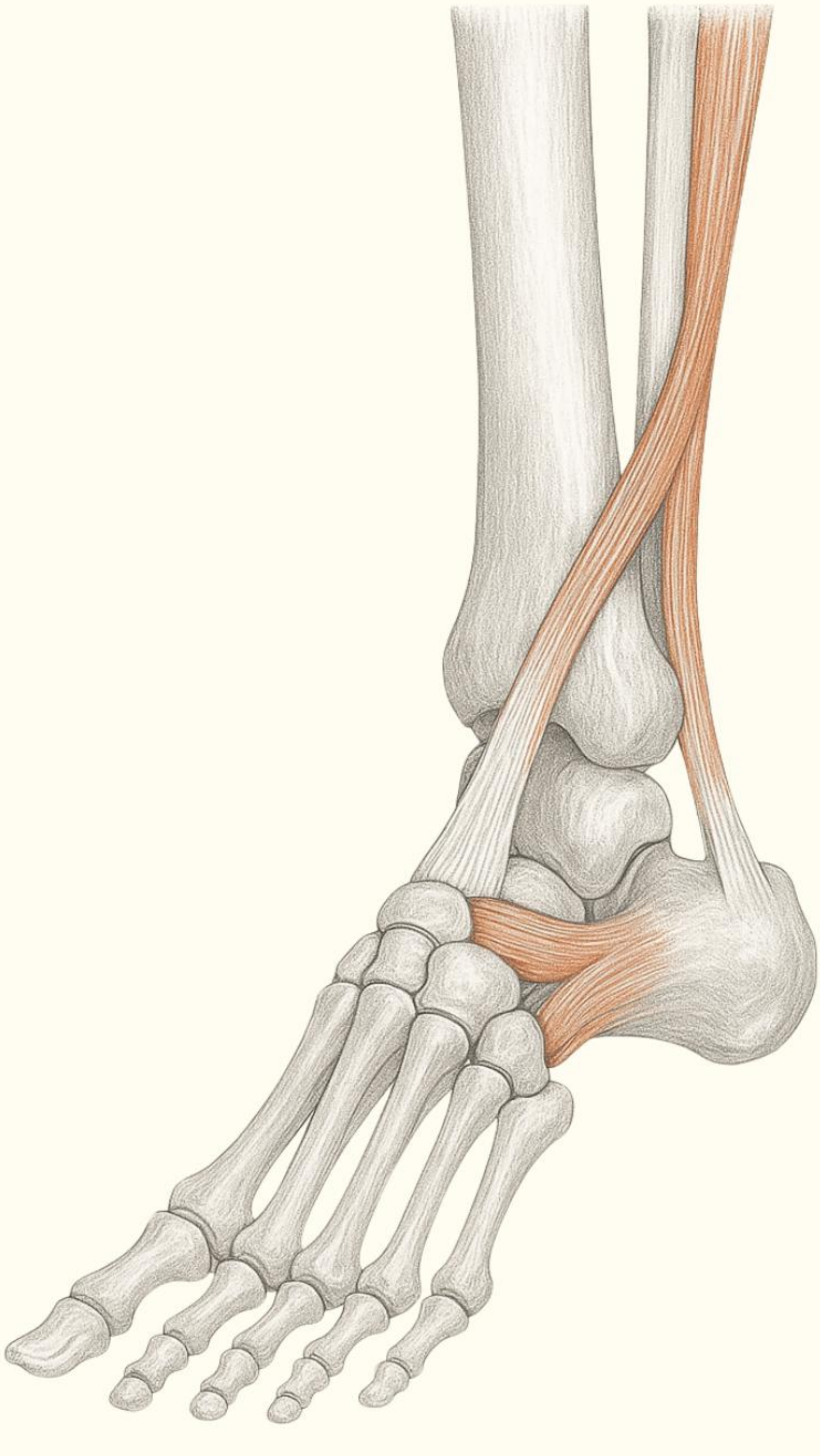


BIOMECHANICS OF TENDONS AND LIGAMENTS

COMPOSITION AND STRUCTURE OF TENDONS

Tendon

A tendon is defined as the junction between muscles and bones. They are structures subjected to a large tensile force (Abat González et al., 2022).

It is a type of regular dense connective tissue of parallel bundles, whose functions are:

- To transmit the load from the muscle to the bone.
- To give information to the brain about joint position.
- To allow movement of the joints thanks to the transmission of muscle contraction.

Composition of tendons

Tendon composition is the sum of three components:

- Thick bundles of type one collagen
- Limited ground substance
- Few fibroblasts, so-called tenocytes.

Tendon cells

Tendon cells are sandwiched between collagen fibers and arranged in a network aligned along the axis of the tendon.

We find the following cells:

- Vascular cells, located on tendon feeding vessels
- Synovial cells, located on paratenon
- Chondrocytes located, on tendon-bone union
- Tenocytes, the most numerous ones in the tendon. These cells are sensitive to mechanical stimuli and adapt the extracellular matrix through anabolic or catabolic changes depending on the magnitude, frequency, direction and duration of the loads. These characteristics allow them to fulfill three functions: the synthesis of the extracellular matrix, the maintenance of tendon homeostasis and the repair of injuries.

Structure of tendons

Tendons have a hierarchical fibrillar organization, with a sequence of collagen molecules forming fibrils, fibers and fascicles.

This structure is surrounded by various layers that reduce friction with the environment:

- Endotenon, that covers the fascicles
- Epitenon, that covers the tendon
- Paratenon, that covers the epitenon.
- Peritenon, the sum of epitenon and paratenon

In addition, there are proteoglycans and glycoproteins aligned with the longitudinal axis of the tendon.

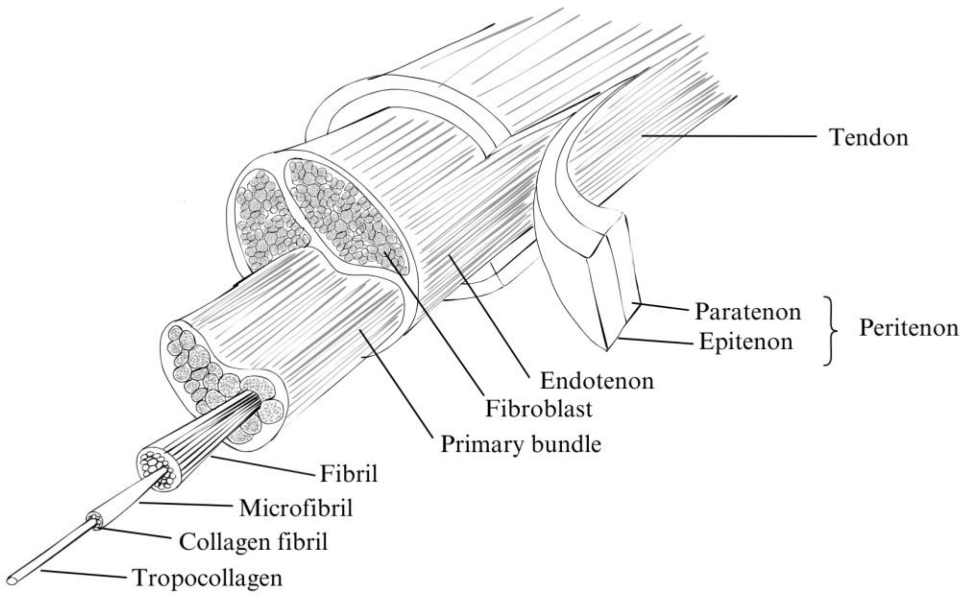


Figure 18. Structure of tendons.

Innervation and neurotransmission

Tendons are structures characterized by its rich innervation composed by mechanoreceptors, nociceptors, and the autonomic system.

Among the mechanoreceptors we find:

- Ruffini's corpuscles which are sensitive to stretch and are located especially in areas with high mechanical requirements.

- Vater-Pacini's corpuscles that are sensitive to transient mechanical displacements and vibration.
- Golgi tendon organs that are sensitive to strain changes and are characterized by a fusiform shape and the connection to groups of muscle fibers.
- Neuromuscular spindles that are sensitive to changes in length and the speed of said length, that allow to send information to the brain about joint position and joint movements.

Moreover, we find nociceptors that are free nerve endings sensitive to stimuli potentially damage to tissue. When they send the alarm signal to the brain it doesn't mean that there is structural damage, only that danger has been detected. Establishing a parallelism, we could say that they are like the parking sensor of the car that beeps when we approach something, not when the car has already crashed.

Finally, we find the receptors of the autonomous system that are located in the walls of blood vessels and are responsible for vasomotor modulation (Vega, 1999).

COMPOSITION AND STRUCTURE OF LIGAMENTS

Ligament

Ligaments are the unions between bones and like tendons, are structures subjected to large tensile forces but less than those of the tendons (Saló i Orfila, 2016).

Regarding the type of tissue, ligament is regular dense connective tissue of parallel bundles whose functions are:

- Joint reinforcement and stability.
- Guide movements by restricting them in certain angles.
- Facilitation of proprioceptive information to the central nervous system.

Composition of ligaments

Ligaments are composed by collagen and elastic fibers, ground substance and fibroblast.

They are similar to tendons but the fibers are less organized. In addition, some of the ligaments have more elastic fibers than collagen fibers.

Ligament cells

Compared to other tissues, ligaments have poor vascularization and few cells. These cells are:

- Fibroblasts, responsible for procollagen synthesis, and their main notable characteristic is the possibility of establishing connections to adjacent cells forming a three-dimensional network.
- Fibrocytes that are fibroblasts trapped in the extracellular matrix and aligned between fibers.
- Endothelial cells.
- Macrophages.

The reason why there are so few cells in the ligaments is that these, together with proteoglycans, elastin and glycoproteins, account for only 25% of the weight of the ligament, since the other seventy-five per cent corresponds to collagen.

Structure of ligaments

Ligaments, like tendons, have a hierarchical fibrillar organization, with a sequence of collagen molecules forming fibrils, fibers and fascicles.

However, the ligament is only surrounded by a thin coating membrane called epiligament with different characteristics in intra-articular ligaments because they are surrounded by a synovial membrane.

Innervation and neurotransmission

In relation to the innervation and neurotransmission, although at first it may seem very similar to tendons, we need to stop and analyze it because they present many differences.

Among the mechanoreceptors we find:

- Ruffini's endings in ligaments are sensitive to joint position, intra-articular pressure and range and speed of movements.
- Paccini's corpuscles, sensitive to acceleration so they are only active during motion.
- Golgi receptors, sensitive to strain changes, specially at the end of the range of motion.

Moreover, we find nociceptors that, as we already know, are free nerve endings sensitive to stimuli that potentially damage to tissue.

It is essential to distinguish between nociception, which always occurs, and is the transmission of the stimulus message to the central nervous system regardless of whether there is damage or not, and pain, which is the interpretation made by the brain of that message and it is not directly related to the structural damage (Fort Vanmeerhaeghe & Romero Rodriguez, 2013).

BIOMECHANICAL PROPERTIES OF TENDONS AND LIGAMENTS

Stress and strain

To start to talk about biomechanical properties, it is very important to differentiate between stress, that is the load applied to the tissue; and strain, that is the longitudinal deformation the tissue undergoes when loaded.

With these two parameters we can generate the stress-strain curves that help us to analyze the mechanical response of the tissues.

In these curves, we can find four different stages («Biomechanics of Tendons and Tendon Failure», 2003):

- Toe region, in which the tissue undergoes a minor load, and suffers a straightening of the crimp inherent in the structure.
- Linear region, in which the tissue is under a greater load, suffering a transient linear deformation.
- Yield point, in which the load is even higher, and the tissue suffers an irreversible deformation.
- Failure point, in which the tissue is under a maximum load, more than it can bear, and suffers an overall deformation and probably an injury.

Biomechanical properties

Taking into account this mechanical response we can deduce that the main biomechanical property of tendons and ligaments is the quasilinear viscoelasticity that means that they have elastic properties that allow them to return to their original shape after deformation and viscous properties that promote that the tissue remains in the deformed state depending on the strain rate.

In addition, tendons have specific characteristics in relation to the strain rates. At low strain rates, they can absorb more mechanical energy but are less effective in carrying loads. But at high strain rates, they become stiffer and more effective in transmitting large muscular loads to the bone (Wang et al., 2012).

FACTORS THAT AFFECT THE BIOMECHANICAL PROPERTIES OF TENDONS AND LIGAMENTS

Etiopathogenesis of tendon injuries

Biomechanical properties of ligaments and tendons are affected by some factors that generally promote injuries.

It is going to be studied now the etiopathogenesis of four tendon injuries (Díaz-Mohedo, 2015):

- Compression forces, so-called impingement, in which it produces a mechanical pinch of the tendon by a bone. His main causes are anatomical abnormalities like the hooked acromion or the presence of osteophytes, and soft tissue inflammation.
- Friction forces, when the tendon rubs against a hard surface. Main causes are overuse and lack of flexibility.
- Tensile forces when these forces exceed the elastic capacity of the tendon generally by overuse.
- Overuse, when we subject the tendon to low intensity repetitive stimuli.

Tendinopathy

All these factors always cause the same injury, called tendinopathies.

Surely you have heard in your environment the typical sentence: “I have tendonitis”, and less commonly, “The doctor told me it is tendinosis”, but these terms are outdated.

Nowadays, we are governed by Cook’s continuum model of tendinopathy, which divides this injury into three stages:

- First stage: “reactive tendinopathy”, which is characterized by a non-inflammatory proliferative response, that means a short-term adaptation with an homogeneous thickening of a portion of the tendon.
- Second stage: “tendon dysrepair”. In this stage a tendon healing attempt occurs, but really it produces an increased matrix degradation and an increase of cell number. This promotes collagen separation, matrix disruption and neovascularization.
- Third stage: “degenerative tendinopathy”, in which the changes in cells and matrix continue, but with more extensive collagen disruption, widespread cell death and extensive growth of new vessels and nerves into the tendon. The worst thing is that these changes are not reversible.

Most common tendon injuries

And since we have entered to analyze the tendinopathies we are going to give very brief brushstrokes on the most common:

Along the upper limb we have two common tendinopathies: subacromial impingement and epicondylitis.

- Subacromial impingement is a compression or entrapment of the rotator cuff and bursa in the subacromial space. The patients refer to pain in the anterolateral side of the shoulder and functional inability to raise the upper extremity.
- Epicondylitis means microtears of the extensor carpi radialis brevis and fibrosis. The patients refer to pain in the lateral border of the elbow with inability to perform grasping tasks. It is called "tennis elbow".

On the other side, we have two common tendinopathies in lower limb: iliotibial band syndrome and patellar tendinopathy.

- Iliotibial band syndrome, characterized by the friction of the iliotibial tendon against the femoral condyle. The patients refer to pain in the lateral side of the knee, especially when climbing stairs, running or sitting for a long time with knee flexion.
- Patellar tendinopathy means inflammation of the patellar tendon and pain in the anterior side of the knee.

Treatment of tendinopathies

Once the most common tendinopathies and their causes have been studied, it is necessary to talk about the therapeutic approach, which is always conservative and based on exercise (Escriche-Escuder et al., 2021).

Nowadays, the most actualized scientific evidence bets on therapeutic exercise programmes supervised by physiotherapists with a total duration of 14 weeks and 70 sessions, with 3 weekly sessions of neuromuscular strength training and 2 weekly sessions of aerobic work, and the range of intensity will vary between 60%-70% of maximal oxygen consumption.

The most current protocol is the MaLaGa protocol, which has five stages:

- Stage one is based on isometric contractions to control symptoms and prepare the neuromuscular system for later phases.

- Stage two continues with isotonic and heavy slow resistance exercises, to improve muscle strength and tendon stiffness.
- Stage three is based on strength training through exercises performed with a velocity loss of twenty per cent, to increase muscle hypertrophy.
- Stage four continues with high-load strength training, to obtain maximal strength benefits due to the hypertrophy and the neural adaptations.
- Stage five finishes with plyometric training and jumps to improve the energy storage capacity of the tendon.

Training in tendinopathies

In terms of preventing tendinopathies, in training programmes we should (Burton, 2022):

- Include progressive resistance training in athletes at risk of suffering tendinopathies, such as jumping athletes.
- Avoid very explosive gestures in non-usual sport customers, the so-called "weekend athletes".
- Include balance training in relation to the specific sport activity.
- Not cause overuse of the upper limb in load above the horizontal line.

In terms of treatment, we should:

- Adapt the mechanical stimuli to the phase of the tendinopathy we are in. It is not the same a reactive tendinopathy that a degenerative tendinopathy.
- Include eccentrics but adapting the load. We know that eccentric exercises are beneficial but risky at the same time.
- Design long-term programmes due to the fact that the progression in load and neural adaptations are slow processes.

Tendon ruptures

Nevertheless, although tendinopathies are the most common injuries of the tendon, they are not the only one. Tendon ruptures may also occur, which are a total or partial interruption of the transverse section of the tendinous tissue (Hess, 2010).

The symptoms are different between total and partial ruptures. In total ruptures, the patients refer: sudden, severe pain; functional inability; and deformity to the retraction of the fibers. But in partial ruptures, the patients refer: diffuse pain maintained over time; progressive lack of strength; and sometimes: bruising and depression on palpation.

Regarding the etiopathogenesis, the causes are the same in both total or partial ruptures:

- Sports activity, especially in the so-called “weekend athletes”.
- Previous tendon degeneration.
- Use of local corticosteroids, like infiltrations.
- Adverse drug reaction, specially in the use of fluoroquinolones.
- Background of gout.
- Blood group cero.
- Biomechanical alteration such as varus, valgus, hyperpronation or anatomical abnormalities.

Most common tendon ruptures

Among the most common tendon ruptures we find:

- Achilles tendon rupture, that is produced by a contraction of the triceps surae to gain impulse which is opposed by body weight. Generally, it is produced in sports activities, especially jumping and running. The patients present Brunet-Guedj sign that is the loss of the physiological equinus of the foot in prone position; and Thompson sign which occurs when compressing the triceps surae with one hand there is an absence of plantar flexion.
- Patellar tendon rupture, that is produced by eccentric contraction of quadriceps against body weight with knee flexion. The patients present high patella and feeling of knee instability.
- Rotator cuff tendon rupture, that is produced by a progressive degeneration by overuse in shoulder abduction, and it is characterized by Jobe sign, which is the inability to maintain the upper limb in abduction against resistance.
- Thumb tendon rupture, that is produced by an extreme force against resistance or fractures of adjacent bones. The patients present an interphalangeal joint in flexion or extension and no active mobility in the opposite direction.

Treatment of tendon ruptures

In relation to the treatment of tendon ruptures we find two options: conservative or surgical approach.

Among conservative approach, the options are:

- Immobilization with plaster during eight weeks. The first four weeks on equine without load and the following four weeks decreasing the equine progressively and authorizing load. This option has two main disadvantages, the incomplete functional recovery and the high recurrence rate.
- Functional treatment with equine orthosis during one month. The first twenty days at thirty degrees of plantar flexion with fifteen or twenty kilos of load; days twenty to twenty-four at twenty degrees of plantar flexion; days twenty four to twenty eight at ten degrees of plantar flexion; and from day twenty eight at neutral position with complete load.

Regarding the surgical approach, the option is a reconstruction of the tendon by the union of the free endings, and after surgery, the use of protocols of early physiotherapy and functional immobilization with dynamic orthosis. This option has some advantages such as better healing, without permanent loss of strength, allowing early rehabilitation with less muscle atrophy and return to normality.

Training after tendon rupture

With this knowledge we can deduce some key points to apply them to the training of our customers.

In terms of prevention, we should:

- Include a warm-up period to increase temperature of tissue and extensibility of the fibers.
- Include previous training with eccentric strengthening before the return to play, to prepare the tissue for the mechanical stimuli.
- Ask the customers, if they are under any pharmacological treatment, to estimate the risk due to this fact.

In terms of treatment, we should:

- Include proprioceptive training to allow the patient to recover body awareness.
- Take into account the factors that caused the injury to avoid them in the first instance, and make a safe readaptation to the injury mechanism.

Etiopathogenesis of ligament injuries

Now, we are going to explore the same parameters in relation to the ligaments.

Firstly, we need to talk about the etiopathogenesis of ligament injuries. The main causes are:

- Force exceeding the resistance of ligament tissue.
- Hyperlaxity or other syndromes involving collagen such as Ehlers-Danlos syndrome or Marfan syndrome.
- Biomechanical alteration, like for example differences in qiu angle in relation to the rupture of the anterior cruciate ligament.
- Hormonal status, due to the fact that during the menstrual cycle more elastine is produced, so there is more ligamentous laxity.
- Muscle imbalance, that produces a higher load on tendons and ligaments.

Sprain

The most common ligament injuries are sprains, that are based on a distention of the capsuloligamentous apparatus caused by a forced movement beyond the physiological limits.

The classification depends on the severity level, and it is the following:

- Grade one, in which the ligament suffers an elongation without tearing, and the patients refer to symptoms like pain and inflammation, but without instability.
- Grade two, in which it produces a partial rupture of ligament fibers, and the patients refer to symptoms like pain, inflammation, ecchymosis, partial functional inability and partial instability.
- Grade three, in which it produces a total rupture of the ligament, and the symptoms are pain, inflammation, ecchymosis, complete functional inability and relevant instability.

Figure 19. Sprain.

Treatment of sprain

When treating a sprain we must distinguish several moments.

At first instance, the so-called RICE protocol is usually applied, which consists of Repose, Ice, Compression with functional bandage, and Elevation.

After this, the recovery process starts and the best option is to apply a therapeutic exercise program based on:

- Gaining mobility, especially dorsal flexion
- Improving motor control and strength
- Including proprioceptive and plyometric training
- Developing a stage of return to play.

Training in sprains

These are some key points in terms of prevention of sprains and treatment of people who have suffered a sprain (Doherty et al., 2017).

In relation to the prevention:

- Analyze the laxity of the ligaments before prescribing exercises to be able to "play" with the ranges of motion.
- Include proprioceptive training, especially in people with a background of sprain to avoid a recurrence.
- Bet on neuromuscular coordination through the use of dual tasks.

In addition, when a customer who has recently suffered a sprain arrive to your training centre, you need to keep in mind that:

- It is useful to use functional bandage or braces to return to play with more security, but it is important not to abuse these tools, because they do the function of maintaining stability, making the ligaments and muscles not perform their stabilizing role and making them "lazy".
- It is relevant to include exercises for quick changes of direction when the customer has enough strength and motor control.
- You have to work on impact exercises progressively.

Ligament ruptures

Another common injury of the ligaments is the ligament rupture that is the interruption of the transverse section of the ligamentous tissue that promotes symptoms such as edema, swelling, pain, ecchymosis and functional inability.

The most common is the anterior cruciate ligament rupture, whose mechanisms of injury are:

- An impulse in a jump and fall with the knee in semiflexion, force valgus and external rotation of the tibia, which will promote a rupture of anterior cruciate ligament, followed by the internal lateral ligament and finally the internal meniscus.
- The turn of the body with the knee in semiflexion, forced varus and internal rotation of the tibia, which will promote a rupture of anterior cruciate ligament, followed by the external lateral ligament and finally the internal or the external meniscus.
- The turn of the body with the knee in extension and forced valgus, which will promote a rupture of internal lateral ligament, followed by the anterior or the posterior cruciate ligament.
- The turn of the body with the knee in extension and forced varus, which will promote a rupture of external lateral ligament, followed by both the anterior and the posterior cruciate ligament.
- A pure abrude hyperextension of the knee, which will promote the solely rupture of the anterior cruciate ligament.

Surgical approach

In 95% of the cases of anterior cruciate ligament rupture, the surgical approach is chosen, which consists of replacing the torn ligament with a plasty.

There are two options for building the plasty:

- Autologous ligamentoplasty, in which the material is from the patient himself, extracted from another area, generally from a tendon such as the patellar or quadriceps tendon.
- Heterologous ligamentoplasty, in which the material is a graft from a tissue bank, from a cadaver. This technique has a risk of rejection but in some cases is the unique option, such as, for example, in people with the Ehler-Danlos syndrome because their tendons are hyperlax too, as are their ligaments, so the autologous ligamentoplasty would be a sure failure.

After the surgery, it is important to choose a long-term rehabilitation program with the physiotherapist based on:

- Recovery mobility.
- Gain strength.
- Return to normality in terms of muscle mass.
- Do a functional readaptation.

Training in ligament ruptures

Regarding the training of people who have suffered a ligament rupture you need to (Zebis et al., 2016):

- Bet on exercises focused on restoring technical skills due to the fact that after surgeries or other traumatic events the brain suffers a phenomena called “smudging” which is like an erasure of the movement patterns that it had.
- To establish a progression from controlled slow pre-planned movements to highly chaotic reactive sport-specific movements.
- To ensure that the patient is psychologically prepared for each new challenge in his recovery process.

However, as in the most cases, you can act in terms of prevention, specially when you work as physical trainers in sport teams, taking into account the following points (Buckthorpe, 2019):

- Include exercises focused on body awareness and motor control at the hip, knee and ankle, during standing, jumping and running.
- Bet on neuromuscular training, focused on quadriceps and hamstrings, on pre-season and during the season.

Joint instability and dislocations

To finish with ligament injuries, we need to talk about joint instability and dislocations due to its high prevalence.

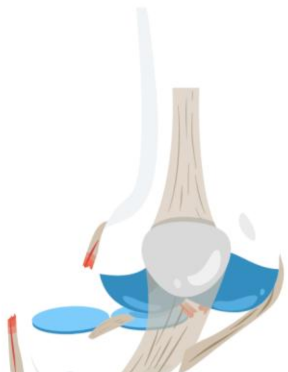
When we have an overstretched or a torn ligament, we are going to suffer joint instability, and this fact could produce a dislocation, which is the complete and stable separation of two joint surfaces.

The main symptoms of dislocations are:

- Deep and fatiguing pain that is exacerbated by moving the joint.
- Absolute functional inability.
- Deformation.
- Edema.

In addition to these symptoms, there are risks such as:

- An increase in the feeling of instability, which can become chronic.



- Bone injury, like fractures or partial loss of bone.
- Nerve injury, like nerve rupture or nerve impingement.

Figure 20. Knee dislocation.

Treatment of joint instability

Regarding the treatment of dislocations, it needs:

- Immediate medical treatment aimed at reducing the dislocation. The longer the dislocation is maintained, the greater the risk of irreversible damage.
- After the reduction, an immobilization of the joint to ensure healing of the damaged tissues. There is great controversy in terms of time of immobilization.
- A therapeutic exercise programme supervised by a physiotherapist with the following characteristics: 12 weeks of duration, 36 total sessions with 3 weekly sessions, working with an intensity from 60-80% of the maximal repetition, and progressing through strength from isometric to isotonic, hypertrophy, neural adaptation without velocity loss and functional readaptation.

If the conservative approach doesn't work or the structural damage is enough, we need to choose the surgical approach which could consist of a ligamentoplasty or in the case of the shoulder, a labral-anchored capsulorrhaphy.

Training in joint instability

Regarding the training in this pathology, we can act to prevent the dislocation, keeping in mind (Ramírez-Pérez & Cuesta-Vargas, 2024):

- To analyze the laxity of the ligaments before prescribing exercise, to "play" with the range of motion.
- Do not abuse overhead exercises or exercise in the position of maximal abduction plus external rotation of the shoulder.

- To ensure strength and stability before looking for hypertrophy.

In addition, in terms of treatment, you should:

- Be careful with the range of motion of the exercises prescribed.
- Establish a plan to achieve a safe readaptation to the mechanism of injury.
- Overlap different stages of treatment in a waterfall manner.

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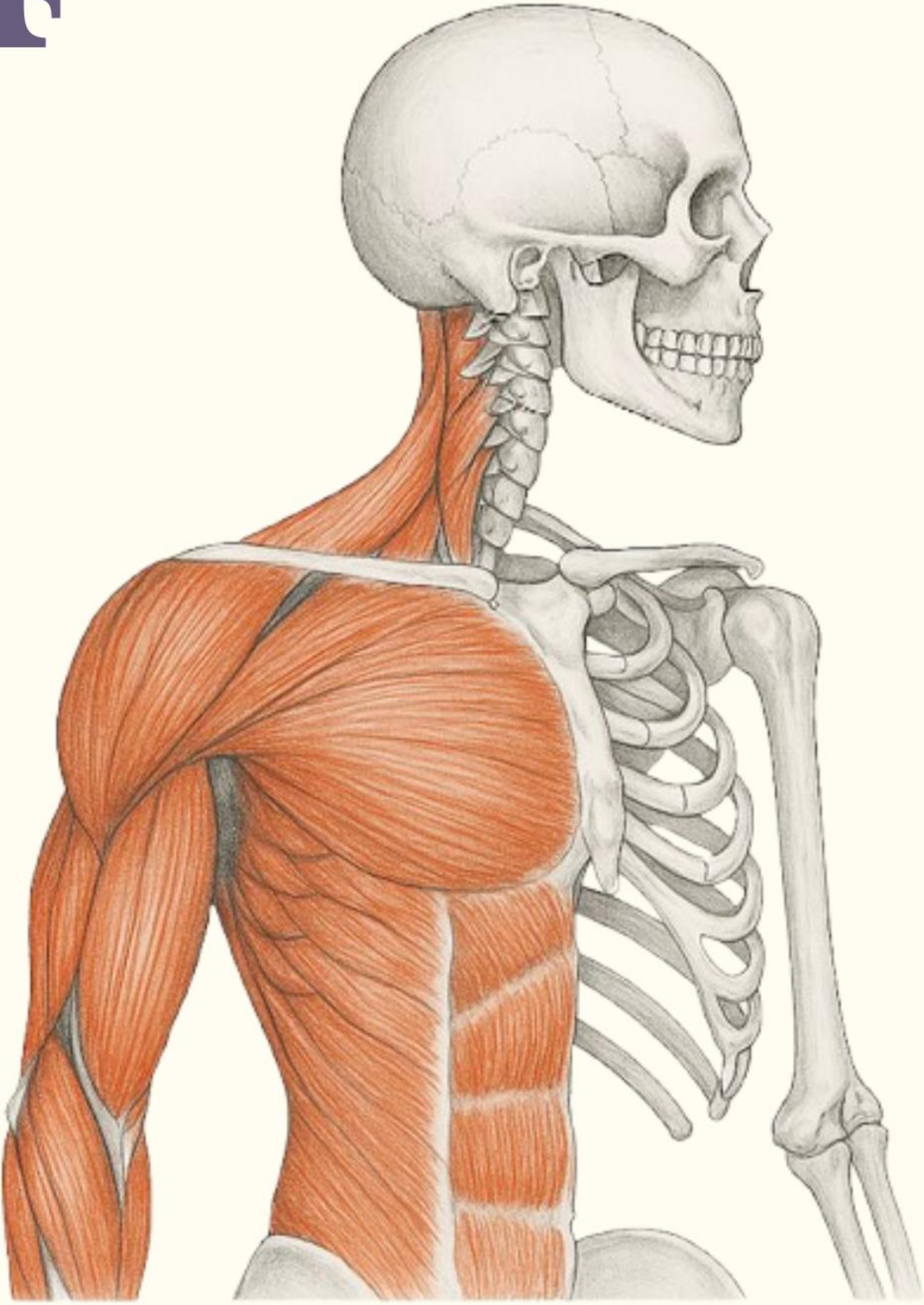

MUSCLE BIOMECHANICS

COMPOSITION AND STRUCTURE OF SKELETAL MUSCLE

Type of muscles

Muscle is a muscle tissue organ of mesodermal origin whose fundamental property is contractility.

According to their structure we can divide muscle tissue in two types:

Stripped muscle tissue

It is an organized structure of myofilaments.

- Skeletal muscle: voluntary contraction to allow motion. It is attached to the bones through tendons
- Cardiac muscle: involuntary contraction to allow cardiac rhythm

Smooth muscle tissue

This type of muscle is without striations.

- Location: walls of viscera and vessels, and dermis
- Involuntary contraction to allow the motion of the walls of the internal organs

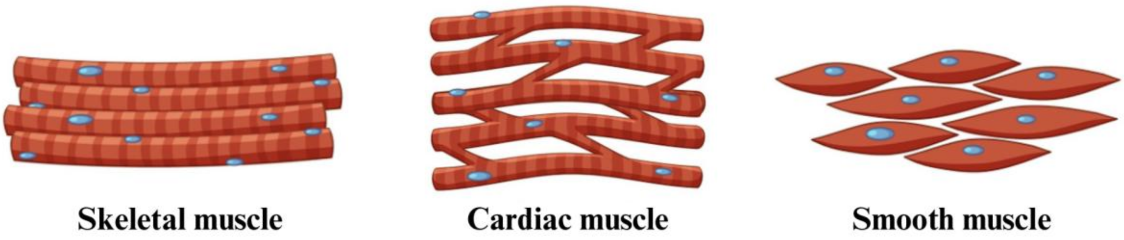

Figure 21. Types of muscular cells.

Cell of skeletal muscle

Muscle cells are called muscle fiber. And their characteristics are:

- Cylindrical shape
- Multinucleated
- Cytoplasm with transverse striations

- Red-colored, because of the high content of myoglobin which is an oxygen-binding protein.

Each muscle fiber receives an axonal ending from a motor neuron forming the motor plate.

Cell elements

- Sarcoplasm: muscle cell cytoplasm, which has transverse bands, organelles and myofibrils.
- Sarcolemma: plasmatic membrane.
  - T-tubules: invaginations associated to the sarcoplasmic reticulum that enter into the sarcoplasm surrounding each myofibril at the level of the bands A-I.
  - Dystrophin: protein that links the actin cytoskeleton to a protein complex in the sarcolemma, which binds to the extracellular matrix.
- Nuclei: flattened shape and there are several hundred for each cell.

Myofibrils

Myofibrils are cylindrical and elongated structures formed by actin and myosin myofilaments. There are about 200 - 3000 per muscle cell.

Ultrastructure

- Thick myofilaments: one protein --> Myosin II.
- Thin myofilaments: three proteins --> Actin, tropomyosin and troponin.

Sarcoplasmic reticulum

Surrounds each myofibril and is formed by a network of smooth endoplasmic reticulum tubules, which converge in 2 terminal cisterns, in the center of which is a T-tubule → TRIAD.

Types of bands

Bands

- A : dark band.
- I: light band.
- H: light band in the center of the A band.

Lines

- M: dark line in the center of the H band.
- Z: dark line in the center of the I band.

The sarcomere is a morphofunctional unit of striated muscle. It is the zone between two Z lines.

MOLECULAR BASIS OF MUSCLE CONTRACTION

Organisation of skeletal muscle

Muscle → fascicle or bundles → muscle cells → myofibrils → myofilaments

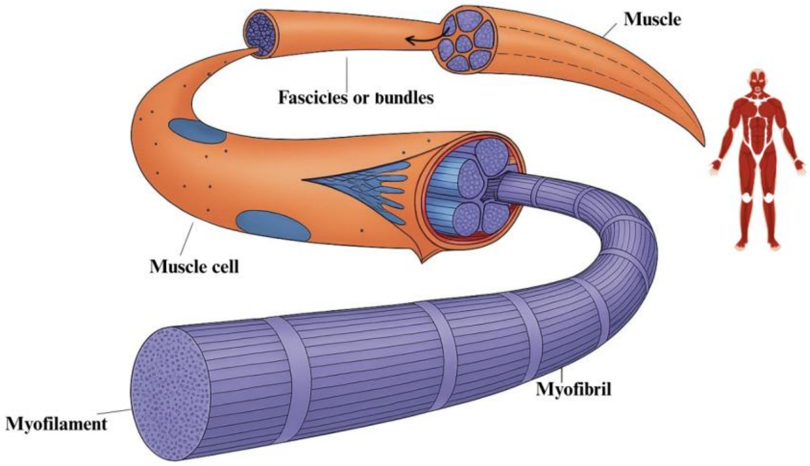

Figure 22. Organisation of skeletal muscle.

Myofilaments

Contractile proteins → transform chemical energy into mechanical energy. Mechanical energy is the key for muscle contraction.

	MYOSIN	ACTIN
Filament type	Thick myofilament	Thin myofilament
Structure	- 2 heavy chains - 4 light chains	G-actin monomers assembled into **F-actin polymers**
Interaction	The globular head has **hinge region** to interact with actin	F-actin binds to **troponin** and **tropomyosin**

Function	Transforms chemical energy into mechanic energy	Crucial structural component of muscle contraction

Ions and molecules for muscle contraction

- Ca 2+: ion released from sarcoplasmic reticulum that enables actin-myosin binding by shifting tropomyosin away from actin sites.
- ATP: energy storage molecule that bind to the globular head of the myosin
- Na+: sodium ion input causes depolarization
- K+: potassium ion output causes repolarization or hyperpolarization
- Acetylcholine: is a neurotransmitter that acts on the motor neuron plate.

Molecular basis of contraction

The contraction of skeletal muscle is an ATP-dependent process that involves interaction between actin, myosin, regulatory proteins and calcium ions. This cycle can be explained in five stages (Lehninger et al., 2005):

1. ATP Binding and Myosin Energization. ATP binds to the head of the myosin molecule, generating the dissociation of myosin from actin. The ATP is then hydrolyzed to ADP and inorganic phosphate (Pi), which energizes and reorients the myosin head (approx 90º relative to the tail).
2. Calcium activation. Calcium ions bind to the TnC subunit of troponin, inducing a conformational change in the troponin complex. This pulls tropomyosin away from the myosin-binding sites on actin, exposing them and allowing interaction.
3. Cross-Bridges Formation. The energized myosin head binds to the exposed actin site, forming a cross-bridge between actin and myosin.
4. Power Stroke. The release of Pi initiates the power stroke, during which the myosin head pivots from 90º to 50º, pulling the actin filament toward the center of the sarcomere. This results in sliding of thin (actin) filaments over thick (myosin) filaments, shortening the muscle fiber.
5. Cycle Continuation. A new ATP binds to myosin, causing it to detach from actin. If calcium remains available, the cycle repeats, if not, contraction ends.

MECHANISM OF MUSCLE CONTRACTION

Mechanisms of contraction

A band will remain constant while I band shortens.

Sliding of thin filaments over thick ones.

Z lines get closer.

Sarcomeres shorten.

Excitation/contraction coupling

1. The nerve impulse reaches the axon terminal and acetylcholine is released thanks to the input of calcium ions.
2. Acetylcholine diffuses to nicotinic receptors on the surface of the sarcolemma, triggering the opening of sodium channels. Sodium enters the cell, leading to the generation of a threshold action potential
3. Action potential propagates across the sarcolemma and down the T-tubules
4. Voltage-gated receptors are stimulated leading to the release of calcium from the T-tubules
5. Calcium binds to troponin, which pulls on tropomyosin, exposing the actin-myosin binding site. This allows the formation of the actin-myosin bridge, leading to muscle contraction (John E. Hall & Michael E. Hall, 2021).

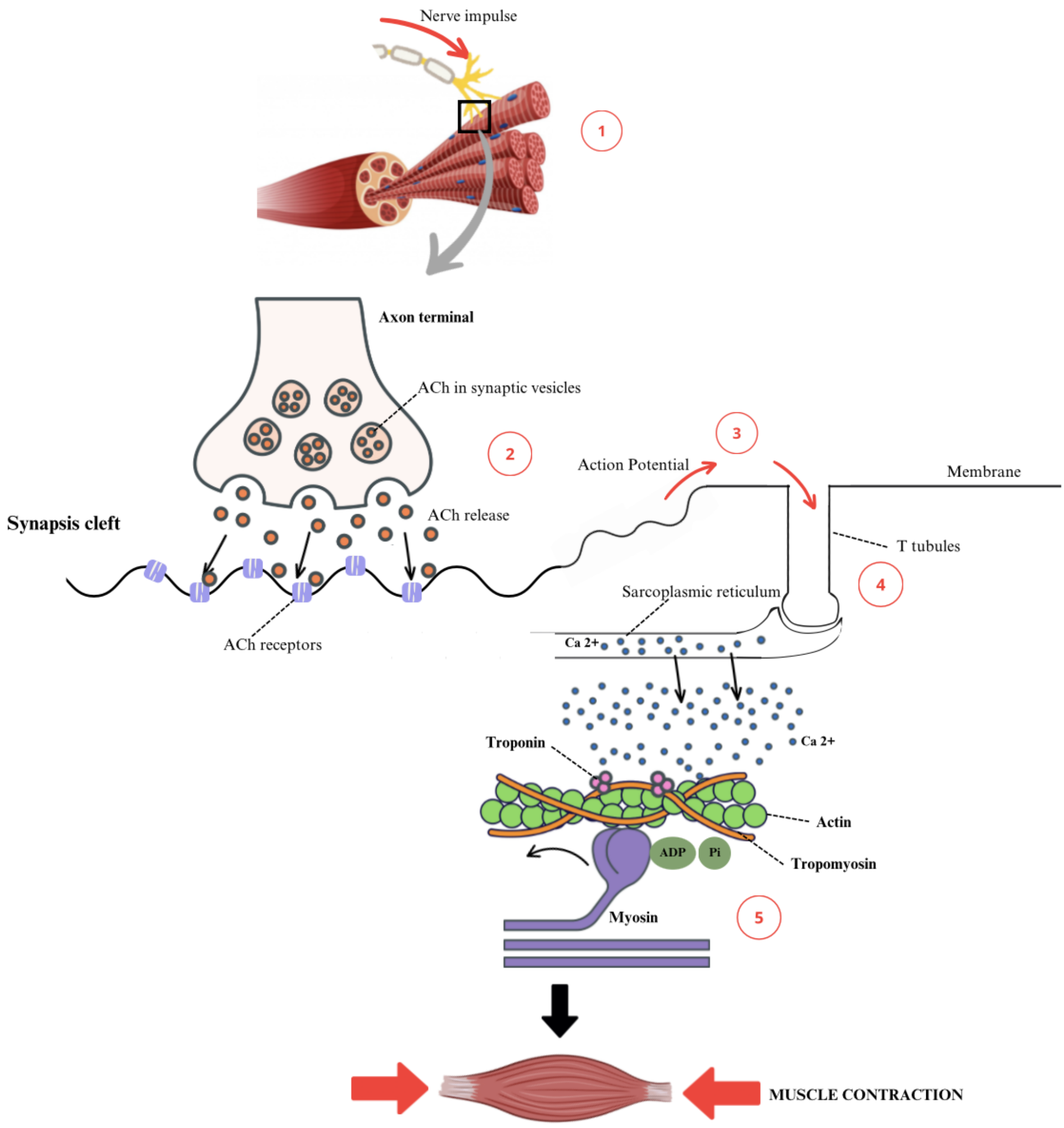

Figure 23. Excitation/contraction coupling.

Muscle relaxation

Acetylcholinesterase breaks down acetylcholine in the synaptic cleft.

Calcium pumps (active transport) bring calcium back into the sarcoplasmic reticulum.

A calcium-binding protein (calsequestrin), helps get calcium into the sarcoplasmic reticulum.

FORCE PRODUCTION IN MUSCLE

Key concepts

The contraction type of muscle activity created in response to a stimulus. This physiological process may or may not result in visible muscle shortening. Instead, it can produce changes in either muscle length, tension, or both, depending on the nature of the contraction. Muscle contractions are thus not solely defined by muscle but rather by the generation of force within the muscle tissue, which may manifest as isometric (tension without shortening), concentric (shortening), or eccentric (lengthening under tension).

The force is the physical capacity to perform a work or a movement. While the tension is the force developed by a muscle per unit area. If we talk about load we mean the force-weight of an object on the muscle. And the last key concept is the power that is the amount of work per time unit.

Type of contractions

Isometric. The developed tension is equal to the load. Because of this, there is no length change in the muscle

Isotonic. The developed tension is not equal to the load. Because of this, there is a change in the length of the muscle. In this case, there is a delay from the muscle activation to the length change (time to reach necessary tension). There are two subtypes:

- Concentric: tension is greater than load and the muscle shortens.
- Eccentric: tension is minor than load and the muscle stretches.

Contraction force graduation

The regulation of muscle contraction force primarily depends on motor unit recruitment.

- Small motor units are activated for fine, precise movements, while large motor units generate greater tension.
- Motor units may fire asynchronously which helps delay fatigue and sustain muscle contraction.
- Wave summation occurs when a second stimulus is applied before the muscle has completely relaxed, resulting in increased force production

- At high stimulation frequencies, the muscle reaches a state of tetanus, where maximum tension is achieved and the muscle stops responding to further stimuli.

MUSCLE FIBER DIFFERENTIATION

Type of fibers

Type I fiber

- Also called slow or *red fibers* (they are called *red fibers* because they contain a high amount of myoglobin and mitochondria, giving them a reddish appearance due to increased oxygen storage and aerobic capacity)
- Allow repeated contractions during long periods
- More resistant to fatigue
- Aerobic metabolic processes
- Energy substrate: glucose and glycogen

Type II fiber

- Fast or *white fibers*
- Two subtypes: IIa and IIb (fasters)
- Allow strong and fast gestures
- Fatigue quickly
- Anaerobic metabolic processes
- Energy substrate: phosphocreatine and ATP

Individual differences

Each person has a different proportion of fiber types. This, plus other factors generate the individual athletic qualities.

Moreover, the individual athletic qualities and the training influence the formation of one type or another of fibers:

- Strength training: converts some IIa fibers to IIb fibers that are larger, stronger and faster.
- Endurance training: converts some IIa fibers to I fibers that work better in long-term efforts.

So, it is more difficult for type I fibers to differentiate into other types, since they are not as versatile as IIa fibers.

Training effects in muscle function

- Improvement in capillarization → more resistance to fatigue.
- Increase of the diameter of muscle fibers → strength and muscle mass (hypertrophy)
- Increase of the enzyme activity (aerobic or anaerobic), depending on the specificity of the training.

IMPORTANT: adaptations are not only morphological, but also physiological.

MUSCLE REMODELING

Plasticity of skeletal muscle

Muscle plasticity is the ability of the muscle to adapt and change in response to stimuli, such as training or aging. Primary myofibers are patterned and specified according to developmental cues.

Adult myofibers exhibit a high degree of plasticity and can phenotypically “remodel” in response to environmental and physiological cues. This ability occurs through activation of signal transduction pathways which remodel the fibers through alterations in gene expression (Potthoff et al., 2007).

Genes involved in muscle remodeling

- Calcineurin → heterodimeric serine protein phosphate.
- Myocyte enhancer factor 2 (MEF2).

Mitochondria: key factor in muscle remodeling

Beyond the regulation by nuclear genes, mitochondria play a central role in skeletal muscle remodeling, due to their remarkable capacity to adapt to a wide range of physiological stimuli.

Among these, physical activity stands out as a potent modulator. The metabolic stress induced by exercise generates a complex signaling cascade that drives mitochondrial adaptation, ultimately enabling the muscle to meet elevated energy demands during sustained contractions.

This adaptive process involves not only an increase in mitochondrial content but also improvements in mitochondrial function and efficiency. These molecular adaptations contribute to shifts in muscle fiber phenotype, particularly favoriting a transition toward more oxidative fiber types. Moreover, exercise-induced mitochondrial remodeling is associated with enhanced expressions of antioxidant enzymes, which contributes to cellular protection against oxidative stress generated during repeated muscle contractions (Quadrilatero, 2023).

Muscle injury

A muscle injury refers to the damage or disruption of muscle fibers, often caused by overstretching, excessive strain, or direct trauma (Díaz-Mohedo, 2015).

- Myopathies and nervous system abnormalities: spasticity, dystonia, Duchenne muscular dystrophy.
- Anatomical or traumatic injuries: contusion, strain, breakage.
- Muscular distress syndromes: diffuse muscle pain (soreness), myofascial pain syndrome
- Minor muscle injury: core sensitization (fibromyalgia, chronic fatigue)

Recovery stages in anatomical injury

- Inflammation phase: During this initial stage, muscle cell disruption leads to metabolic alterations and the release of coagulation factors. This is followed by vasoconstriction (lasting 10-15 minutes), then vasodilatation and hyperemia (increased blood flow) lasting approximately 24 to 36 hours.
- Proliferation phase: In this phase, bridges form between the edges of the injury, resulting in a dense network of capillaries and connective tissue. It is characterized by a “race” between tissue repair and regeneration
- Remodelling: Starting around day 20, collagen fibers begin to align along the lines of tension, eventually forming a “functional scar” that supports tissue recovery.

Training in muscle injury

Prevention

- Do not make explosive gestures without a warm-up
- If the muscle is in a state of maximum fatigue we have to avoid demanding/explosive gestures
- Biarticular muscles: maximum strength exercises can not be performed on one end of the muscle if the other end is in maximum stretch

Treatment

- During recovery, always training under the supervision of a healthcare professional
- Careful with eccentric contractions

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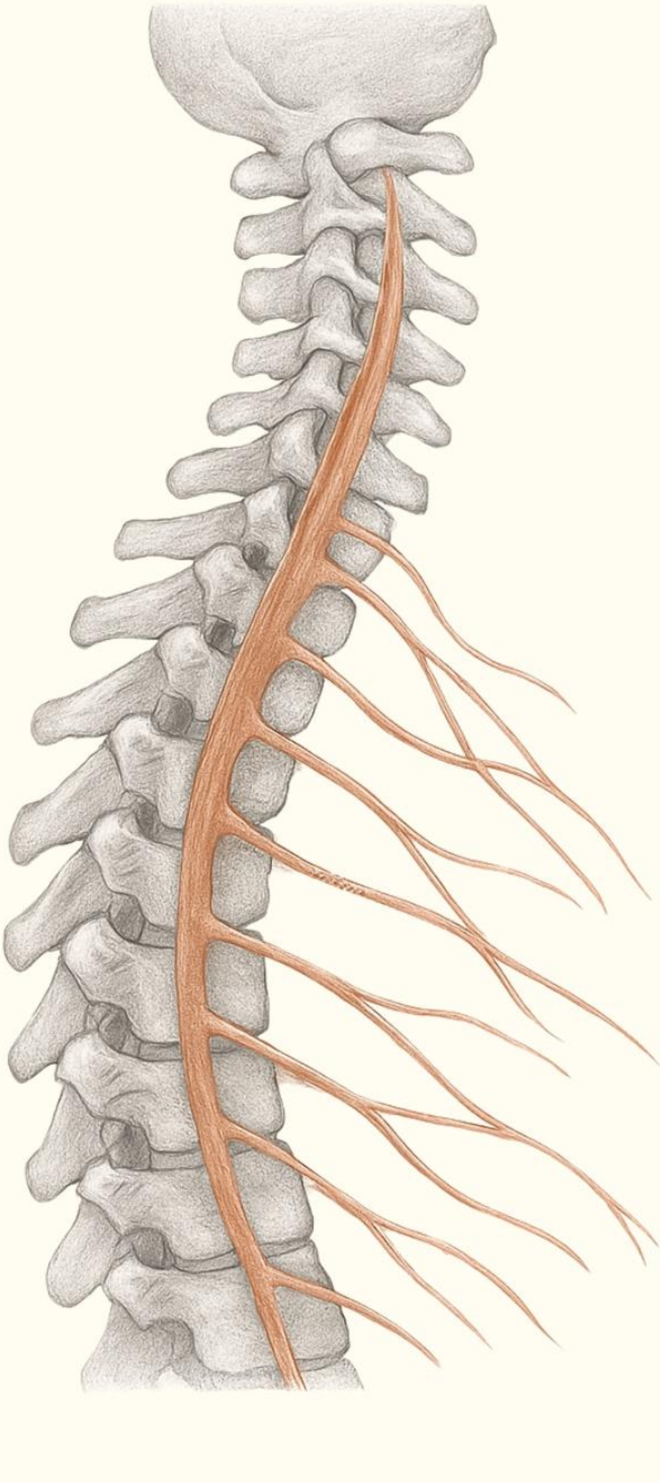


BIOMECHANICS OF PERIPHERAL NERVES AND SPINAL NERVE ROOTS

BIOMECHANICS OF PERIPHERAL NERVES AND SPINAL NERVE ROOTS

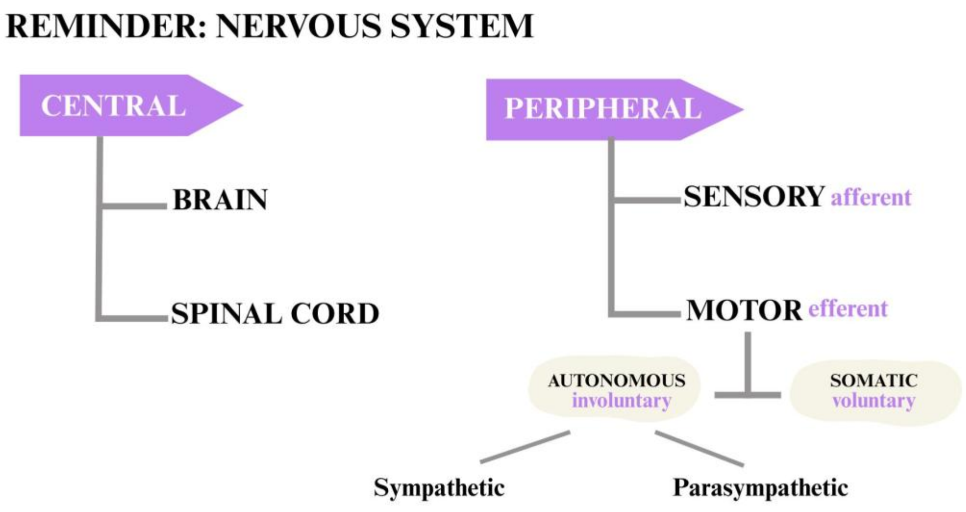


Figure 24. The nervous system's organisation.

Peripheral nervous system

Function: to allow the communication between internal and external media with the central nervous system.

It is made up by:

- Peripheral nerves: to drive nerve impulses. There are afferent or sensitive nerves (to CNS) and efferent or motor (from CNS).
- Gangla: craniospinal (afferents) and vegetative (efferents).
- Nerve endings: sensitive or receptor; and motor or effector.

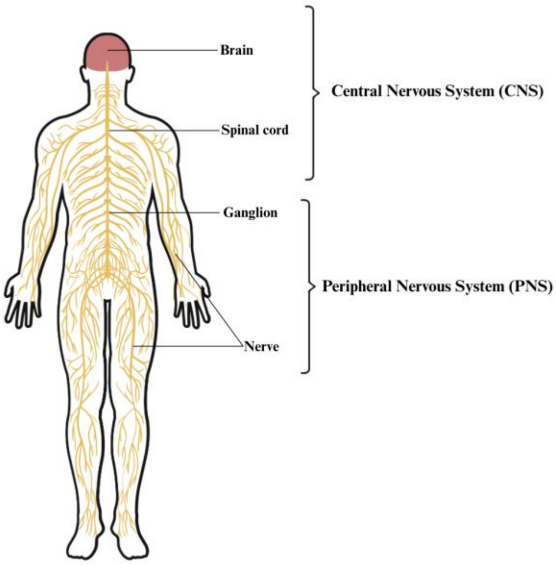


Figure 25. Central and peripheral nervous systems.

Peripheral nerve

Group of nerve fascicles that are held together by vascularized connective tissue (Wavreille et al., 2011).

There are three protective layers:

- Endoneurium: thin layer of lax connective tissue that surrounds each nerve fiber.
- Perineurium: connective tissue surrounding each nerve fascicle.
- Epineurium: dense connective tissue surrounding the entire nerve.

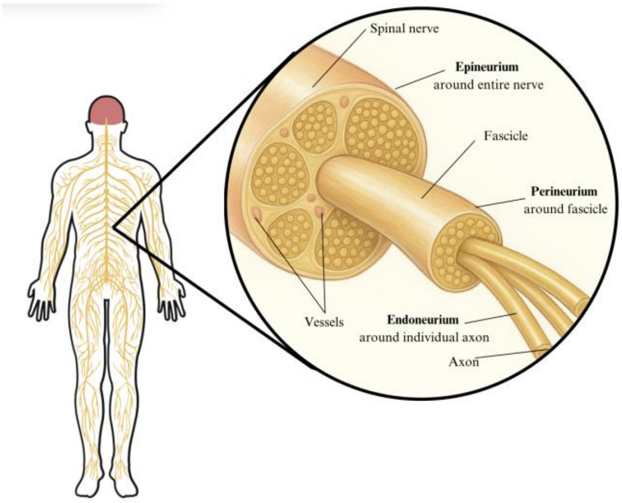


Figure 26. Protective layers of the peripheral nerves.

Types of neurons in the peripheral nervous system

The neuron is a structural, trophic and functional unit of the nervous system that conducts electrochemical impulses to control, modulate and integrate the functions of the tissues (Ulrich Welsch, 2008).

Types of neurons:

- Sensitive neuron: located in afferent nerves. It sends information from receptors to the CNS.
- Somatic motor neuron: located in efferent nerves. It sends information from the CNS to the skeletal muscles.
- Autonomous motor neuron: located in efferent nerves. It sends information from the CNS to smooth muscle, cardiac muscle, and glands through an autonomic ganglia.

Autonomous peripheral nervous system

Sympathetic autonomous PNS

- Location: thoraco-lumbar.
- Function: to prepare the body for stressful situations or physical activity.
- Answer: “fight or run away”

Parasympathetic autonomous PNS

- Location: craniosacral.
- Function: to act on the basal activities of the organism.
- It prevails during the rest time.

Simple theory of nervous system physiology

Sensory reports:

- Conscious (senses)
- Unconscious

Integration:

- Central nervous system

Motor responses:

- Voluntary
- Involuntary

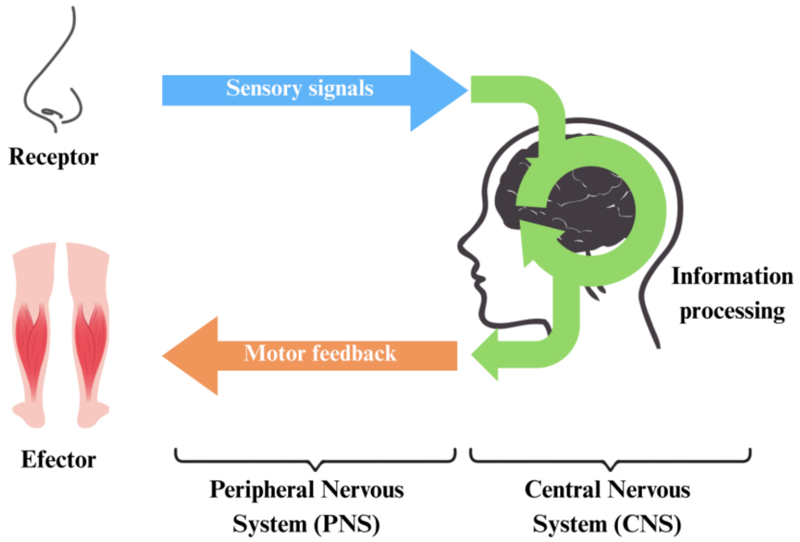


Figure 27. The nervous system’s physiology.

Neural drive

Thanks to the action potential, that is rapid change in the membrane potential that propagates along the entire length of the nerve.

All-or-none principle: once the stimulus reaches threshold, the action potential is always the same, even if the intensity of the stimulus changes

There are 5 stages:

- Latency period: the resting membrane potential remains stable.
- Slow depolarization: decrease in potential difference across the membrane.
- Rapid depolarization: membrane potential quickly becomes more positive
- Rapid repolarization: membrane potential tends to return to its resting value.
- Hyperpolarization: the cell has a more negative membrane potential than that on rest

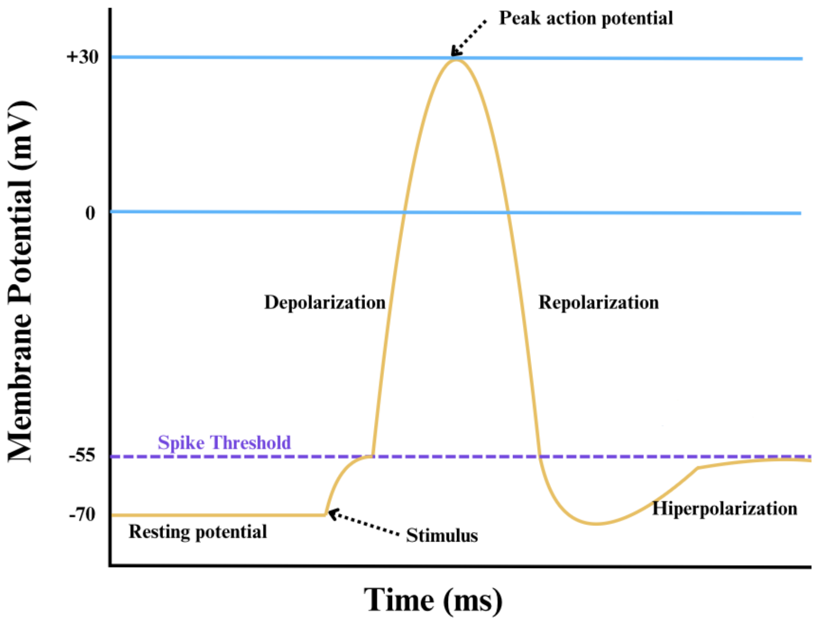


Figure 28. Graph of the neural drive.

Ionic changes in the action potential

Sodium channel:

- Rest state: the conformation prevents the passage of sodium ions → M gate closed and H gate open.
- Activated state: on depolarization the M gate opens → sodium enters.
- Inactivated state: 5 milliseconds after the activated one but also on depolarization → H gate closes.

Potassium channel:

- Rest state: the conformation prevents the release of potassium ions → N gate closed
- Activated state: on depolarization the N gate takes 5 milliseconds to open → Potassium comes out
- When the membrane potential returns to the resting value, the N gate closes slowly, thus allowing hyperpolarization (John E. Hall & Michael E. Hall, 2021).

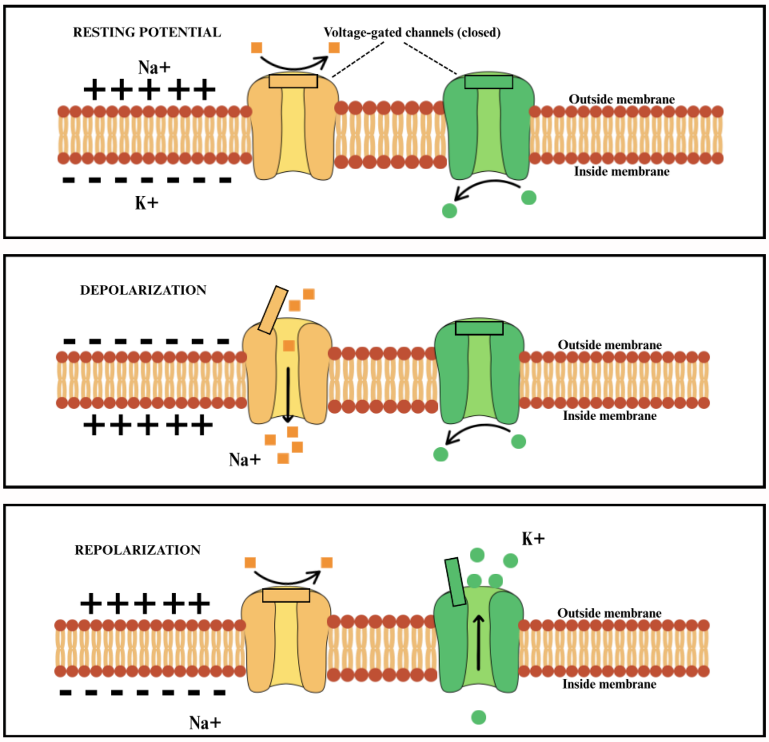


Figure 29. Sodium-potassium pump.

ANATOMY AND PHYSIOLOGY OF SPINAL NERVE ROOTS

Spinal nerve roots

Function: to provide functional and structural neural continuity between peripheral nerves and spinal cord (Beel et al., 1986).

- Histological characteristics: lack of connective sheaths, epineurium and perineurium, typical of the peripheral nerves.
- More sensitivity: more susceptible to irritation and damage due to the compressive and tensile forces.
- Relative to nerve, individual roots are about 50% smaller in cross-sectional and 70% smaller in mass/unit length.

Anatomy of spinal nerve roots

Location: junctional foramina or intervertebral foramina.

There are two roots:

- Posterior root: afferent → sensitive
- Anterior root: efferent → motor

The roots unite to form the trunk of the spinal nerve. The trunk is divided into:

- Anterior or ventral ramus
- Posterior or dorsal ramus

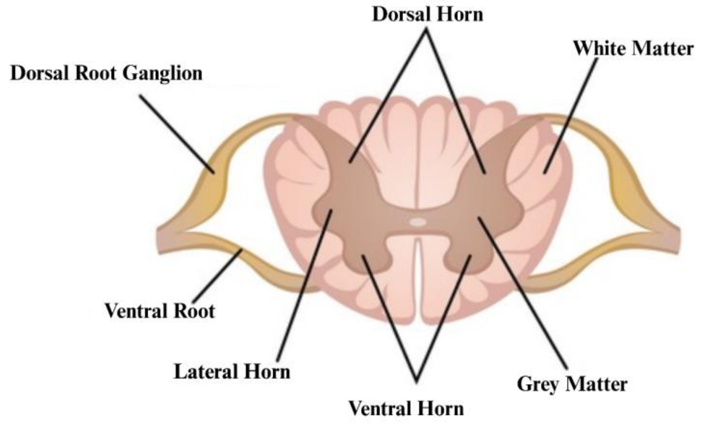


Figure 30. Spinal nerve roots.

Nerve Plexuses

The axons of the anterior ramus are usually configured in the form of nerve plexuses:

- Cervical plexus: Roots C1-C4 (neck, thorax and head)
- Brachial plexus: Roots C5-T1 (upper limb)
- Lumbar plexus: Roots L1-L4 (abdomen, genitals and lower limb)
- Sacral plexus: Roots L4-S4 (perineal and gluteal region, and lower limb)
- Coccygeal plexus:Roots S4-S5 (coccygeus region)

Physiology of spinal nerve roots

There are 4 stages:

1. The sensory information arrives through the posterior root (spinal ganglia) to the posterior horn of the cord.
2. Synapse with an alpha motor-neuron.
3. Afferent fibers exit through the anterior horn of the cord.
4. The impulse travels through the anterior root towards the muscle for generating the motor response.

This occurs in spinal reflex arcs that do not require higher processing. If the afferent signal is more complex, it must go up to the brain and the response must go the other way.

BIOMECHANICAL BEHAVIOUR OF PERIPHERAL NERVES AND SPINAL NERVE ROOTS

Mechanical properties of peripheral nerves

Classification and definition of mechanical properties of peripheral nerves	
Property	**Definition**
Sliding properties	Thanks to the elasticity of connective layers. This allows the nerve trunk to adapt to the different positions of the segments of the limbs.
Wavy architecture	Adapt their length depending on the stretching forces
Progressive strech	Gradual rupture of the most voluminous fascicles and the most fragile, prior to the rupture of the nerve trunk. It may compromise the vascular supply due to an increase in intrafascicular pressure
Nerve compression	Nerve compression is worse tolerated by nerves rich in fascicles and whose epineurium thickness is small

Tensile stress

It produces excursion → displacement of the nerve relative to the surrounding nerve bed (Topp & Boyd, 2006).

- If it is elongated → convergence: nerve glides toward the moving joint
- If tension is relieved → divergence: nerve glides away from the moving joint (realigned)

Relationship stress-strain:

- Toe region → nerve is markedly elongated relative to the applied load
- Linear region → straightening of wavy connective tissue and constant elongated
- Ultimate load → transition between the recoverable and permanent strain
- Plastic region → nerve reaches its ultimate elongation and undergoes mechanical failure.

Compressive stress

It causes the displacement of internal contents of the nerve in transverse and longitudinal directions.

Extra-neural compression causes an immediate displacement of endoneurial fluid to the edges. So, the damage to axons and myelin is greatest at the edges of the compression zone, where the shear forces are highest. At the edges, its produced these damages:

- Myelin retraction.
- Widening of nodes.
- Paranodal demyelination.

Mechanical properties of spinal nerve roots: differences with peripheral nerves

- The proportional limit force is frequently the maximum force tolerated by the roots → point of failure.
- The force sustained by roots as the proportional limits is positively correlated with the cross-sectional area.
- In relation to nerves, roots present much smaller values of strength, stiffness, density and proportional limit force.
- Relatively little applied force → obvious damage in nerve roots.

NERVE INJURY AND PAIN

Nerve injury classification

Seddon and Sunderland established a classification based on the severity and the possibility of repair (Burnett & Zager, 2004).

Neuropraxia (Grade 1):

- Does not involve loss of nerve continuity
- Functional loss
- Transient

Axonotmesis (Grade 2, 3 and 4):

- Complete interruption of the nerve axon and myelin
- Mesenchymal structures are preserved
- Complete denervation but great prospect of recovery

Neurotmesis (Grade 5)

- Disconnection of a nerve
- Functional and structural loss
- Recovery is not possible without surgical intervention

Neural degeneration after injury

In neurapraxia grade 1 → pathological changes are mild or absent

In axonotmesis grade 2 → wallerian degeneration:

- Physical fragmentations of both axons and myelin
- Neurotubules and neurofilaments become disarrayed and axonal contour becomes irregular

In axonotmesis grade 3:

- Retraction of the ends of nerve fibers
- Intrafascicular scar tissue

In axonotmesis grade 4 and neurotmesis grade 5:

- Endoneurial tubes are disrupted, and axons and Schwann cells are no longer confined
- The nerves ends become a swollen mass.

Neural regeneration

- Sequence of regeneration:
  1) Neuronal cell body
  2) Segment between the cell body and the injury site
  3) Injury site
  4) Segment between the injury site and the end organ
  5) End organ

Possible sequels after regeneration are the impairment in functional motor recovery, specially in terms of proprioception and failures in sensory recovery that consist of decreasing or increasing of sensitivity and pain

Neuropathies

Injury of the peripheral nervous system in which the second neurons of the pyramidal pathway are affected.

Symptoms

- Hypotonia
- Abnormalities in the electromyogram
- Hypoactive or absent tendon reflexes
- Loss of strength, more evident in small muscle groups

Ethiopatology

- Metabolic abnormalities: diabetes, hypotension, hypothyroidism
- Infections: HIV, leprosy
- Autoimmune diseases; Guillain-Barré syndrome
- Toxics: heavy metals, drugs, alcohol
- Paraneoplastic syndromes
- Hereditary: charcot marie-tooth
- Drugs: anti epilepsy

Classification of neuropathies

Classification of neuropathies based on Topographical, Evolutionary, Clinical and Electroneuromyography factors	
Classification	**Definition**
Topographic	- Polyneuropathies: affect many nerves symmetrically distally. - Mononeuropathies: affect one nerve progressively. - Multiple mononeuropathies: affect different nerve trunks asymmetrically. - Radiculopathies: affect nerve roots.
Evolution time	- Acutes: less than a week. - Subacutes: some weeks or months. - Chronic: several months or years.
Clinical	- Sensitive. - Motor. - Mixed or sensitive-motor.
Depending on electroneuromyography	- Demyelinating. - Axonal. - Mixed.

Training in nerve injury

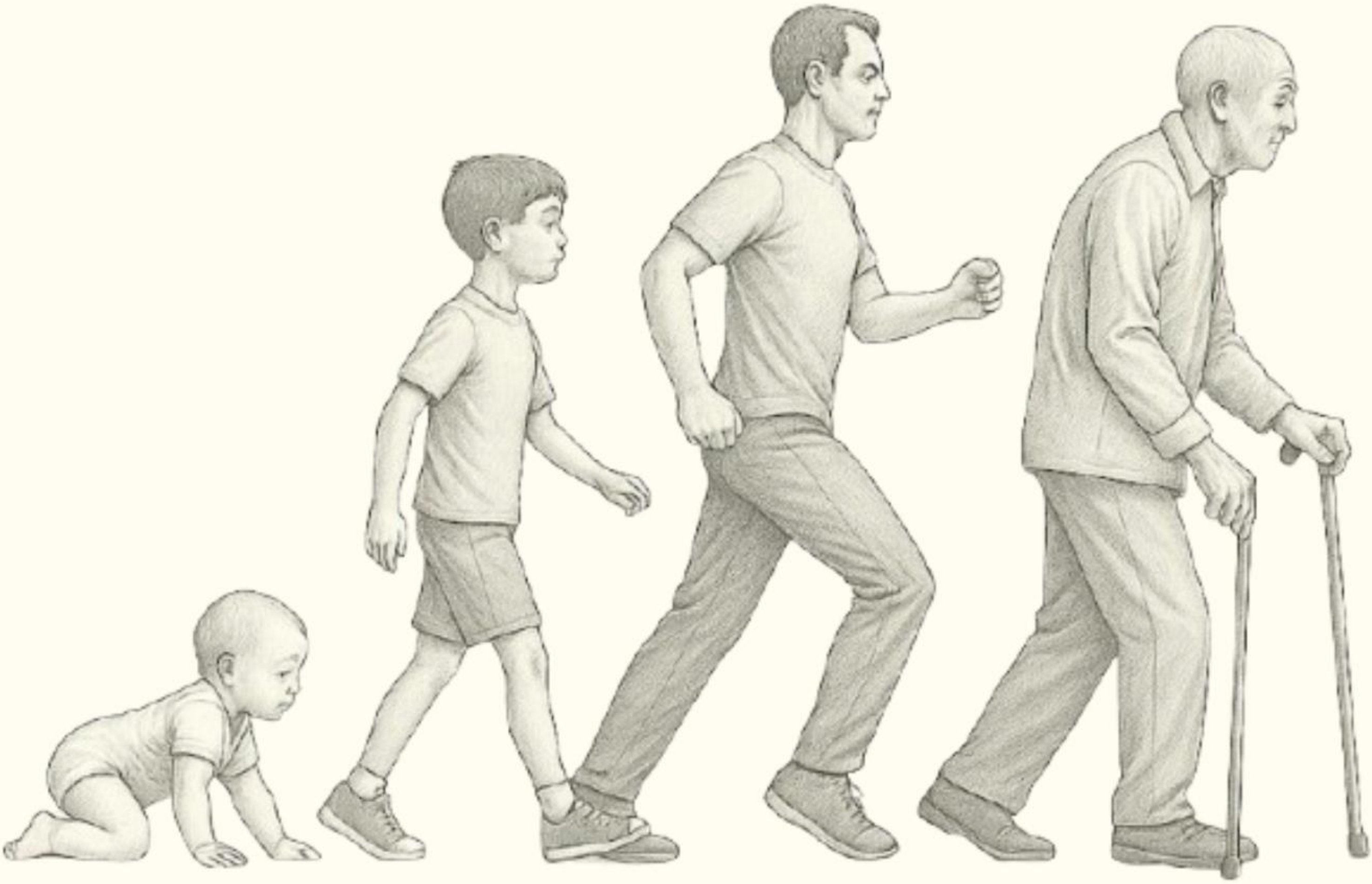
Nerve interruption

- Work a lot on proprioception.
- If there is a sensitive disorder, working with different textures and adapting the environment to the person.
- If there is motor disorder, set very simple goals so that the person does not get frustrated.

Neuropathy

- Look for the cause (cancer, diabetes,...) and focus efforts on adapting the training to improve that cause.
- Be careful with the sensitivity disorders.
- To include neuropedagogy of pain* and strategies of dual tasks in cases of great pain.

6



HUMAN MOVEMENTS ACROSS LIFE STAGES

FUNCTIONAL INDEPENDENCE: A LIFELONG GOAL

Problems of dependence

Dependence is the loss of personal autonomy in some sense and conditioned due to the physical or mental disability, social limitations or economic, or other circumstances. This can lead to certain consequences, such as:

- Decrease in quality of life.
- Mental health disorders: feeling guilty and being a burden to others.
- Increase of social spending: more medical consultations and more socio-health resources.
- Physical, mental and socioeconomic problems for caregivers.

Factors that influence dependence

The risk factors that influence dependence are:

- Age and concomitant diseases.
- Impairment in physical performance.
- Impairments in cognitive status.
- Living in rural environments.
- Poor nutrition.
- Depressive symptoms.
- Low self-efficacy.
- Low economic level.

Functional independence

Functional independence is the physical and mental capacity to carry out actions of daily living, maintain the body and subsist in an autonomous way. The main goal is to achieve an increased number of independent elderly people, with the functionality to main focus in the healthcare of elderly people, also it broadens the conception of health-disease evaluation and gives particularity to healthcare.

FIM

Functional Independence Measure (FIM) is the most used tool for analysing self-care, sphincter control, locomotion, mobility/transfer, communication and social cognition. It includes 18 items, of which 13 are motor items and 5 cognitive items (Ribeiro et al., 2018).

Score for each item (from 1 to 7):

- 1. Total assistance.
- 2. Maximal assistance.
- 3. Moderate assistance.
- 4. Minimal assistance.
- 5. Supervision.
- 6. Modified independence.
- 7. Complete independence.

The aim is measuring the degree of dependence of the elderly, and to quantify the demand for care that they could present.

FIM questionnaire:

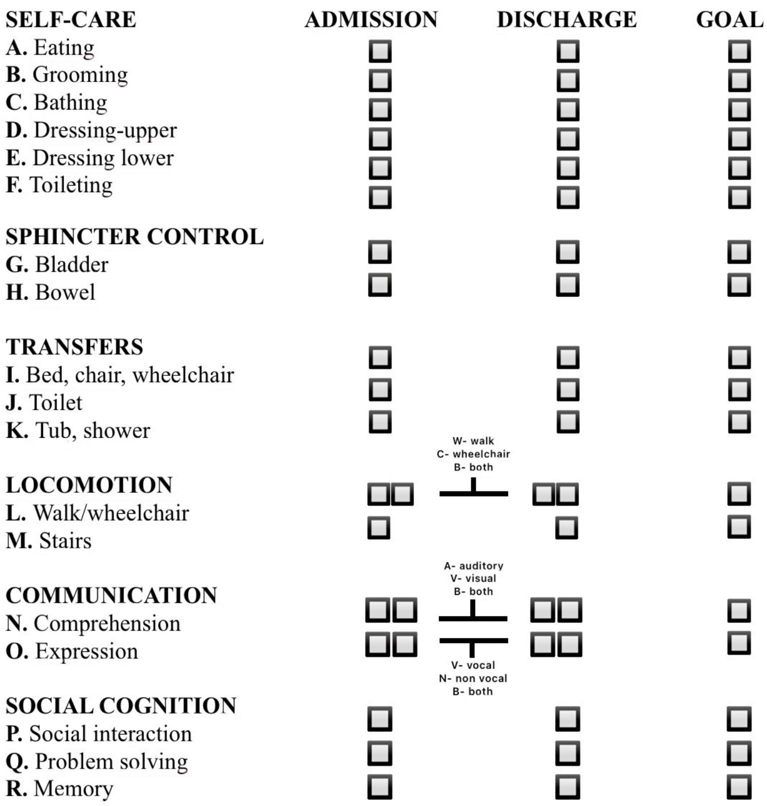


Figure 31. FIM Questionnaire.

Functional independence: the universal goal

We can know functional independence as the improvement of life quality, decrease of mental health disorders and increase of physical activity level, that generates a decrease in chronic diseases and mortality. Moreover, it is a cost-effectiveness factor, as there are less hospital admissions, fewer surgical interventions, less spending on drugs and less spending on socio-health Human Resources (Gill et al., 1996).

THEORIES OF HUMAN DEVELOPMENT

Human development

It is defined as a system that balances the demands of the environment with the internal resources of organizations, institutions or sectors in the health, educational and labor fields.

The concept of human development is explained by the differences between three possible theories that have been developed over the years: quality of life theory, subjective well-being theory and theory of social representations (García-Lirios, 2019).

Quality of life theory

Its development is limited to general levels of health, education and employment, but each one as a reflection of the opportunities of the state management to be able to achieve levels of comfort, recreation or leisure.

It corresponds with high of medium levels of access and enjoyment resources. So, in a situation of shortage, quality of life loses meaning, and we need to make reference to subjective well-being.

Subjective well-being theory

It is understood as experiences that, when considered positive, become significant for those who experience them and, based on this fact, assume that their development is favorable.

Here we find the main difference between subjective well-being and quality of life theories because subjective well-being is not measured from the level of resources but from what it means for each person to be satisfied with themselves and others.

From this perspective, human development means commitment, influence, empathy and satisfaction.

Theory of social representations

It is defined as the consequence of the processing of information that the individual carries out when exposing himself to social media.

It makes that reality is interpreted as members of a group and of a culture, which allows an ecosystem of social interaction.

So, this theory understands development as the capacity to develop and integrate into an understable construct for a social group.

MOTOR DEVELOPMENT AND MOTOR CONTROL

Human motor development

Motor development is defined as a sequential and dynamic process that occurs throughout childhood in order to acquire a large number of motor skills while the nervous system is madurating, with the aim to achieve physical and functional independence (Hadders-Algra, 2018).

It is closed linked to psychological, social, sensorial and proprioceptive development, so we need to take into account some factors that influence the motor skills learning such as:

- Opportunities to perform an action.
- A motivating environment that poses a challenge to force or encourage the action to achieve an objective.
- A stimulating social environment and cultural influence that influences motor behaviour.
- A sensory, emotional and social development.
- New skills that allow new opportunities for learning and exploration.

The key: neuroplasticity

It is understood as the potentiality of the nervous system to modify itself forming neural connections in response to new information, sensory stimulation, development, dysfunction or damage.

When we are newborn, early motor behaviour is organised by means of activity of basic networks in the brainstem and spinal cord. This is called primary variability and allows to adapt motor behaviour to the specifics of the environment.

The secondary variability means that each adaptation starts at function-specific ages.

This process takes many years of additional exploration, experience and developmental changes in the brain, before achieving the adult configuration.

Risk factors in motor development

Motor development is not a perfect process, so it is needed to know the risk factors that influence motor development:

- Low birth weight.
- Cardiovascular, respiratory, neurological, visual or hearing disorders.
- Neonatal infections.
- Malnutrition.
- Premature birth.
- Cognitive delay.
- The low socioeconomic conditions and the low educational levels of the parents.

Key characteristics of motor development

As motor development is so relevant, there is a guide to Standish some milestones that children need to achieve in certain ages .

- Newborn have the ability to move their arms and gesture.
- 3 months old: the child looks at hands and uses his arms to lift his head.
- 6 months old: the child plays with his feet, can change the objects between his hands and is able to sit for a limited period of time.
- 9 months old: the child is able to sit and starts crawling. Moreover, he is able to carry weight when standing and reaches for objects.
- 12 months old: the child stands while hield on and moves by crawling or lateral walking. In addition, he gets the fine pincer.
- 18 months old: the child is able to walk and get up without assistance. Moreover, he is able to scribble and turn pages of a book.
- 24 months old: the child is able to run, changing directions and beginning to jump, and walk up and down stairs.
- 36 months old: the child is able to stand on one leg, jump and begins to pedal a bicycle. Moreover, he performs the digital grip.

Warning signs in motor development

In addition to the orientational guide of milestones to be met, there is a guide of alarm signs which if we detect them in a child may indicate an atypical motor development:

- Persistence of archaic reflexes, or presence of abnormal muscle reflexes.
- Hypotonia or hipertonia.
- Tremors, seizures, clonus or hypokinesia.
- Anomalous postures with asymmetries, or observation of atypical walking like tiptoes, ataxic or hemiparetic gait.

- Language problems.
- Behavioural disorders such as hyperactivity, negativity or irritability.
- Sleep disorders.
- Strabismus, nystagmus or gaze deviation.
- Several months delay in developmental milestones according to chronological age.

Motor control

Nowadays, the most accepted definition for motor control is "the area of physics exploring laws of nature defining how the nervous system interacts with other body parts and the environment to produce purposeful coordinated actions"(Levin & Piscitelli, 2022).

The primary motor cortex is responsible for motor control.

There are two theories about motor control:

1. The direct theory says that the central nervous system outputs muscle force through the direct activation of muscles from higher brain centers.
2. The indirect theory says that force production results from the specification of neurophysiological parameters that may influence, but remain independent of biomechanical variables, determining the conditions and context in which muscle may act to produce a given task within a given environment.

So we can deduce from both theories that motor control is not a stable condition, but can be worked on and optimized through training strategies.

BODY SYSTEMS CHANGES

Changes in aging

Aging is a progressive, intrinsic and universal process that occurs in all living beings over time, as an expression of the interaction between the individual's genetic program and their environment.

This physiological process is accompanied by different changes at the multisystem level, affecting cardiovascular, respiratory, musculoskeletal, nervous, digestive, inmune, endocrine and genitourinary systems (Mora Bautista, 2008).

Cardiovascular system

Along the cardiovascular system we can find:

- Increase in blood pressure.
- Decrease of cardiac output.
- Decrease of the ability to respond to stress.
- Decrease in the amount of blood ejected, a fact that reveals an alteration in cardiac pump.
- Thickening of the left ventricle in response to atherosclerotic changes.
- Progressive loss of myocardial cells.
- Disturbances in cardiac rhythm.
- Decrease in maximal oxygen consumption.
- Imbalance in the relationship between contribution and consumption, that generates a deterioration of aerobic capacity.

Respiratory system

Along the respiratory system, we can find:

- Changes in volumes and capacity, that generate restrictive or obstructive dysfunctions.
- Decrease of antagonistic synergistic process of respiratory muscles.
- Decrease of the maximum capacity, number and motility of movement.
- Sternocostal joint calcifications, that promote restrictions of movement.

- Decrease of the reaction of chemoreceptors due to arterial thickening, generating an increase of residual volume.
- Decrease in the strength of respiratory muscles.
- Decrease of the mobility of the rib cage, that leads to acute respiratory failure with retention of secretions.

Musculoskeletal system

Regarding the musculoskeletal system, we can find the following changes:

- Loss of muscle mass, which is called sarcopenia.
- Loss of muscle fibers is associated with decreased strength, which leads to muscle atrophy.
- Weakness that limits the movement and performance of their basic daily activities.
- Deficiencies in range of motion.
- Loss of bone mass, which is called osteopenia.
- Loss of collagen and elastic fibers, which decreases the structural capacity to support loads.
- Slow and insecure gait with an easy loss of balance.
- Suppression of kinesthetic stimulation, and lowering of arousal thresholds and reception of stimuli, causing alteration in motor feedback processes.

Nervous system

In relation to nervous system, we can find:

- Decrease of size and number of cells, causing changes in brain function.
- Decrease in dendrites and synapses.
- Accumulation of damage elements that produces confusional states or dementia.
- Decrease of brain volume with increased neuronal atrophy and death.
- Neurotransmitter alterations, that led to a decrease in reaction capacity, coordination, neural drive speed, blood flow, memory, attention span, and learning, mental and intellectual capacity.
- Slowdown in the speed of response, perception, writing and movement coordination speed.
- Bradykinesia and dyskinesia.
- Slowing of the processing of visual and auditory sensory information.
- Memory loss.

Digestive system

Along the digestive system, we can find the following alterations:

- Decrease of chewing and swallowing functions.
- Decrease of esophageal motility.
- Increase of gastroesophageal reflux.
- Loss of appetite.
- Atrophy of the salivary glands.
- Decrease of epithelium and atrophy of the submucosal and muscular layer of the stomach.
- Decrease of digestive enzymes.
- Loss of intestinal absorption capacity.
- Decrease of perialtasis, generating constipation.

Immune, endocrine and genitourinary systems

In the immune system we have:

1) A decrease in immunity due to thymic involutin, and decrease of lymphocytes and interleukins.
2) Moreover, an increase of antibodies.

In endocrine system, we can find:

1) Decrease of levels of triiodothyronine (TI-three) and thyroxine (TI-four).
2) In addition, an increase of glucose intolerance.

Along genitourinary system, we have:

1) A decrease of glomeruli, with the consequent decreased glomerural filtration, and renal fibrosis.
2) In addition, sexual impotence.

LOCOMOTION PATTERNS ALONG THE LIFESPAN

Basic patterns of movement (BPM)

Patterns of movements are essential motor skills for the development of complex skills, necessary to participate in a great variety of activities throughout life.

Basic patterns of movement are classified into:

- Locomotor activities, which are used to move the body from one place to another as for example, running, skipping or galloping.
- Manipulative activities, that are used to project or receive objects as for example, throwing, kicking, or bouncing.

The learning of these patterns occurs in three stages: initial, elementary, and mature.

In the mature stage, at six years old, it is hoped that the child performs mechanically efficient, coordinated and controlled movements.

Locomotion patterns

These include the projection of the body to external space, and may imply:

- In one execution, many types of movements can be carried out to reach the goal.
- The movement can be changed when the execution requires it.
- That the movements can be altered according to the demands of the environment.

We can find two different types of locomotion patterns:

1. Basics: jumping, running or walking.
2. Combined: glides,climbing, shifts with changes of directions or jumps with obstacles.

Changes in locomotion pattern due to aging

These movements are supposed to be carried out under the same pattern throughout life, but changes of aging also affect this aspect.

So we can find:

- Slowdown in the execution of locomotion patterns.

- Dysfunctional gait characterized by the fact that the toes do not detach, the unipodal phase is shorter and the length of the stride is reduced.
- A decrease of the range in which elements of such patterns are performed.
- The loss of ability to execute combined patterns.
- Abnormal pattern development as adaptation to changes in the musculoskeletal system.

PREHENSION

Prehension or grip

Pretension or grip is defined as grabbing or grasping an object with the hand.

Grip strength is a very relevant parameter because it is considered as a biomarker of aging, bone mineral density, malnutrition, cognition, depression and sleep (Bohannon, 2019).

Moreover, this parameter is not only a biomarker of medical status but also a biomarker of future status, because it is a disease and mortality predictor.

Different researchers have observed that:

- A decrease of five kilos in grip strength, supposes an increased risk of cardiovascular disease.
- Values of grip strength greater than eighteen kilos imply a low risk of mortality.

7

GENERAL PRINCIPLES OF WELLNESS AND FITNESS

CONCEPTUAL INTRODUCTION

Wellness

It is defined as the balance of a spectrum of health-related elements in one's life, and it includes seven dimensions that are: physical, emotional, intelectual, social, environmental, spiritual and occupational dimensions.

Wellness implies a constant and deliberate effort to stay healthy, avoiding risk factors and thinking in achieving the highest potential for well-being.

The term wellness lifestyle alludes to practicing behaviors that will lead to positive outcomes in the seven dimensions of wellness.

Fitness

It is defined as the discipline that focuses on being physically fit and healthy, having the necessary qualities to carry out a specific physical task.

Fitness focuses on pushing the limits to improve physical appearance and taking care of aesthetics. So, its main aim is the development of the physical dimension, and implies effort and sacrifice.

Wellness vs Fitness

Once we have understood wellness and fitness, we can establish four comparative fields in terms of their differences (Hoeger et al., 2019):

- Regarding the concept, fitness is related with only the physical condition; while wellness implies physical, emotional and social well-being.
- In relation to the aim, fitness is looking for physical development; and wellness focuses on the quality of life improvement.
- As for the methodologies, fitness works the intensity to push the limits; while wellness uses exercises that provide balance and harmony.
- Referring to the activities, fitness may include high intensity training, suspension training, Body Pump, CrossFit or spinning, while wellness could include yoga, tai chi, Pilates, dance or even walking.

HEALTHY BEHAVIOR

Healthy lifestyles

This term alludes to a more or less integrated set of healthy practices that an individual adopts.

It refers to physical activity, nutrition, personal hygiene, sleep, road and environmental safety, sexuality, drug use, and even, social participation.

The main reason to talk about this at the university level is the fact that the current evidence reveals that the habits that are acquired during the university stage are consolidated during adulthood, so we can say that you are the best target population (Bennasar-Veny et al., 2020).

So, we are getting into the three most influential factors of lifestyles (Belogianni & Baldwin, 2019):

1) Physical activity: The World Health Organisation (WHO) established some recommendations for adults, understanding these groups as the ages between eighteen and sixty-four years old.

   The recommendations are to practice at least one 150 weekly minutes of moderate aerobic physical activity or 75 weekly minutes of intense physical activity.

   However, to obtain greater benefits for health, we need to practice at least 300 weekly minutes of moderate physical activity or 150 weekly minutes of vigorous physical activity. In addition, we need to include strength exercises 2 or more days per week.

   These recommendations will give us the following benefits: decrease of the level of fatigue; improvement of sleep quality, academic performance and cognitive function; and most importantly, the prevention of health problems related to physical inactivity, which are, nowadays, the major problem of public health in all countries of the world.

2) Nutrition: No diet yet has been found with more favorable evidence than the Mediterranean (Navarrete-Muñoz, 2015). This diet includes the following requirements of intake:
   - Use of olive oil for cooking.
   - Two or more rations of vegetables per day.
   - Three or more pieces of fruit per day.
   - Less than one ration of red meat per day.

- Less than one ration of carbonated or sugary drinks per day.
- Three or more rations of legumes per week.
- Three or more rations of fish per week.
- Less than three rations of industrial pastry portions per week.
- One or more rations of nuts per week.
- And preferred consumption of chicken, turkey or rabbit.

The reason for the use of this diet is the fact that it is considered a cardiovascular risk protective factor.

3) Sleep**:** It generates a great impact in the neurological restoration of the organism and in the development and adequate functioning of the individual in the society.

Sleep quality implies eight different dimensions:

- Sleep induction.
- Wake up during the night.
- Time of the final awakening with respect to the desired.
- Total sleep duration.
- Overall quality of sleep.
- Sensation of well-being during the day.
- Physical and mental functioning during the day.
- Sleep during the day.

It is so relevant to take care that sleep disorders may cause an increase of psychological stress and coping strategies for this, together with a worsening of academic performance and mood (Średniawa et al., 2019).

FITNESS PRINCIPLES

The six main principles of fitness or training in general (González, 1985; López Chicharro & Fernández Vaquero, 2023):

Progressive overload

It is the elevation of training demands over time.

The increase in training generates an increase in the aptitude to support the sports demands, that is, it generates an adaptation. Nonetheless, this is not so easy and we need to take into account the following four dimensions:

- Frequency: The cadence of training sessions. For example, it is recommended to practice endurance between three and five days per week, and strength and flexibility, two or three days per week. However, we need to be careful with overload.
- Intensity: The hardness execution. Generally, we achieve greater benefits with higher intensities, but we need to be careful with clinical populations.
- Time: The duration of the training, and maintains an inverse relationship with the intensity. To avoid injuries, it is recommended that beginners train with less intensity and more duration.
- Type of Exercise Modality: Endurance gives central changes and strength leads to peripheral changes.

Specificity

It is the development of basic physical qualities and specific qualities linked to specific sports. There are three main dimensions:

- Oxygen consumption: The capacity of the cardiorespiratory and metabolic systems to supply oxygen and is very between for example a marathon and a judo match.
- Local changes: Adaptations of the muscle groups implied in the specific sport gesture.
- Priority of qualities: For example, in martial arts, the priorities are strength, velocity both execution and reaction, and flexibility.

Continuity

- Do not interrupt training, because it dilutes the load.
- Be consistent in the optimal training factors: nutrition, hydration and rest.

- Take into account that in injured athletes we need to avoid the complete interruption of the training, including alternative exercises.

Reversibility

The adaptation to training reduction. It is important to keep in mind the following statements:

- Benefits are reversible.
- If we adapt to lower levels of training, we lose fitness.
- The training should be consistent in frequency, intensity and duration.
- 50% of qualities are lost in two months.
- It is easier to recover fitness in a more trained subject.

Supercompensation

When we do physical exercise, it produces “damage” to the organism. After that, there is a recovery period, and then a supercompensation period.

In this period, we achieve a better condition than the one in the last training.

So, we can deduce that the repetition of training will produce stable adaptations in the organism, but loads cannot definitely increase, and have to be subject to fluctuations over time.

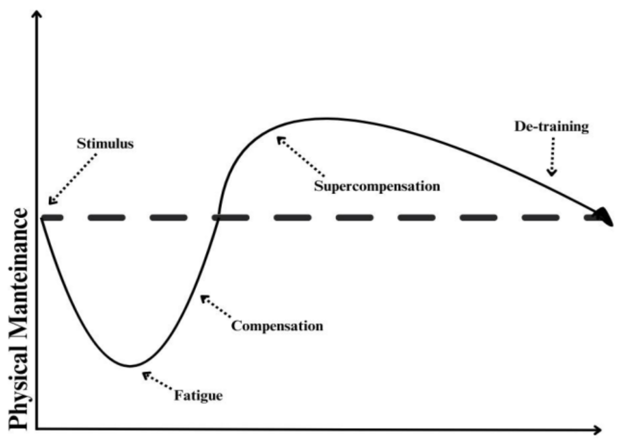


Figure 32. Supercompensation.

Individual differences

- Adaptability of each athlete.
- Individual innate characteristics.

- Different responses to types and amounts of training that are genetically predetermined but it can almost always be improved.
- The stimulus must be adjusted to the starting conditions. We need to avoid equal formulas for everyone.
- Establish realistic objectives.

CARDIORESPIRATORY FITNESS, MUSCULAR FITNESS, AND FLEXIBILITY

Cardiovascular fitness

There are responses mediated by neural mechanisms, such as hypothalamic central command, that produce an increase of the sympathetic nervous activity and a decrease of the parasympathetic, together with an endocrine response. Moreover, it generates vasodilation in muscle and lungs, and vasoconstriction in skin and viscera (Smith et al., 2014).

On the other hand, responses mediated by humoral mechanisms, such as metabolites that produce local arteriolar vasodilation; and adrenaline, cortisol, testosterone and antidiuretic hormone, that cause hyperglycemia and greater assertiveness and aggressiveness.

Finally, hydrodynamic responses, which produces an increase of vasoconstriction, pumping action by muscle contraction, an increase of vascular resistances, and an increase of venous return on the right side and filling volume on the left ventricle.

Moreover, in this system we find:

- Changes in the cardiac output, promoting the increase of the systolic volume at the beginning of the exercise but there comes a point that it even decreases. Also, the heart rate increases until a later point when it stabilizes.
- Regarding arterial pressure, if we are practicing endurance exercise, systolic pressure increases and diastolic pressure is maintained or decreases; but if we are practicing strength exercise, systolic and diastolic pressures increase.
- A reversible central adaptation, which means a decrease in heart rate at rest, an increase of the cavities and thickening of the walls of the heart, an increase of the relationship volumen/beat, and an increase of myocardial perfusion.

Respiratory fitness

There are changes at three different levels:

1. In the relationship ventilation/perfusion, we find a linear increase of the ventilation until the anaerobic threshold, and a linear increase of the cardiac output, until the maximal effort. So, the relationship at rest is zero point eight, and during exercise varies between one point two, or one point three.

2. In the relationship ventilation/minute, if we are practicing a stable exercise, there is an initial sharp increase, and then gradual increase until it flattens out and adapts to the load; while if we are practicing an incremental exercise, there is an incremental increase.
3. When we reach an anaerobic threshold, the body products lactate, and try to buffer it with bicarbonate. This reaction produces carbon dioxide and water, and increase the breathing to expel the carbon dioxide.

Muscular fitness

The three components are:

- Muscular strength: the ability to generate force with a muscle or a group of muscles.
- Muscular endurance: the ability to perform repeated contractions with a muscle or group of muscles under submaximal load.
- Muscular power: the rate at which muscles perform work.

The responses of the muscles to the exercises promote:

- Improvement of bone health.
- Decrease of adiposity.
- Increase of the three components of muscular fitness.

Flexibility

It is a conditional basic physical quality, that is, subject to energy processes. There is a genetic predisposition but it can be improved through training.

In relation with the response to exercise, we find:

- Decrease of pain and increase of tolerance, that generates an increase of the range of motion.
- Increase of muscular elasticity, that leads fluider and wider movements.
- Improvement of motor control, that causes a decrease of the block movements.

BODY COMPOSITION, NUTRITION, AND WEIGHT MANAGEMENT

Body composition

The human body is mainly composed of four molecular-level components:

- Water: 50-70%
- Fat: 10-30%
- Protein: 12-20%
- Minerals: 5-10%

Nonetheless, body composition analysis is usually done by dividing body mass into the following categories: muscle mass, bone mass, fat mass and hydration level.

It's important to understand that the composition differs greatly from one person to another. There are many differences depending on the sex and the physical activity level of the person, even type of sport practice. Moreover, the same person could change the body composition a lot in a short time.

For example, if Sophie is a woman and a high-level athlete at 15 years old, with a fat level of twelve percent, and at 17 years old, she stops competing, at 18 years old she could have a fat percentage of approximately twenty-three per cent.

Assessment of body composition

Regarding the assessment of body composition, we have different measurement tools (Borga et al., 2018).

1. Body mass index: the most known, it is the body weight normalized by height squared. This score provides a classification but without data on body composition.
2. Anthropometry: it implies the measurement of folds and body perimeters. It is an indirect estimation of body composition.
3. Dual-energy: EX-ray absorptiometry, known by its acronym DI - EX - EI, is a two-dimensional imaging technique, in which the attenuation of the EX-ray is dependent on the thickness of the tissue. This is the gold standard.
4. Bioelectrical impedance analysis, known by its acronym BI - AI - EI. The impedance is assumed to be proportional to the height and inversely proportional to the cross-

sectional area, and the electrical equivalent is a resistor. This tool makes a pretty accurate estimation.

Nutrition

Three essential principles:

1) Varied and healthy diet.
2) Control the proportions provided by each type of nutrient.
3) Basic distribution is 50% of vegetables, 25% of proteins and 25% of carbohydrates.

Nevertheless, the diet has to be specific for each person, and of course, for each type of sports practice. For example: in the diet of a professional cyclist previous to competition or hard training you can find:

- About vegetables, a reduced amount, less than 20%, and the choosing of those that contain less fibres and have a lower absorption.
- Regarding the proteins, the normal amount of 25%, and the use of white mass.
- To carbohydrates, an increased amount, more than 55%. In addition, during the training or the competition, the cyclist has to intake at least 65 grams of carbohydrates per hour.

Weight management

It is a continuous process and implies a great commitment. Nowadays, the most common diets are (Thom & Lean, 2017):

- Low-fat diets that focus on improving low-density lipoprotein cholesterol.
- Low carbohydrate diets, with the aim to improve triglycerides and high-density lipoprotein cholesterol.
- Mediterranean diet, focused on decreasing the cardiovascular risk.
- High protein diets, to increase muscle mass.

The main benefit of weight loss with any of these diets is the improvement of almost all obesity-related co-morbidities and metabolic biomarkers.

Nevertheless, nowadays, weight is no longer considered such a determining factor, but body composition is more so.

STRESS AND DISEASE

Stress

Three different approaches to the definition of stress:

- The epidemiological approach says that a specific life event generates an equivalent amount of stress for all individuals. So, it defines stress by reference to independent ratings that reflect how others, aggregated, judge the negative impact of particular events. This approach has been successful in predicting morbidity, disease progression and mortality.
- The psychological approach says that the same event can be stressful for some individuals but not others; and defines stress as an experience that occurs when individuals simultaneously appraise events as threatening or otherwise harmful and their coping resources are inadequate. This approach has been useful in predicting risk for morbidity and mortality.
- The biological approach says that the impact of the stressors is indexed via perturbations of physiological systems. It establishes that in the short term, these physiological perturbations generate adaptive behavioural action or coping strategies; but in the long term, they become maladaptive reactions and risk for disease.

Relationship stress-disease

To explain this relationship, there are six essential stages (Cohen et al., 2016):

1) Environmental demands, and on the other hand, our individual stressful life events.
2) Demands appraised as stressful, so becomes perceived stress.
3) Our body answers to this stress with a negative emotional response.
4) Poor health decisions and behaviour. Moreover, there is an activation of sympathetic-adrenal-medullary mediators and hypothalamic-pituitary-adrenal systems.
5) Disease related physiological changes.
6) Possible increased risk of disease, or even an onset or disease progression.

SUBSTANCE USE AND ABUSE

Substance use to improve sport performance

The most commonly used substance in sport are:

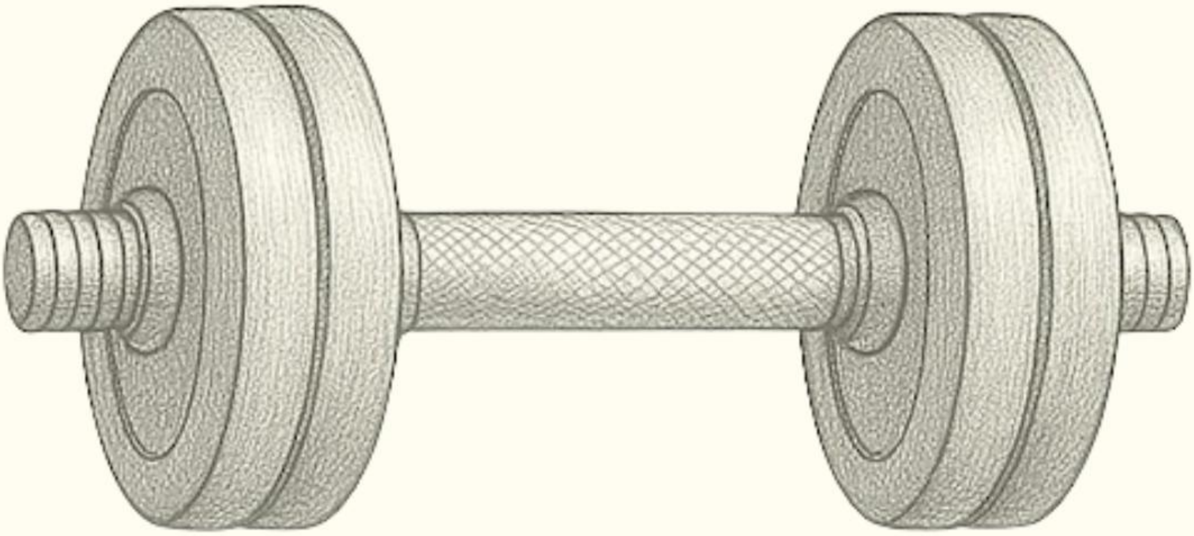
- Protein and creatine, to increase muscle mass.
- Energy drinks, to accelerate the metabolism and to increase energy.
- Vitamin supplements to increase antioxidant factors and decrease fatigue.

Substance abuse to improve sport performance

However, many people turn to illegal substances to achieve unprecedented improvements in athletic performance with little efforts, but this practice may bring fatal consequences. For example, the use of anabolic steroids can cause cardiac problems, an increase in arterial pressure, renal damage, and aggressive behaviour.

In addition, the use of erythropoietin may lead to: hypertension, stroke, peripheral thrombosis and blockage of the coronary arteries.

8



PRINCIPLES OF STRENGTH EXERCISES

REASONS FOR EXERCISE

Strength

Strength is the most important conditional basic physical quality, that is the ability to overcome or oppose an external weight or resistance through muscle contraction.

There are different classifications of strength:

- We can divide it into dynamic strength, which implies an acceleration such as throwing; or static strength, which produces a deformation, such as a push.
- On the other hand, we can differentiate active strength, which includes maximum strength, swift force, and resistance force; or reactive strength, which is the one in which we take advantage of the elastic and reactive components, such as plyometric exercises.

If we train one type, transfer to others is low, so we need to focus on each component specifically.

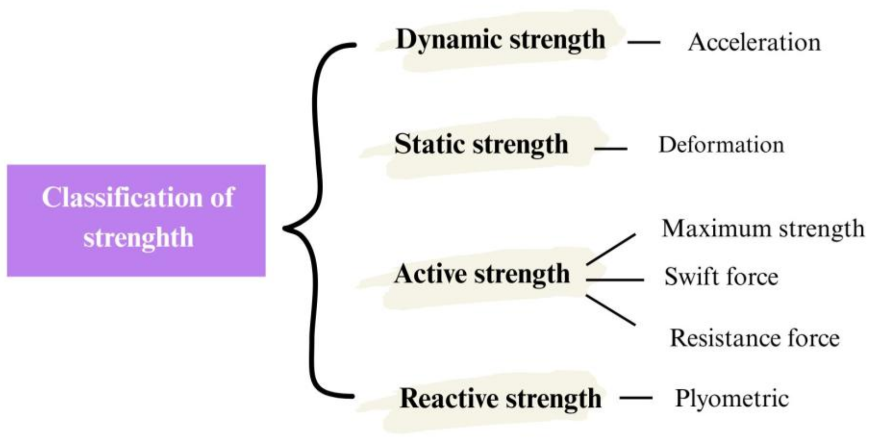


Figure 33. Types of strength.

Derived capabilities

The rest of the conditional basic physical qualities are different manifestations of strength. They are the following capabilities:

- Endurance, that is the ability to maintain a more or less intense effort for as long as possible, against the fatigue, and can be divided into: aerobic endurance, which has a long duration and a low intensity; or anaerobic endurance, which has a short duration and a high intensity.

- Speed, that is the ability to perform one or more movements in the shortest possible time, and could be divided into reaction speed, limited by the speed of neural drive; and execution speed that is the muscle contraction speed.
- And finally, flexibility or range of motion (ROM), that is the ability to perform a movement in the largest possible range, and it is given by muscular elasticity and joint mobility.

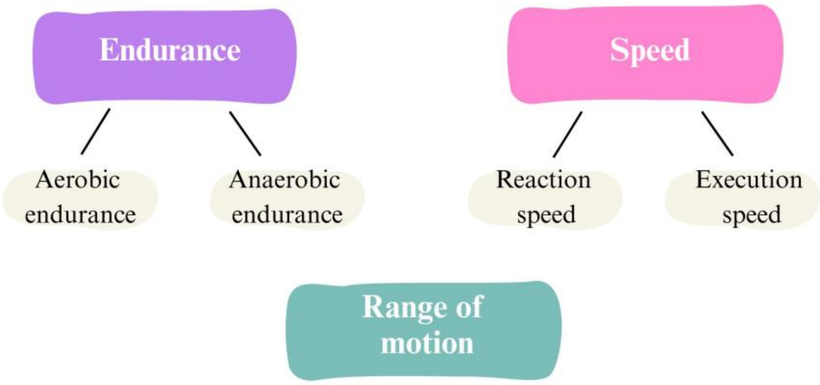


Figure 34. Capabilities derived from strength.

Effects of strength training

Now, we already understand the different concepts. What are the reasons to do strength exercises? (López Chicharro & Fernández Vaquero, 2023).

The effects of strengthening training are wide in the neural and muscular areas. Regarding the neural adaptations, we find:

- Efficiency improvement in the neural recruitment pattern.
- Improvements in central neural system activation.
- Improvements in the synchronization of motor units
- Slowing of neural inhibitor reflexes.
- Inhibition of the Golgi tendon organ.

On the other hand, in relation with the muscular adaptations, we find:

- Increase of myofibrils

- Increase of actin-myosin myofilaments.
- Increase in sarcoplasm.
- Increase of connective tissue. In this point, we need to be careful, because if the connective tissue develops very quickly, it can generate a muscle rupture, and this phenomena is one of the clues to suspect the use of steroids.
- If we combine all these muscle effects, the adaptation called hypertrophy is generated.

Muscle atrophy

Nonetheless, strength training brings not only direct positive effects, but also indirect ones, since it is able to avoid adverse phenomena such as muscle atrophy, that is the loss of muscle mass that generates a decrease of size, strength and mobility.

In relation to this entity, we need to know some key points such as:

- In cases of immobilization , the loss is more abrupt in the first week, approximately 3% or 4% per day.
- It mainly affects the type one fibers.
- The recovery is longer than the immobilization.
- Our body has a partial solution that is muscle memory. This is the ability of the muscles to recover the performance lost after a period of inactivity, so reduces recovery times. However, it is important not to risk everything to muscle memory, but to use cross-strength training in cases of immobilization

TYPES OF EXERCISE

We know why we need to do strength exercise, we are going to analyse the different types of strength exercise (Lum & Barbosa, 2019; Sato et al., 2022).

Static strength: Isometric exercise

Firstly, the static ones, that are called isometric exercises. These exercises involve tension without any change in muscle length, and the dosage depends on our aim.

If we want to increase hypertrophy, we need to do exercise at 70% or 75% of our maximum repetition, with a sustained contraction between 3 and 30 seconds per repetition.

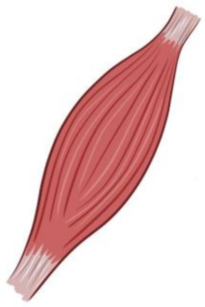


Figure 35. Isometric contraction.

The total duration of the sustained contraction in the session should be between 8 and 150 minutes.

However, if we want to increase maximum strength, we need to do exercise at 80% or 100% of our maximum repetition, with a sustained contraction between 1 and 5 seconds, and the total duration of the sustained contraction should be between 30 and 90 seconds.

Isometric exercise has four main benefits:

- To avoid overly fatigue while still acquiring neuromuscular adaptations.
- To improve strength in any joint position.
- To improve sports specific movement that requires mainly isometric strength.
- To improve strength without pain and movement in injured patients.

Dynamic strength: concentric exercise

Secondly, the dynamic exercises can be divided into isokinetic and isotonic, subdivided in concentric, eccentric and the couple concentric-eccentric.

In concentric exercise, the force provided by the muscle is greater than the resistance, and the dosage depends on the aim, establishing the following relationship:

- Strength with 6 or 8 repetitions.
- Hypertrophy, with 10 or 12 repetitions.
- Endurance with more than 15 repetitions.

In terms of intensity, the traditional 60% or 85% depends on the objective.

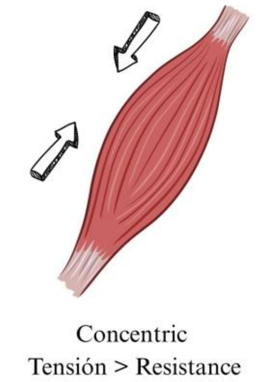


Figure 36. Concentric contraction.

This type of exercise reports some benefits like: an increase in muscle strength; a decrease in the risk of injury compared to eccentric; and shorter recovery after exercise.

However, it also presents a main disadvantage which is the minor neuromuscular adaptations.

Dynamic strength: Eccentric exercise

In addition, we have the eccentric exercise, in which the force provided by the muscle is minor than the resistance, and the common dosage is three or five sets, with six or eight repetitions and with an execution at very low speed.

The main benefits of this type of exercise are an increase in muscle strength, an increase in tissue elasticity, an increase in neuromuscular adaptations, and an increase in proprioceptive qualities. The main disadvantage is the greater risk of injury.

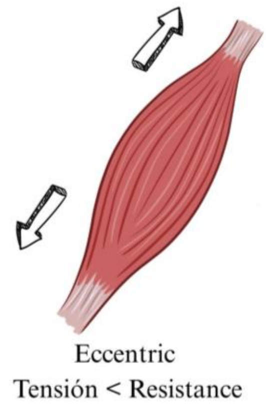


Figure 37. Eccentric contraction.

Dynamic Strength: Concentric-eccentric exercise

Moreover, we have the couple concentric-eccentric, which combines shortening-stretching cycles, taking advantage of elastic force.

The most common exercises are plyometrics, whose typical dosage implies one or two weekly sessions, between ten to thirty sets, with ten to twenty-five repetitions. The main characteristic is the log rest time, from two to eight minutes between sets; and the intensity depends on the height

The main benefits are:

- To favor the transfer from strength to speed or explosive force.
- Increase the rhythm of activation of the motor units.
- Increase of the neuromuscular adaptations, to allow powerful and fast gestures.
- Improvement of the efficiency, generating a decrease in the coupling times between the eccentric and concentric phases.

Dynamic strength: Isokinetic Exercise

Finally, we have the isokinetic exercises, that are performed at a constant and preselected speed, while the resistance varies to compensate for the force applied at each point of range of motion.

The main benefits of this type of exercise are a decrease in the risk of injury; an increase in muscle strength; and an improvement in the ability to control the force in the joint.

Nonetheless, isokinetic exercise has two main disadvantages: exercise equipment is overpriced and it is done in laboratory conditions that don’t resemble reality.

Summary of volume and intensity in dynamic and static strength		
STATIC STRENGTH: Isometric		
Hypertrophy	MR (intensity): 70%-75% Volume: 3-30 s/rep Total volume: 8-150 min.	
Maximum strength	MR (intensity): 80%-85% Volume: 1-5 s/rep Total volume: 30-90 s.	
DYNAMIC STRENGTH: Concentric		
Strength	Volume: 6-8 rep.	

Hypertrophy	Volume: 10-12 rep	MR(intensity): 60%-85%
Endurance	Volume: +15 rep	

TYPES OF ENDURANCE

As we have already commented, the endurance could be aerobic or anaerobic. However, this division is not so clear, because we can differentiate three types of exercise depending on the source of energy (López Chicharro & Fernández Vaquero, 2023).

Efforts of short duration and maximum strength

Firstly, efforts of short duration and maximum strength, whose energy sources are the chemical bond of ATP; and phosphocreatine.

The most specialized fibers are type IIb fibers.

There are limited muscle stores of ATP and phosphocreatine, so they are depleted in a few seconds. However, these energetic substrates are in permanent resynthesis.

One example of this type of effort is weightlifting.

Efforts of short duration and high intensity

On the other hand, we find efforts of short duration and high intensity, whose energy sources are both glucose in the form of glycogen, which corresponds to aerobic resistance; and anaerobic glycolysis, which corresponds with anaerobic resistance.

The most specialized fibers are type IIa fibers.

This occurs because there are limited muscle stores of glycogen, so lactate is produced but could be recycled as fuel. Nonetheless, in the absence of oxygen, the Krebs cycle is not enough, and lactic acid accumulates, which is called an anaerobic threshold, and generates exhaustion and muscle pain.

One example of this type of effort is the 1500-meter athletics competition, which is considered the most difficult sporting competition from an energetic point of view, as it requires a perfect balance of all energetic pathways.

Efforts of long duration

In addition, we have efforts of long duration, whose energy sources are aerobic glycolysis and fat oxidation, both correspond to aerobic endurance.

We can consider that aerobic glycolysis is an efficient pathway for energy, but has limited glycogen stores, in both muscle and liver. So, when glycogen runs out, we collapse.

At that moment, the beta oxidation of free fatty acids appears, which is the less efficient pathway and it is only used for very prolonged efforts because although there are large reserves available, their yield is very small.

The most specialized fibers are type I.

One example of this type of effort is a marathon, in which the reserves are not sufficient, and in addition to using both energy pathways, glucose intake is required during the competition.

Summary of type of efforts, fibers type and energy sources	
Short duration & max. strength	
Fiber	Energy sources
Type II b fibers	ATP and phosphocreatine
Short duration & high intensity	
Fiber	Energy sources
Type II a fibers	Glucose (Glycogen)
Long duration	
Fiber	Energy sources
Type I fibers	Aerobic glycolysis and fat oxidation

Energy sources and resistance types

So, if we try to establish a relationship between energy sources and resistance types, we could say that:

- Anaerobic endurance uses ATP, as an immediate form of energy expenditure; and if the exercise lasts up to thirty seconds, the phosphocreatine facilitates the resynthesis of ATP.

- Aerobic endurance uses glucose, that predominates from three minutes of exercise; and when glycogen runs out approximately at twenty minutes and even more at four hours, uses fat acids.

So, we can deduce that all pathways are presented from the beginning, but depending on the duration of the exercise, one or the other will prevail.

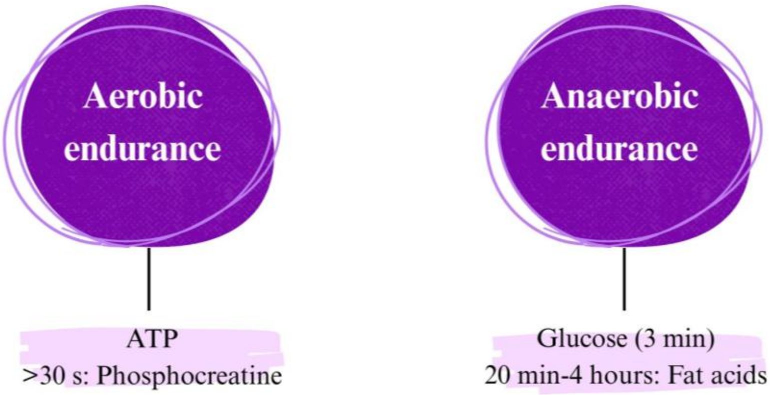


Figure 38. Aerobic vs anaerobic endurance.

Aerobic-anaerobic transition

Taking into account that it is a continuous process, it is important to know how the aerobic-anaerobic transition is, which is determined by two thresholds.

Lactic threshold that begins when we start using lactate, occurs at the intensity of physical activity in which the oxygen supply is unable to sustain energy production.

The aim of determining the lactic threshold is to establish the capacity of energy production at very high speeds.

We need to keep in mind that this threshold is not the same for everyone, because less trained people use more lactate for less amount of training.

On the other hand, we have the ventilatory threshold, that is the equivalent to what happens in the blood but at respiratory level.

EXECUTION OF EXERCISE

Related with the execution of the exercises we must distinguish three key parameters: time, force and speed execution (Vasconcelos Raposo, 2019).

Execution time

Regarding the execution time, it is the set of times you invest in each of the parts of a single repetition of a specific exercise.

We need to differentiate four parts with its own execution time:

- Eccentric phase time, in which we should spend at least two or three seconds because it is the most relevant phase in the gain of strength.
- Transition time must be reduced to increase the ability to take advantage of the elastic energy accumulated from the eccentric phase for the concentric phase.
- Concentric phase time, which is essential for the generation of movement, so it is usually trained under the order "as fast as possible".
- Pause time, which corresponds to the time in which we maintain the peak of concentric contraction.

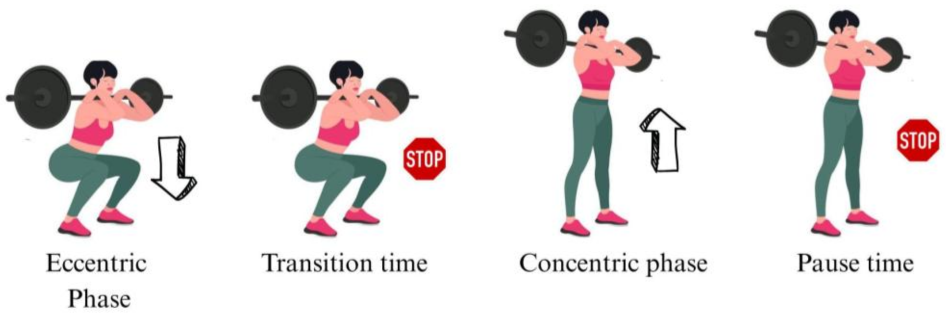


Figure 39. Execution time.

Execution force

On the other hand, we have the execution force, that is the capacity with which we generate intramuscular tension against a determined resistance, in a single repetition of a specific exercise.

The most common indicator is maximum repetition, that is the highest force that the neuromuscular system can generate in a single maximal contraction.

Relationship between aim, maximum repetition and number of repetitions		
Aim	**MR**	**Repetitions**
Anatomic adaptation	30%-40%	30-50 reps
Resistance strength	50%-70%	15-20 reps
Hypertrophy	70%-80%	10-12 reps
Strength	60%-80%	6-8 reps
Maximum strength	85%-100%	1-6 reps
Power	30%-60%	1-6 reps

Execution speed

The execution speed is the speed at which the athlete is able to move a load, expressed in meters per second (m/s). This is the most reliable indicator of training intensity.

We can find:

- Maximum speed, that means doing the exercise at maximum possible speed against a load that we can control.
- Dynamic maximum force, that is to mobilize a maximum load as fast as possible, or what is the same, doing a maximum repetition in the shortest possible time.
- Power, that is to generate the greatest possible force in the shortest possible time.
- Resistance to power, that means generating the maximum force possible, in the shortest possible time and in a sustained manner over time.
- Resistance to force, that is to maintain a rate of force against a load that we can control sustained over time.

EXERCISE TECHNIQUE

Technique

The technique is the way of executing sports actions following a series of temporal-spatial patterns models that guarantee efficiency.

The main parameters are:

- Position, that is the way of placement of the body parts before interacting with the exercise equipment.

- Grip, that is the way of holding the barbell or dumbbell to move the load.

- Displacement, that alludes to the dynamic changes of position during the execution of the exercise.

- Breathing, that is the way of acquiring and expelling air couple to the execution of the exercise.

Position

Regarding the position, we are going to talk about the most common ones:

- Standing, in which we need to have an upright spine, legs hip-width apart and arms close to the body.

- Trunk flexion, in which we need to have knees extending without locking, straight back but maintaining physiological curvatures, and shoulders aligned.

- Knee flexion, in which we need to have the heels stuck to the ground, the spine should be semi-inclined without fully flexing the trunk, and the armas aligned by the lateral side of the knees.

Grip

As for the grip, we can find four different types of grips:

- Supine grip, that is, palms facing the ceiling, and it is used for exercises that work biceps.

- Prone grip, that is, palms facing the ground, and it is used for rowing and pull-ups.

- Hammer or neutral grip, that is, palms looking at each other, and it is used for openings, and exercises that work triceps.
- Mixed or alternative grip, that is, one palm facing the ceiling and the other one facing the ground, and it is used for dead weight.

Displacement

Referring to displacement, there is no perfect method, but it depends on the aim, the risk of injury, the fitness, the specific gesture, and of course, the structural or functional limitations of the subject.

For example, someone who has limited external rotation in both shoulders due to surgery cannot use a barbel that is not guided from behind the head. That does not mean they will get injured for modifying the technique. They simply need to adapt it to their abilities to achieve the same effectiveness.

This is something you should always keep in mind: you are not going to train perfect people. They do not have to adapt the exercise, you are the one who needs to adapt the exercise to each person.

Breathing

In relation with the breathing, we can differentiate three ways:

- Active breathing, that is, inhale during the concentric phase and exhale during the eccentric phase. This technique is the most used in dynamic exercises with overload.
- Passive breathing, that is, inhale during the eccentric phase and exhale during the concentric phase. This technique is the most recommended due to the need to oxygenate to make the effort.
- Valsalva technique, that means, staying in apnoea during the concentric phase, This technique should not be performed or recommended, because it increases the interal pressure (vascular, intrathoracic and intracranial pressure), generating a collapse, that supposes a high risk of cardiovascular events.

EXERCISE PROGRAM DESIGN

Parameters

In order to design a strengthening program we need to take into account the following parameters (López Chicharro & Fernández Vaquero, 2023):

- Aim, that summarizing could be pure muscle strength, muscle endurance or explosive force.
- Number of sets and repetitions.
- Recovery or rest time, both between sets and between sessions.
- Total duration of the session.
- Frequency of the sessions.

General recommendations (Healthy subject)

Some general recommendations for health subjects could be:

- To achieve pure muscle strength, working at 6 or 8 of his maximum repetition.
- To achieve muscle endurance, working at 15 or 20 of his maximum repetition.
- To achieve muscle power, working at less than 10 of his maximum repetition at very high speed, with a loss of speed minor than 20%.

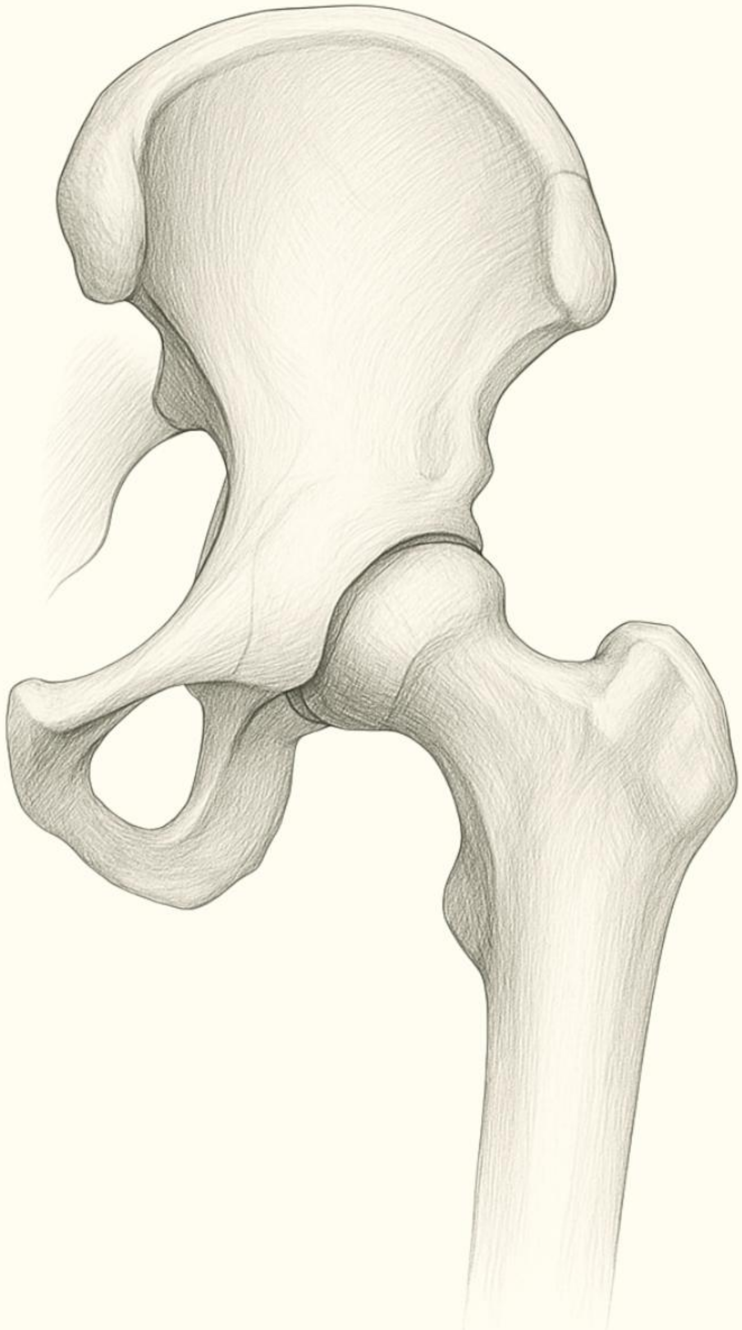
Regarding the number of sets and repetitions and their corresponding rest times, we can establish two categories:

- Isometric exercises, with 4 sets of 20 seconds of contraction, with 60 seconds of rest between sets.
- Or isotonic exercises, with 6 sets of 8 repetitions with 60 seconds of rest for strengthening; or 4 sets of 12 repetitions, with 90 seconds of rest for endurance.

Concerning the total duration, it should be 45 minutes, because, when an hour passes from the beginning of the session, all the hormones have run out.

The general recommendations establish a frequency of 2 or 3 weekly sessions, separated by 48 hours. Finally, regarding the progression, when the perceived intensity decreases, we could increase the load by 5%.

PRACTICAL SECTION



HIP JOINT COMPLEX

HIP JOINT COMPLEX

ANATOMIC CONSIDERATIONS

The hip is the proximal joint of the lower limb, whose main function is to provide enough balance, reason for which this joint requires a junction of dynamic and static stabilizers that accomplish this requirement. Due to this purpose, instead of being the second most mobile joint, the hip joint is the only joint one we cannot decouple with human strength.

In regard to the type of joint, the hip is a ball-and-socket joint formed by the femoral head (convex) and the acetabulum (concave). This structure ensures three degrees of freedom: flexion-extension, abduction-adduction, and external rotation-internal rotation.

RANGE OF MOTION

Due to most of the muscles that surround the hip are biarticular muscles, the range of motion of this joint could be modified depending on the position of the knee.

FLEXION:

- Active flexion with extended knee: 90º.
- Active flexion with flexed knee: 120º.
- Passive flexion with extended knee: 120º.
- Passive flexion with flexed knee: 140º.

EXTENSION:

- Active extension with extended knee: 20º.
- Active extension with flexed knee: 10º.
- Passive extension with extended knee: 20º.
- Passive extension with flexed knee: 30º.

ABDUCTION: 45º.

ADDUCTION: 10º - 15º.

INTERNAL ROTATION: 30º - 40º.

EXTERNAL ROTATION: 60º.

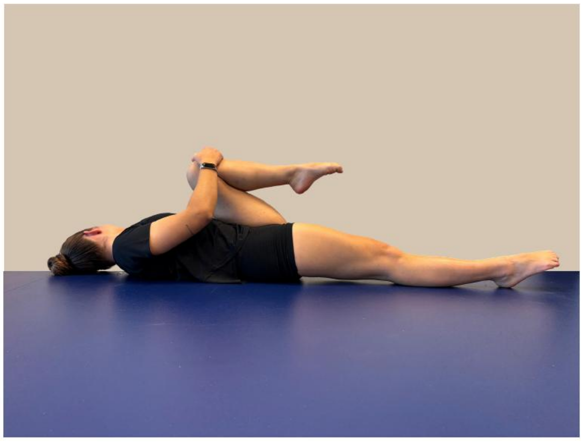
MAIN HIP MUSCLES

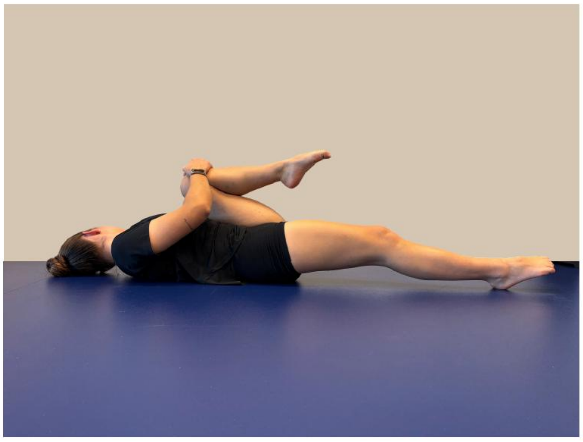
MUSCLE	FUNCTION
Psoas major	Flexion + External Rotation
Tensor fascia lata	Flexion + Abduction + External Rotation
Quadriceps	Flexion
Aductor	Flexion + Adduction + Internal Rotation
Sartorius	Flexion + Abduction + Internal Rotation
Gluteus major	Extension + External Rotation
Gluteus medius	Abduction + External Rotation
Gluteus minor	Adduction + Internal Rotation
Pyramidal	Abduction + External Rotation
Hamstrings	Extension

HIP JOINT TESTS

THOMAS TEST

- PERFORMANCE: patient in supine position, and we ask him to bring the opposite knee to his chest.
- OUTCOME: test is positive if the tested leg is lifted off.
- SIGNIFICANCE: shortening or snapping of the psoas.

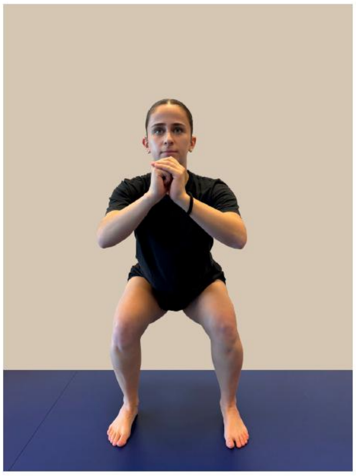


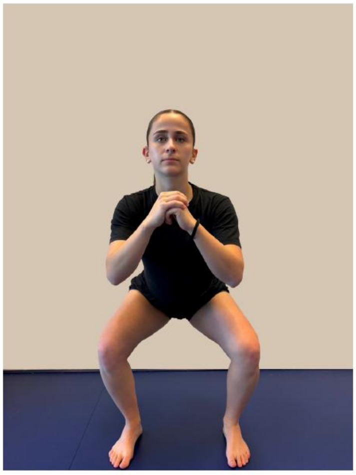


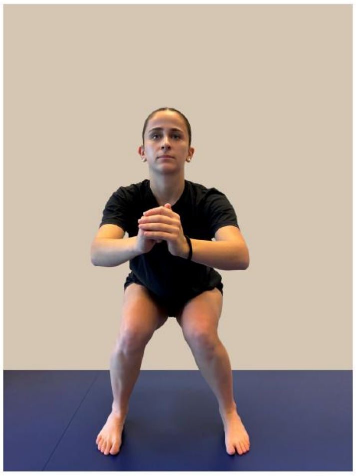
NEGATIVE **POSITIVE**

SQUAT AND LUNGE TEST

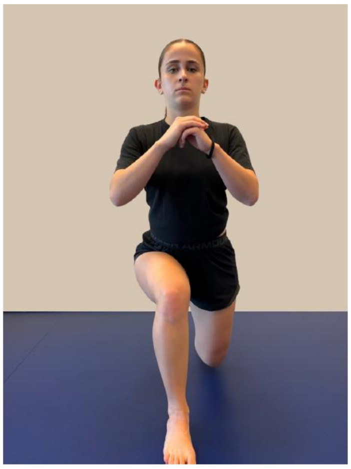
- PERFORMANCE: patient standing and we asked him for a squat and after, doing a lunge.
- OUTCOME: the hip tends to go into internal or external rotation in an exaggerated way.
- SIGNIFICANCE: neutral profile, anteversion or retroversion → muscle weakness.

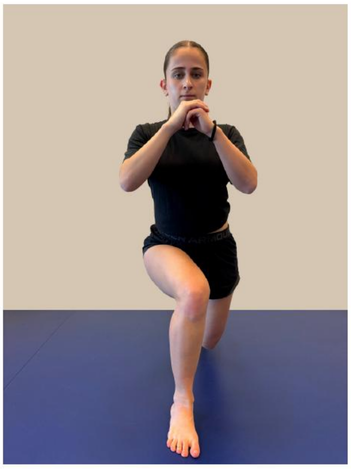


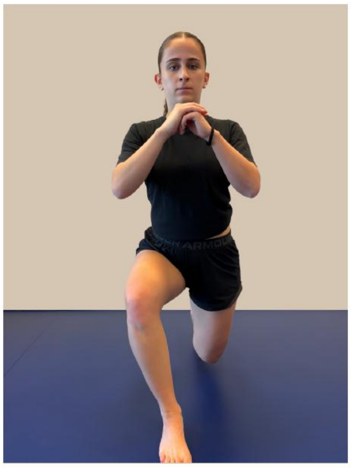




NEGATIVE **POSITIVE** **POSITIVE**



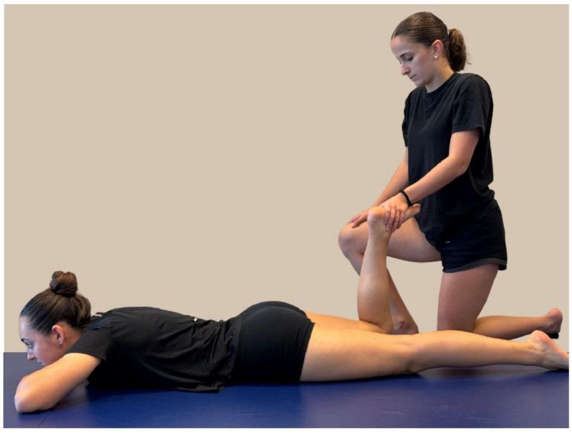




NEGATIVE **POSITIVE** **POSITIVE**

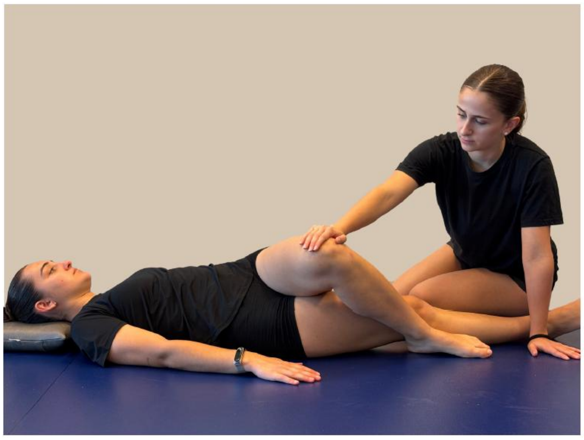
GLUTEAL TEST

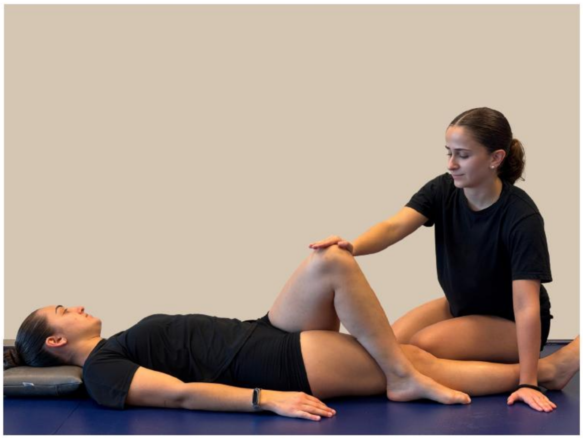
- PERFORMANCE: there are two possibilities:
  + Gluteus major: patient in prone position with the knee flexed at 90º and the hip is externally rotated. We ask for a push to the ceiling against our resistance.
  + Gluteus medius: patient in lateral position with the knee flexed at 90º. We ask for an abduction of the hip against our resistance.
- OUTCOME: test is positive if we detect weakness.
- SIGNIFICANCE: muscle deficit.



GLUTEUS MAJOR

**The test is positive if we detect weakness, but there are no reference values.*



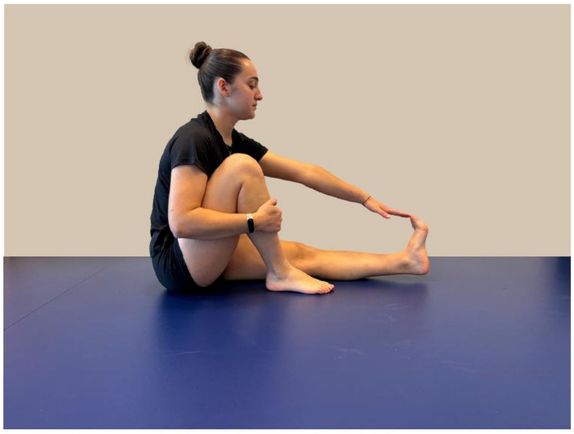


GLUTEUS MEDIUS

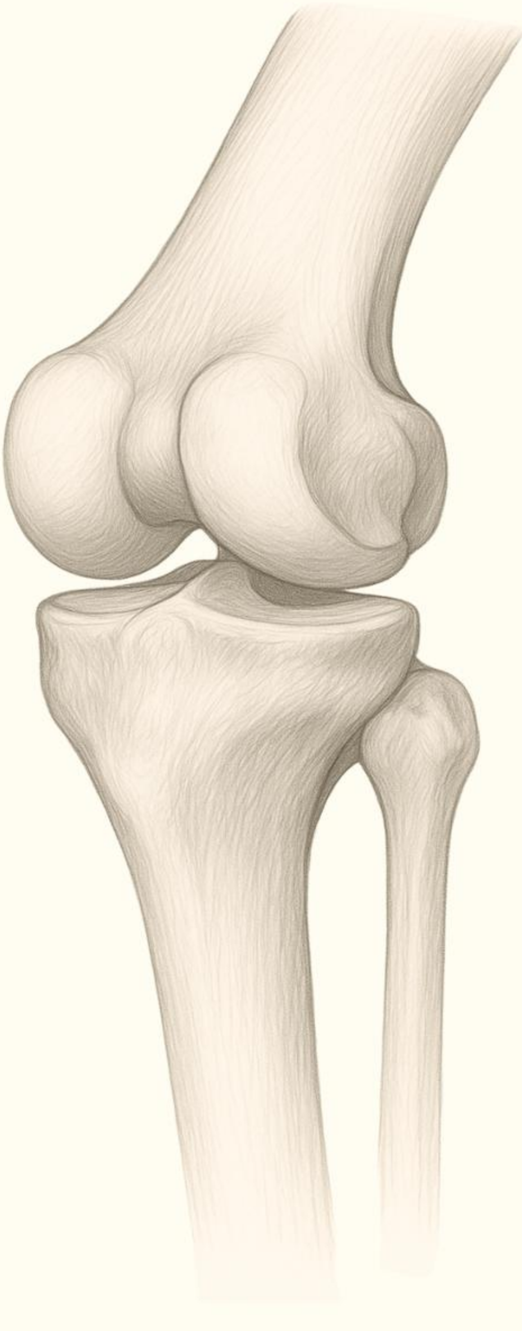
**The test is positive if we detect weakness, but there are no reference values.*

BACK SAVER SIT AND REACH TEST

- PERFORMANCE: the patient is sitting with the knees in a complete extension. We ask him to flex the contralateral knee and try to touch the toes with the hand on the tested side.
- OUTCOME: distance from fingers to toes.
- SIGNIFICANCE: shortening of the hamstrings.



**The test is positive if the person is unable to touch their toes with their fingers.*



KNEE JOINT COMPLEX

KNEE JOINT COMPLEX

ANATOMIC CONSIDERATIONS

Knee is the intermediate joint of the lower limb, and it is a condylar joint formed by the femoral condyles (convex) and the tibials glenoids (concave). This structure provides a single degree of freedom: flexion - extension, but this movement is accompanied by an accessory movement of rotation.

This joint complex encomprises another fake joint too which is the femoro-patellar junction, formed by the patella and the femoral trochlea separated by a prepatellar cartilage. This fake joint has movements such as slides.

The menisci is very relevant for this joint because this fibrocartilage is responsible for the transmission of the compression forces in the joint.

RANGE OF MOTION

Due to the existence of some biarticular muscles surrounding this joint, the range of motion sometimes depends on the position of the hip.

FLEXION:

- Active flexion with extended hip: 120º.
- Active flexion with flexed hip: 140º.
- Passive flexion with extended hip: this range is not really stable across the population.
- Passive flexion with flexed hip: 160º.

EXTENSION:

- Active: 0º.
- Passive: 0º.

ACCESSORY MOVEMENTS:

- Internal rotation: 30º.
- External rotation: 60º.

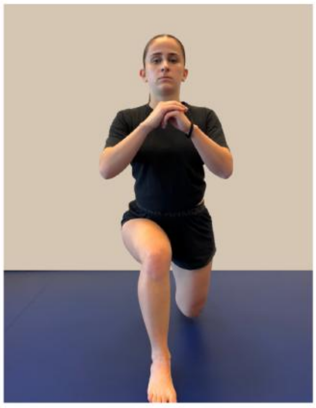
MAIN KNEE MUSCLES

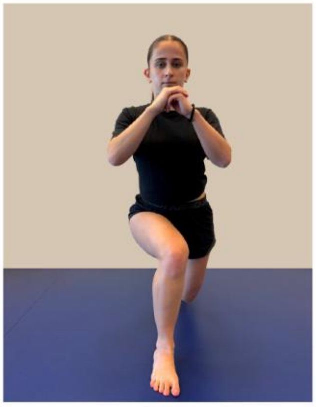
MUSCLE	FUNCTION
Quadriceps	Extension
Sartorius	Flexion + Internal Rotation
Semitendinous	Flexion + Internal Rotation
Semimembranous	Flexion + Internal Rotation
Femoral biceps	Flexion + External Rotation
Popliteal	Flexion + Internal Rotation

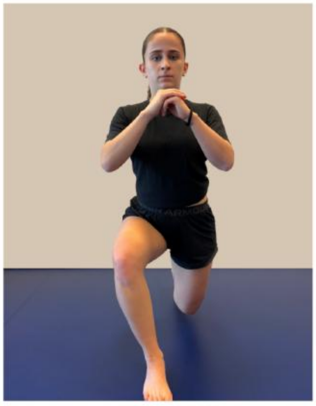
KNEE JOINT TESTS

LUNGE TEST

- PERFORMANCE: the patient is standing, and we ask him to do a lunge.
- OUTCOME: valgus collapse → internal rotation and adduction of the hip + knee valgus + external tibial torsion + prone foot.
- SIGNIFICANCE: hypoactivity of hip separators with hyperactivity of the approximators. In addition, hypoactivity of knee internal rotators and hyperactivity of knee external rotators.



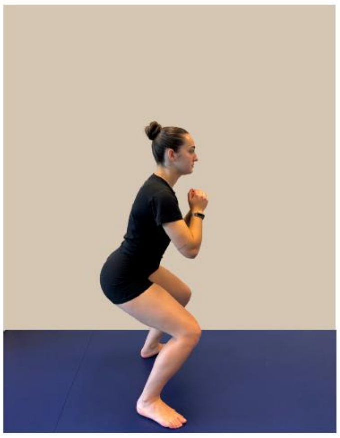


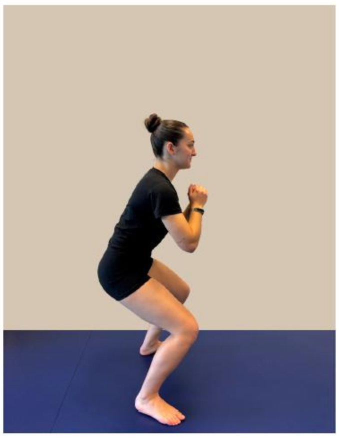


NEGATIVE **POSITIVE** **POSITIVE**

SQUAT TEST

- PERFORMANCE: the patient is standing and we ask him to do a squat.
- OUTCOME: "bat wing" → during the descent a posterior pelvic bascule is produced.
- SIGNIFICANCE: tension in hamstrings.

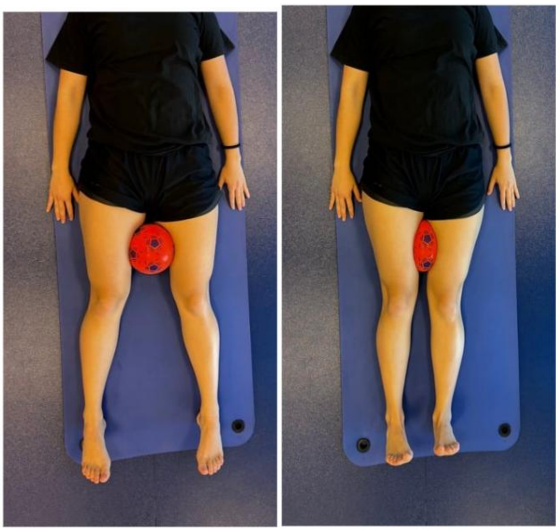




NEGATIVE **POSITIVE**

VASTUS MEDIALIS AND ADDUCTOR MAGNUS CO-CONTRACTION TEST

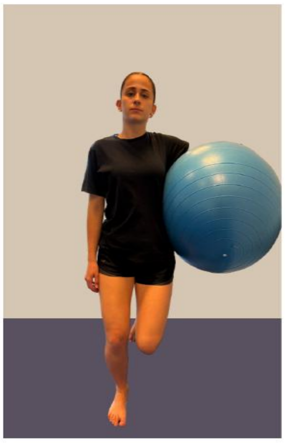
- PERFORMANCE: patient in supine position and we place a ball between his knees. We ask him to do a knee extension at the same time that he presses the ball.
- OUTCOME: low contraction or excessive tremor.
- SIGNIFICANCE: hypotonia in vastus medialis.



**The test is positive if we detect weakness or excessive tremor, but there are no reference values.*

MONOPODAL SUPPORT TEST WITH FITBALL

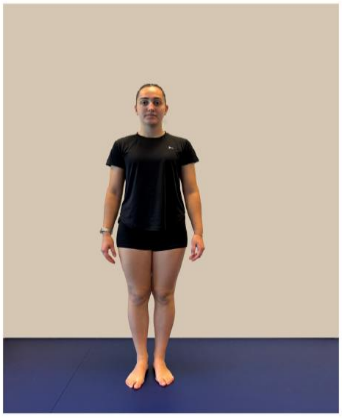
- PERFORMANCE: the patient is standing and we place a fitball between his body and the wall. We ask him to keep monopodal support with the leg away from the wall.
- OUTCOME: spring extension of the supporting knee.
- SIGNIFICANCE: compensation to cover hypotonia of the vastus medialis.

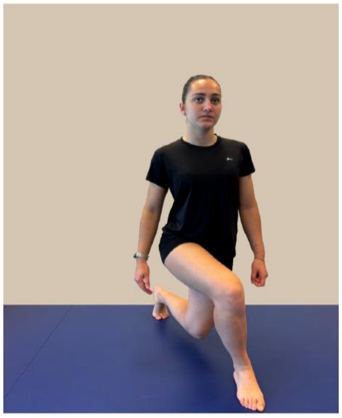


**The test is positive if we detect a spring extension of the supporting knee.*

ANTEROMEDIAL LUNGE TEST

- PERFORMANCE: the patient is standing and we ask him to do a lunge directed to the medial line.
- OUTCOME: number of repetitions in thirty seconds, and internal rotation of the hip.
- SIGNIFICANCE: weakness of the separators and external rotators of the hip.

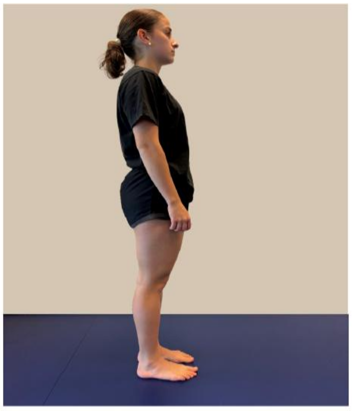




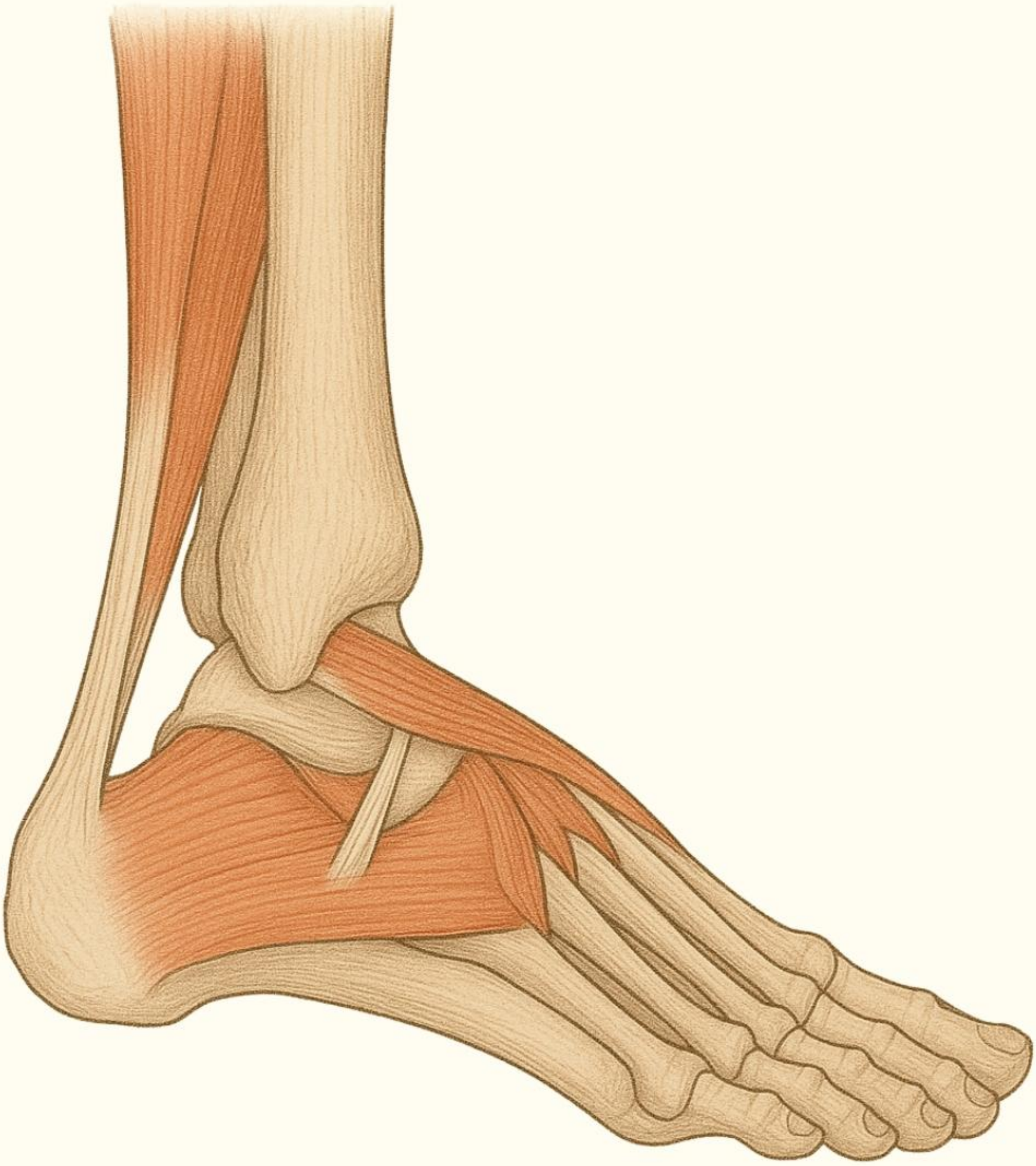
**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

BALANCE SIT AND REACH TEST

- PERFORMANCE: the patient is standing with monopodal support and we ask him to touch the opposite heel to the ground well in front of the supported foot.
- OUTCOME: number of repetitions in thirty seconds, and instability.
- SIGNIFICANCE: weakness of the gluteus medius and vastus medialis.



**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*



ANKLE JOINT COMPLEX

ANKLE JOINT COMPLEX

ANATOMIC CONSIDERATIONS

The ankle is formed by three joints:

- DISTAL TIBIO-FIBULAR JOINT: it is a fibrous joint (syndesmosis) which is formed by the triangular zone of the inferior part of the fibula plus the inferior external facet of the tibia.
- TIBIO-FIBULAR-TALAR JOINT: it is a throclear joint, with a single degree of freedom (dorsiflexion - plantar flexion). This joint is formed by the tibiofibular mortise (concave) and the talar pulley (convex).
- SUBTALAR JOINT: it is a trochlear joint, with a single degree of freedom round to the "Henke axis" (inversion - eversion). This joint is formed by the underside of the talus (concave) and the upper face of the calcaneus (convex).

RANGE OF MOTION

DORSIFLEXION: 20º - 30º.

PLANTAR FLEXION: 30º - 50º.

INVERSION: it cannot be measured in degrees because it is a combination of three movements → plantarflexion + adduction + supination.

EVERSION: it cannot be measured in degrees because it is a combination of three movements → dorsalflexion + abduction + pronation.

MAIN ANKLE MUSCLES

MUSCLE	FUNCTION
Anterior tibial	Dorsiflexion + Inversion
Large extensor of the thumb	Dorsiflexion
Common extensor	Dorsiflexion + Eversion
Short lateral peroneus	Plantarflexion + Eversion
Long lateral peroneus	Plantarflexion + Eversion

ANKLE JOINT TESTS

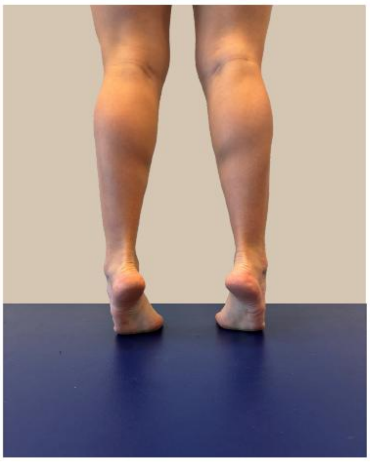
SOLEUS LENGTH TEST

- PERFORMANCE: the patient is standing with the heel supported and the foot separated from the wall. We ask him to touch the wall with his knee. We should repeat the test until the patient finds the position in which the heel lifts off the ground.
- OUTCOME: distance from the tip of the first toe to the wall minor than eleven centimeters.
- SIGNIFICANCE: possible soleus shortness → decreased ankle mobility.

NEGATIVE **POSITIVE**

DOUBLE HEEL RISE TEST

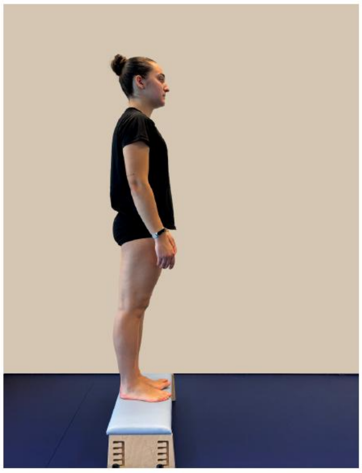
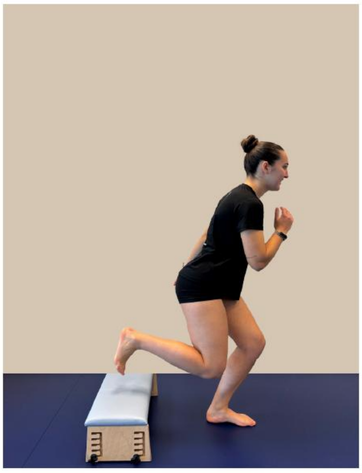
- PERFORMANCE: the patient is standing and we ask him to stand on tiptoe.
- OUTCOME: test is positive if the calcaneus doesn't change from valgus to varus.
- SIGNIFICANCE: weakness of the posterior tibial.



NEGATIVE **POSITIVE**

LANDING TEST

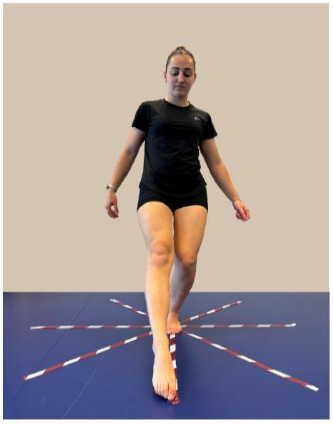
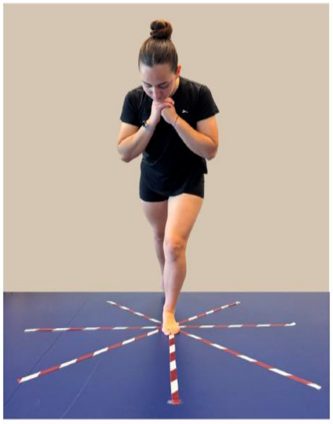
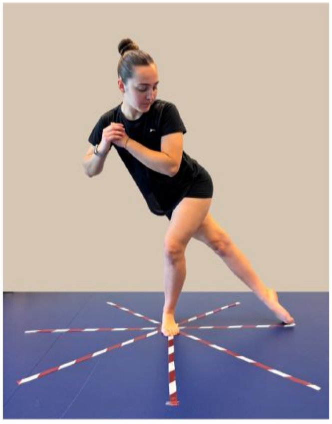
- PERFORMANCE: the patient is standing on a step and we ask him to perform an unipodal landing.
- OUTCOME: instability.
- SIGNIFICANCE: weakness of the peroneal muscles.

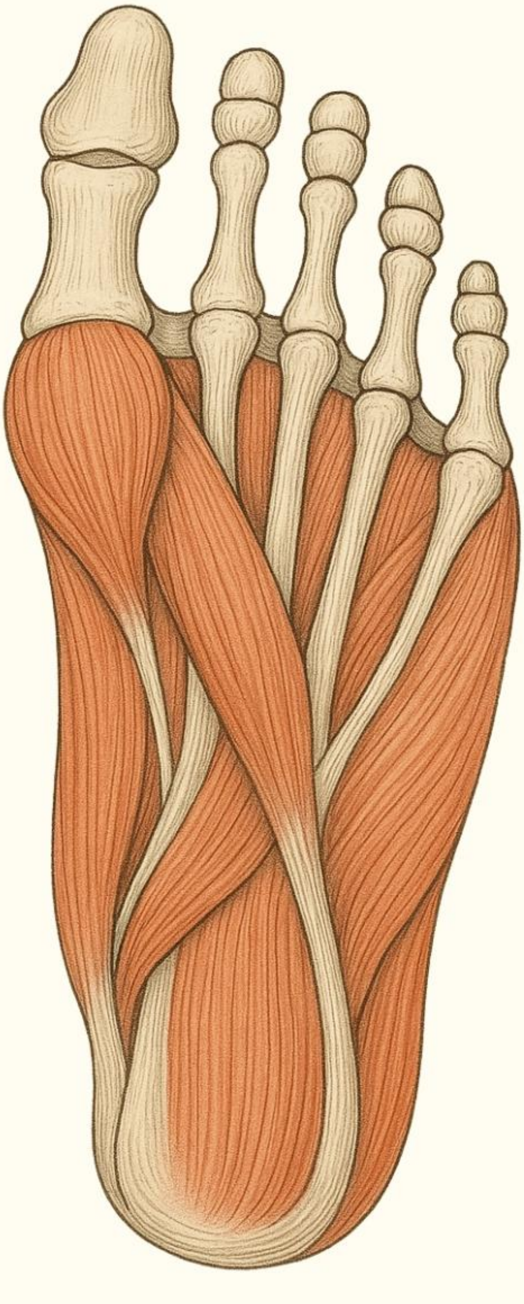
**The test is positive if we detect instability during the landing phase.*

STAR EXCURSION BALANCE TEST

- PERFORMANCE: the patient is standing on unipodal support and we ask him to touch the eight tips of the star with the opposite foot.
- OUTCOME: reach distance and instability.
- SIGNIFICANCE: muscle imbalance, lack of flexibility and lack of proprioception.

**The test is positive if we detect an incapacity to reach the tips of the star, or if we detect instability.*



FOOT JOINT COMPLEX

FOOT JOINT COMPLEX

ANATOMIC CONSIDERATIONS

The foot is formed by five joints:

- MEDIOTARSAL OR CHOPART JOINT: it is an arthrodia joint, which is formed by the calcaneus plus cuboid (saddle) and the talus plus scaphoid (bull-socket).
- TARSOMETATARSAL OR LISFRANC JOINT: it is an arthrodia joint, which is formed by the three cuneiforms plus coboid and the metatarsals.
- INTERMETATARSAL JOINTS: they are synovial joints, which are formed by the lateral surfaces of the metatarsals.
- METATARSOPHALANGEAL JOINTS: they are condylar joints, which are formed by the metatarsal heads (convex) plus the phalangeal bases (concave). These joints have two degrees of freedom → flexion - extension, and abduction - adduction.
- INTERPHALANGEAL JOINTS: they are throclear joints, which are formed by the head of the proximal phalanges (convex) plus the bases of the distal phalanges (concave). These joints have a single degree of freedom → dorsiflexion - plantarflexion.

MAIN ANKLE AND FOOT MUSCLES

MUSCLE	FUNCTION
Anterior tibial	Dorsiflexion + Inversion
Posterior tibial	Plantarflexion + Inversion
Common extensor	Dorsiflexion + Eversion + Extension (toes)
Extensor of thumb	Dorsiflexion + Eversion + Extension (thumb)
Peroneus brevis	Plantarflexion + Eversion
Peroneus longus	Plantarflexion + Eversion
Gastrocnemius	Plantarflexion

FOOT JOINT TESTS

NAVICULAR DROP TEST

- PERFORMANCE: the patient is sitting with the knee and the hip flexed at 90º. We do a mark in the scaphoid tuberosity and after that, we ask him to stand up and we mark the scaphoid tuberosity again.
- OUTCOME: difference between both marks greater than ten millimeters.
- SIGNIFICANCE: pronated foot → weakness of the supinators.

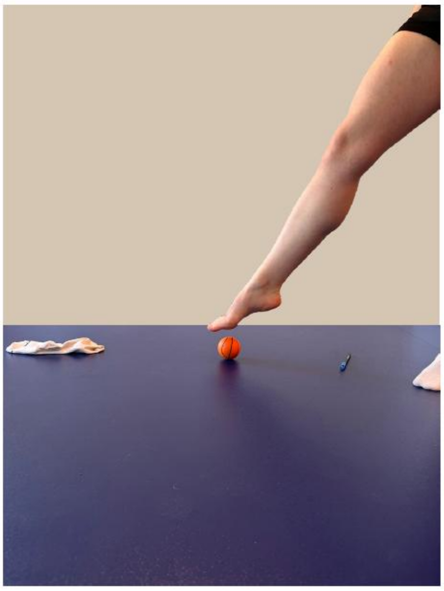
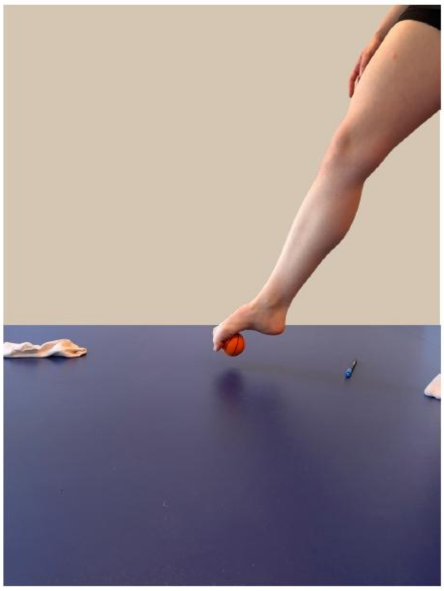



POSITIVE

INTRINSIC MUSCLE TEST

- PERFORMANCE: the patient is standing and we ask him to pick up different objects from the floor with his toes and place them in a box.
- OUTCOME: impossibility of doing it or the objects fall on the way.

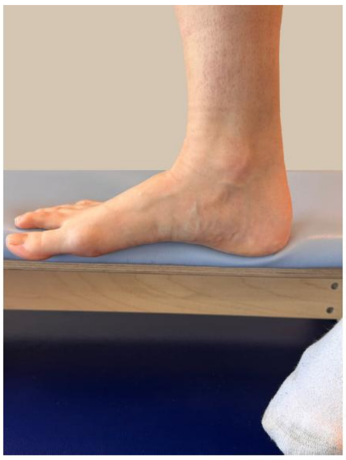
- SIGNIFICANCE: weakness of the intrinsic muscles.

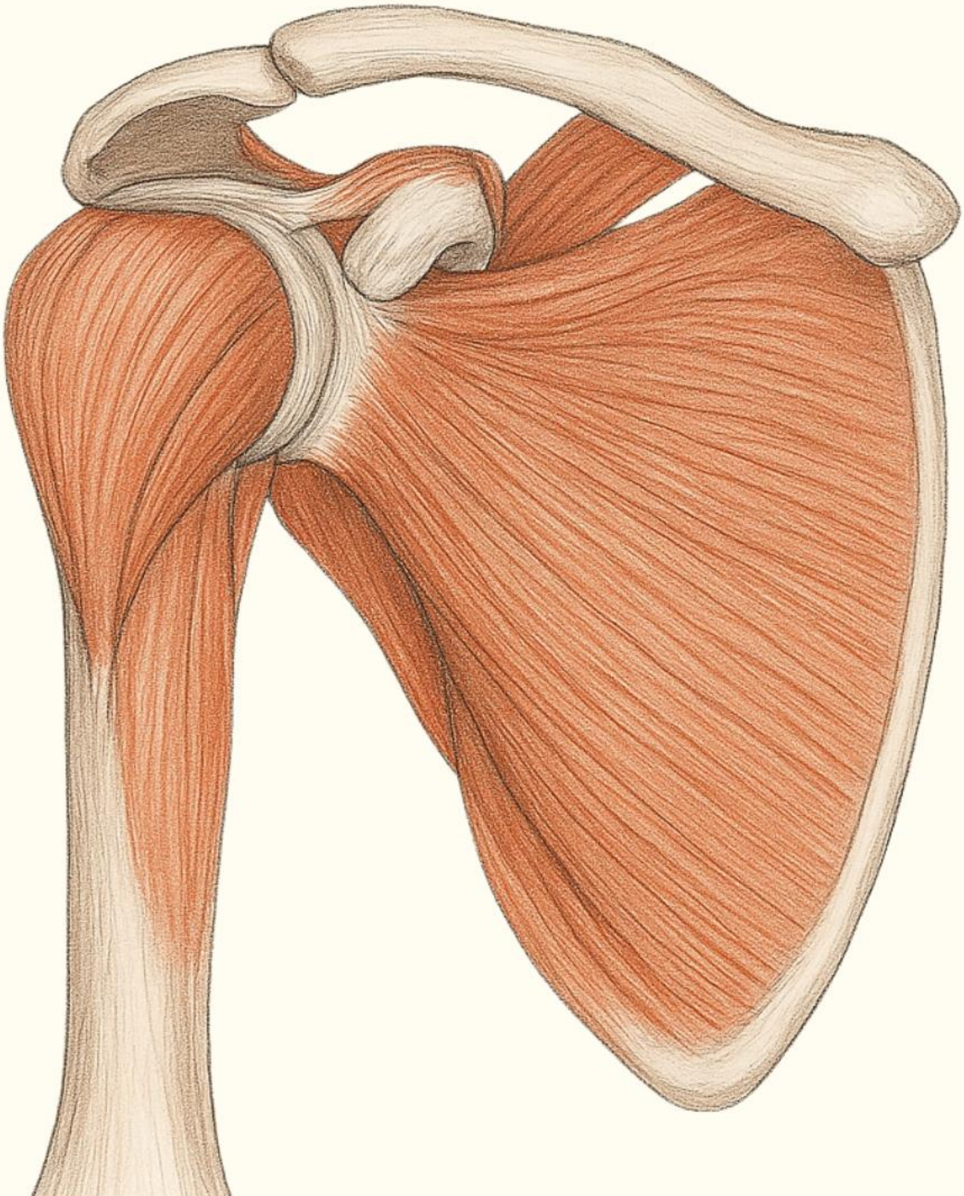
**The test is positive if we detect incapacity of catching the objects or excessive time to catch them, but there are no reference values.*

LATERAL STEP DOWN TEST

- PERFORMANCE: the patient is standing on a step with an unipodal support only on the last four toes. We ask him to make the gesture of dropping and going up laterally from the step.
- OUTCOME: step fall or loss of the arch of the foot.
- SIGNIFICANCE: pronated foot → weakness of the supinators.

**The test is positive if we detect a step fall or loss of the arch of the foot.*



SHOULDER JOINT COMPLEX

SHOULDER JOINT COMPLEX

ANATOMIC CONSIDERATIONS

Shoulder is the proximal joint of the upper limb and it is the most mobile joint in the body. The main challenge to be accomplished by this joint is to reach a balance between mobility and stability.

Shoulder is not an unique joint, but it is formed by five joints:

- GLENOHUMERAL JOINT: it is an enarthrodia joint formed by the humerus head and the glenoid cavity.
- SCAPULOTHORACIC JOINT: it is a fake joint, which is formed between two muscles. These muscles are the subscapular and the anterius serratus.
- ACROMIOCLAVICULAR JOINT: it is an arthrodia joint formed by the clavicule and the acromion.
- STERNOCOSTOCLAVICULAR JOINT: it is a reciprocal engagement formed by the clavicule, the manubrium, and the first rib.
- SUBACROMIAL OR SUBDELTOID JOINT: it is a fake joint which is located between two muscles. These muscles are the deltoid and the supraspinatus.

RANGE OF MOTION

This joint has freedom in all movement planes:

FLEXION: 180º.

EXTENSION: 45º - 50º.

ABDUCTION: 180º.

ADDUCTION: 30º - 45º.

INTERNAL ROTATION: 90º.

EXTERNAL ROTATION: 90º.

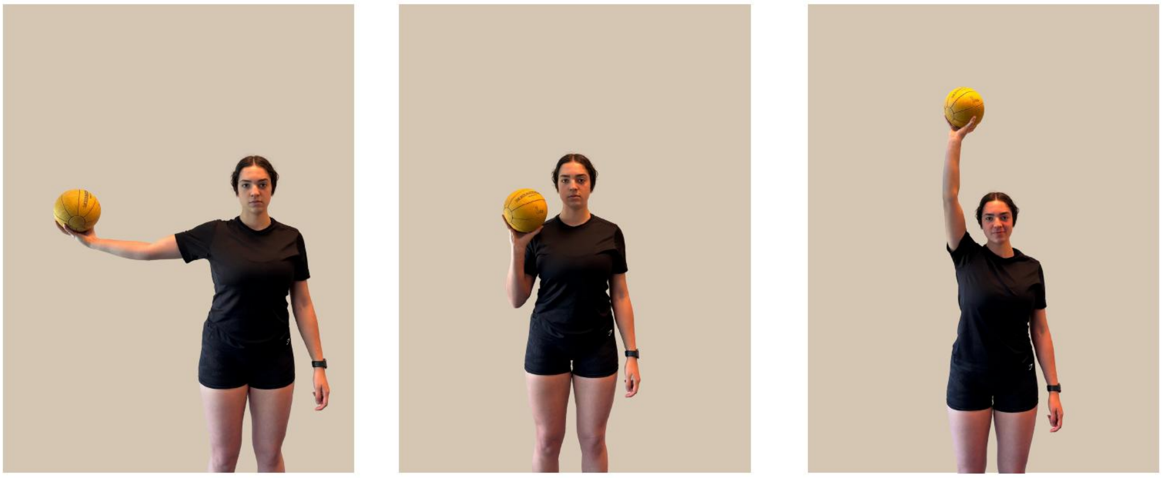
MAIN SHOULDER MUSCLES

MUSCLE	FUNCTION
Biceps brachii	Flexion
Trapezius	Scapular rotation
Major pectoral	Flexion + Adduction + Internal Rotation
Anterior deltoid	Flexion + Internal Rotation
Middle deltoid	Abduction
Posterior deltoid	Extension + External Rotation
Subscapular	Adduction + Internal Rotation
Supraspinatus	Abduction + External Rotation
Infraspinatus	External Rotation
Teres major	Extension + Adduction + Internal Rotation
Teres minor	Adduction + External rotation

SHOULDER JOINT TESTS

BALL ABDUCTION EXTERNAL ROTATION TEST

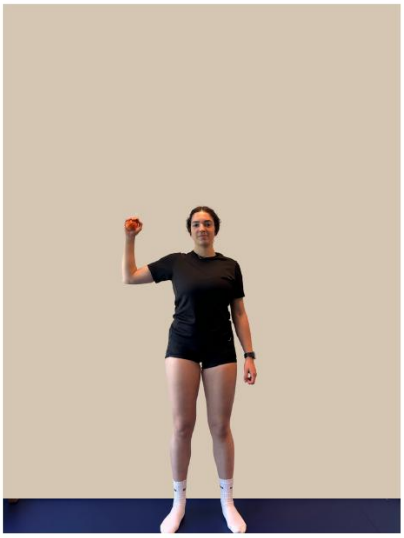
- PERFORMANCE: the patient is standing and we ask him to do the following steps:
  + Keeping a 3 kg ball on the hand with the shoulder at 0º of abduction and the elbow completely flexed.
  + Elbow extension until the shoulder is positioned at 90º of abduction.
  + Elbow flexion.
  + Lift the ball above the head with the elbow completely extended.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: weakness in the rotator cuff muscles.

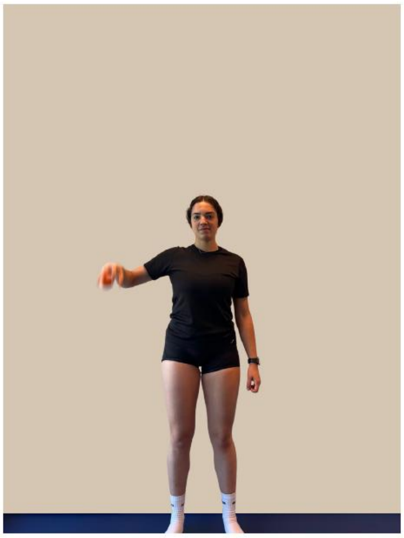


**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

DROP CATCHES TEST

- PERFORMANCE: the patient is standing and we ask him to do the following steps:
  + Keeping a tennis ball on the hand with the shoulder at 90º of abduction and the elbow at 90º of flexion.
  + Drop the ball and try to catch it doing an internal rotation of the shoulder.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of reaction speed and/or limitation of the internal rotation range of movement.

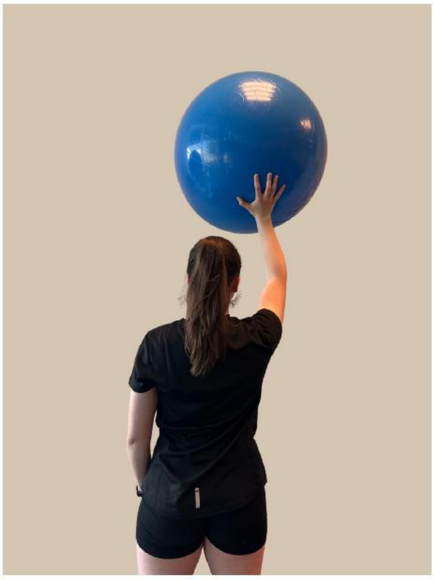


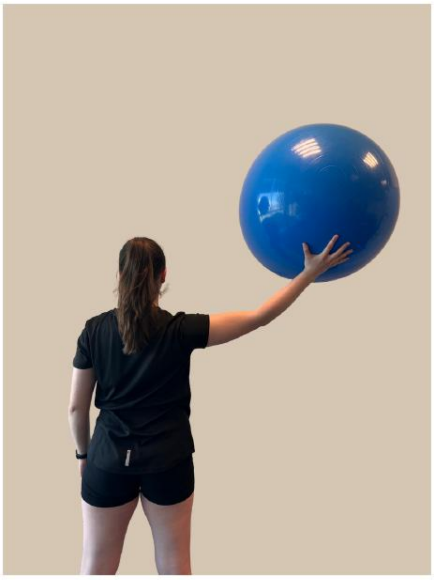


**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

BALL TAPS TEST

- PERFORMANCE: the patient is standing and we ask him to do the following steps:
  + Keeping a fitball between the hand and the wall with the shoulder at 180º of abduction.
  + Bounce the ball off the wall up to 90º of shoulder abduction and come back.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of shoulder stability.

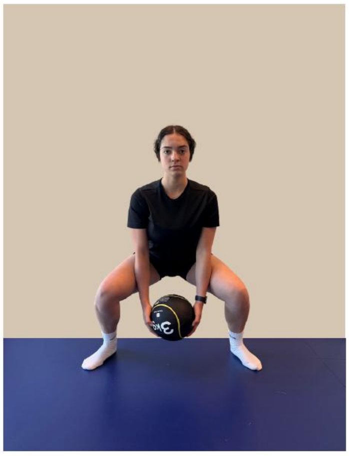
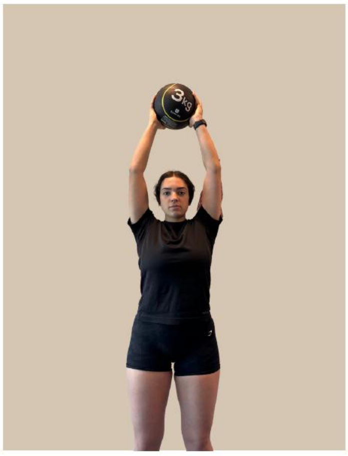




**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

OVERHEAD SNATCH TEST

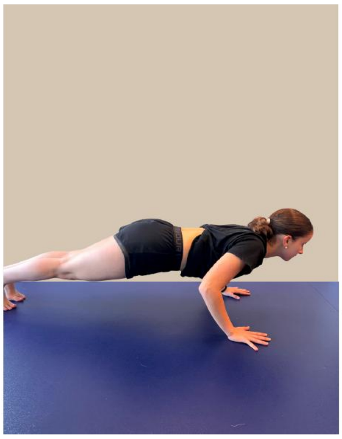
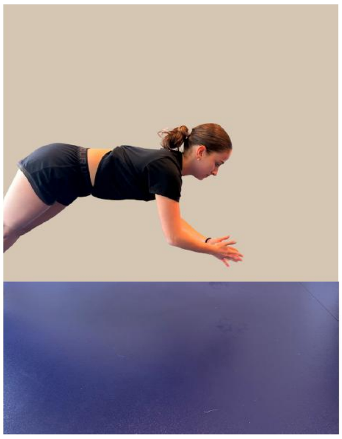
- PERFORMANCE: the patient is standing and we ask him to perform squats while lifting a ball of 5 kg overhead and down.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of shoulder muscles strength.

**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

PUSH-UP CLAPS TEST

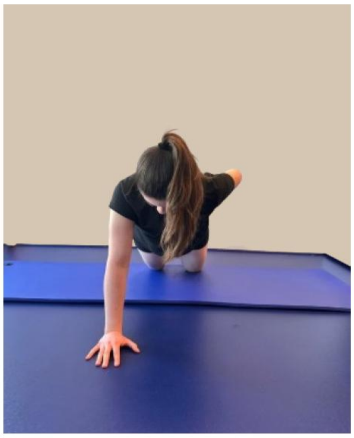
- PERFORMANCE: the patient is in a push-up position and we ask him to perform an explosive jumping push-up.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of stability and lack of strength.

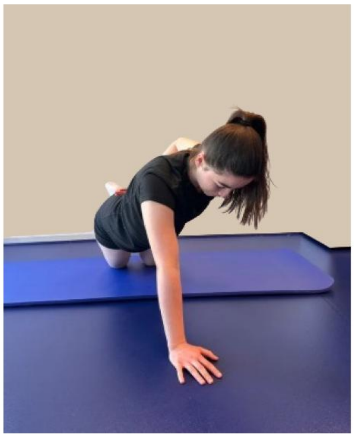



**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

LINE HOPS TEST

- PERFORMANCE: the patient is in a push-up position but with the knees supported on the ground and only one hand on the ground. We ask him to try to jump between the right and left sides with the hand.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of mobility and lack of stability.

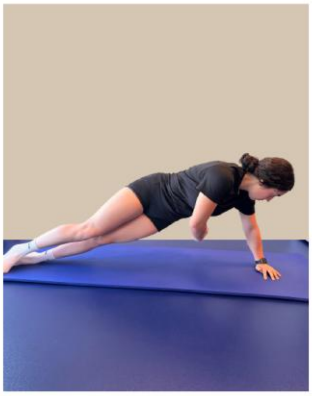


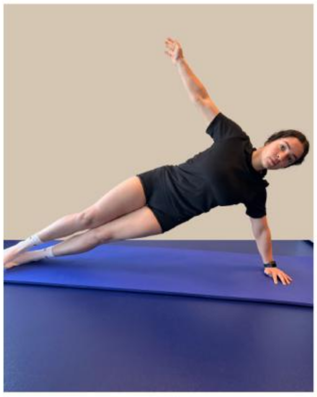


**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

SIDE HOLD ROTATIONS TEST

- PERFORMANCE: the patient is in side plank position and we ask him to try to rotate the trunk until reach the hand supported on the ground with the other hand, and come back.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of mobility and lack of stability.

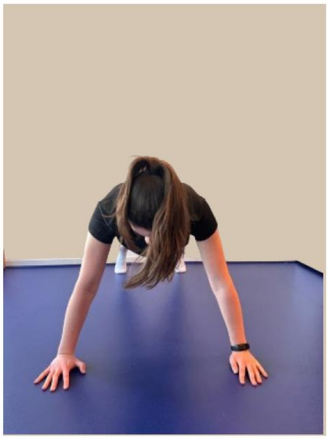


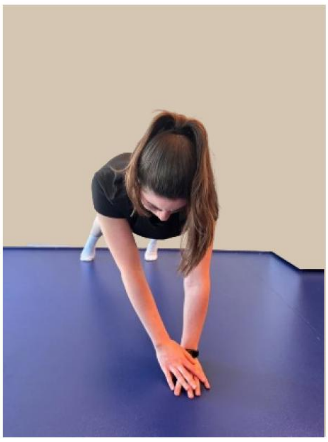


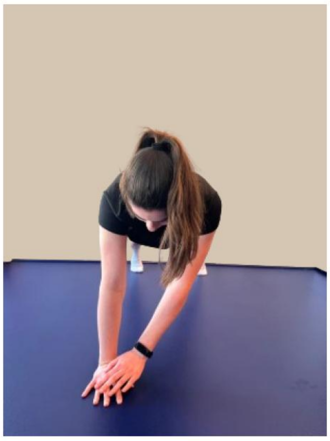
**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

MODIFIED CLOSED KINETIC CHAIN UPPER EXTREMITY STABILITY TEST (MCKUES TEST)

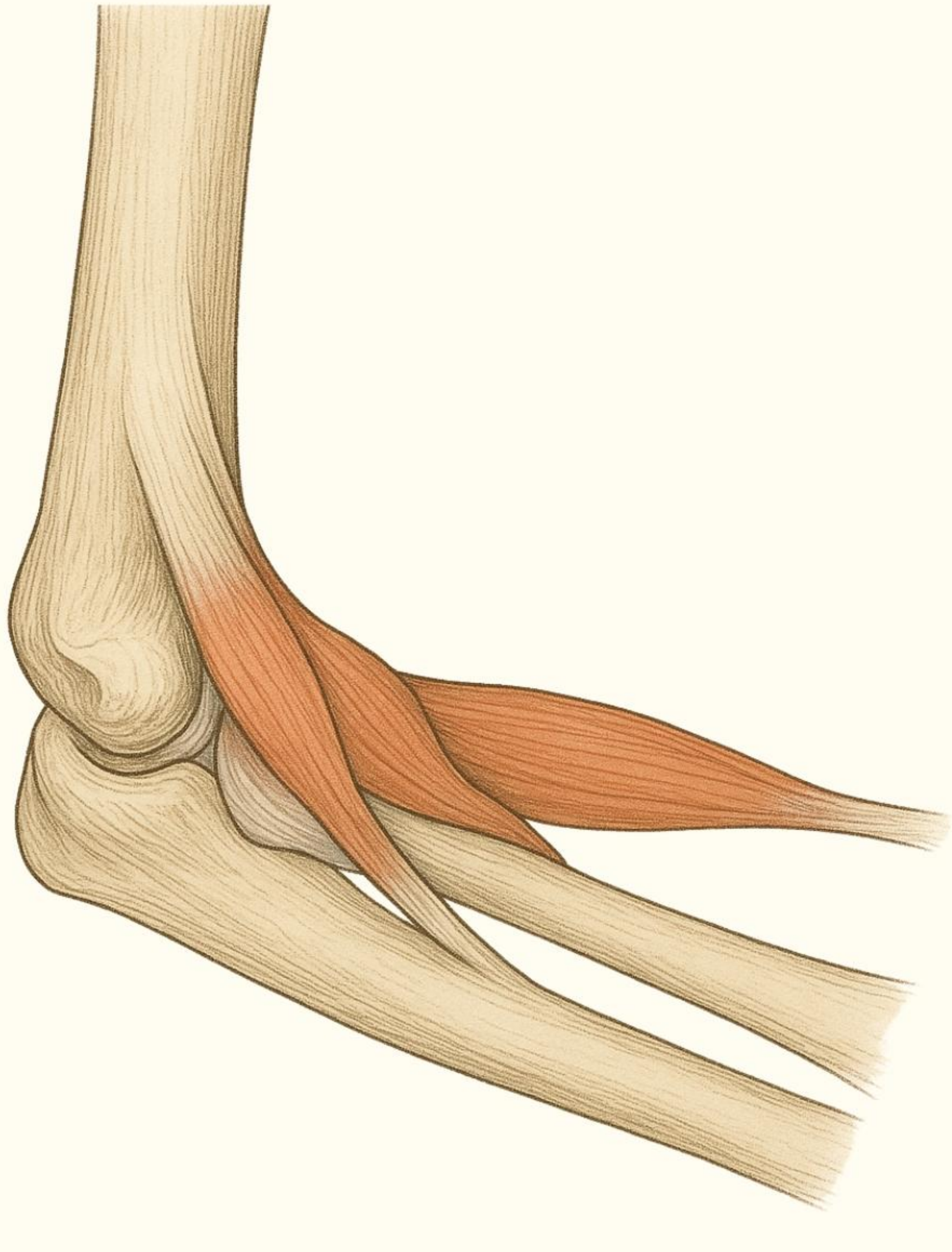
- PERFORMANCE: the patient is in a push-up position with the hands separated by 90 centimeters.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: lack of stability.







**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*



ELBOW JOINT COMPLEX

ELBOW JOINT COMPLEX

ANATOMIC CONSIDERATIONS

Elbow is the intermediate joint of the upper limb and it presents a physiological valgus. Iis formed by three joints:

- HUMEROCUBITAL JOINT: it is a throclear joint, and its movements are flexion-extension.
- HUMERORADIAL JOINT: it is a condylear joint, and its movements are flexion-extension
- RADIOULNAR JOINT: it is a pivot joint, and its movements are supination-pronation.

RANGE OF MOTION

FLEXION:

- Active: 140º - 145º.
- Passive: 160º.

EXTENSION: 0º - 5º.

SUPINATION: 75º - 90º.

PRONATION: 75º - 90º.

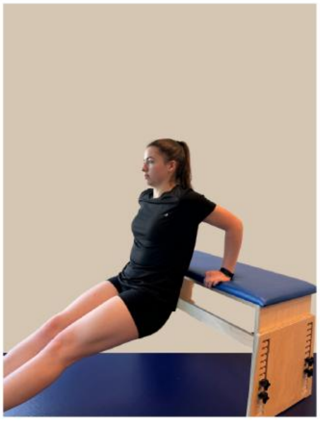
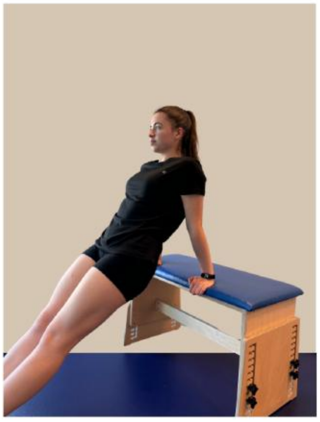
MAIN ELBOW MUSCLES

MUSCLE	FUNCTION
Biceps brachii	Flexion + Supination
Triceps brachii	Extension
First radial	Flexion
Second radial	Flexion
Large supinator	Flexion + Supination/Pronation
Short supinator	Supination
Teres pronator	Flexion + Pronation
Anconeus	Extension

ELBOW JOINT TESTS

TRICEPS DIPS TEST

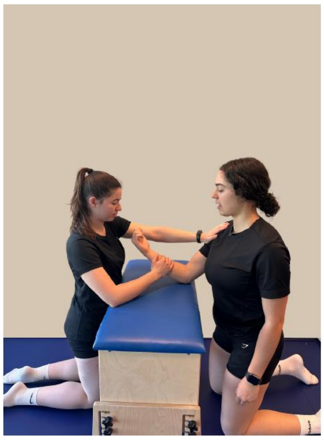
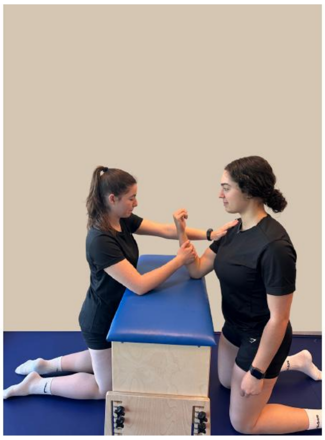
- PERFORMANCE: the patient is placed with the back in front of a low bench, and the elbows and the knees completely extended. We ask him to flex his elbows and come back.
- OUTCOME: number of repetitions during 1 minute.
- SIGNIFICANCE: triceps weakness.

**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

BICEPS MUSCLE MANUAL TEST

- PERFORMANCE: the patient is standing in front of the evaluator, and we ask him try to flex the elbow against the evaluator's resistance.
- OUTCOME: number of repetitions during 1 minute (+ measure the strength if we have a dynamometer).
- SIGNIFICANCE: biceps weakness and/or any injury in the biceps tendon.

**In this test, there are no positive or negative results, since the number of repetitions is the outcome we look for to perform intra-subject comparisons.*

COZEN TEST

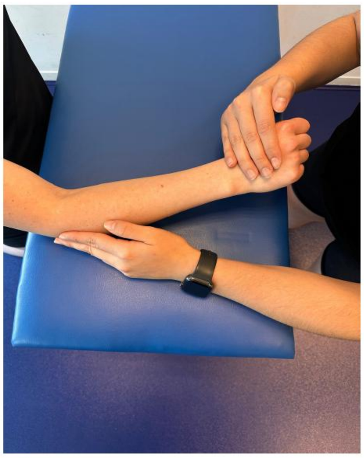
- PERFORMANCE: the patient is standing with the elbow at 90º of flexion and next to the body. The evaluator is going to oppose resistance on the elbow and the wrist. We ask the patient to try to perform wrist extension and radial inclination.
- OUTCOME: pain.
- SIGNIFICANCE: “tennis player's elbow”.

**This test is positive if the patient reports pain.*

GOLFER TEST

- PERFORMANCE: the patient is standing with the elbow at 90º of flexion and next to the body. The evaluator is going to oppose resistance on the elbow and the wrist. We ask the patient to try to perform wrist extension and ulnar inclination.
- OUTCOME: pain.
- SIGNIFICANCE: “golf player elbow”.

**This test is positive if the patient reports pain.*

WRIST AND HAND JOINT COMPLEX

WRIST AND HAND JOINT COMPLEX

ANATOMIC CONSIDERATIONS

Wrist is the distal joint of the upper limb, and it is formed by two joints:

- RADIOCARPAL JOINT: it is a condylar joint which is formed by the carpal condyle (convex) plus the glenoid cavity (concave).
- MIDCARPAL JOINT: it presents two types of joints. The condylar joint formed by the first row of the carpal plus the junction of the "big" bone and the "hook bone"; and the arthrodial joint formed by the scaphoid and the junction of the trapezius and the trapezoid.

In regards to the hand, we can find three joints:

- TRAPEZIUSMETACARPAL JOINT: it is a reciprocal engagement between the trapezius and the base of the first metacarpal. This joint provides movements of antepulsion - retropulsion, and abduction - adduction.
- METACARPOPHALANGEAL JOINT: it is a condylar joint between the head of the metacarpal and the base of the proximal phalanx. This joint provides movements of flexion - extension, and abduction - adduction.
- INTERPHALANGEAL JOINT: it is a throclear joint between the head of the phalanx and the base of the next phalanx. This joint provides movements of flexion - extension.

RANGE OF MOTION

The wrist presents the following range of motions:

- FLEXION:
  + Active: 85º.
  + Passive: 90º.
- EXTENSION:
  + Active: 85º.
  + Passive: 90º.
- ULNAR INCLINATION (ADDUCTION): 45º.
- RADIAL INCLINATION (ABDUCTION): 15º.

The joints that composed the hand present small movements which cannot be measured using a goniometer.

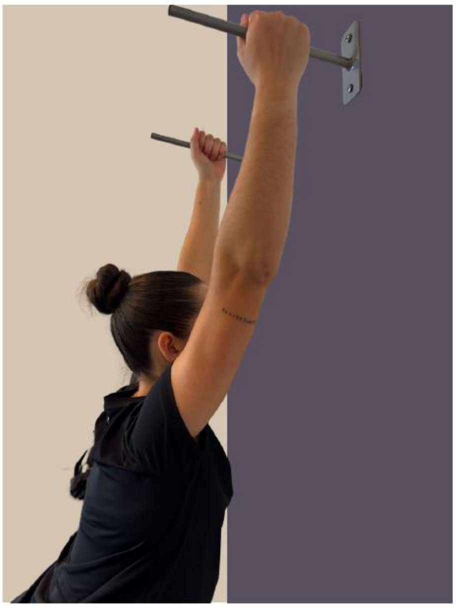
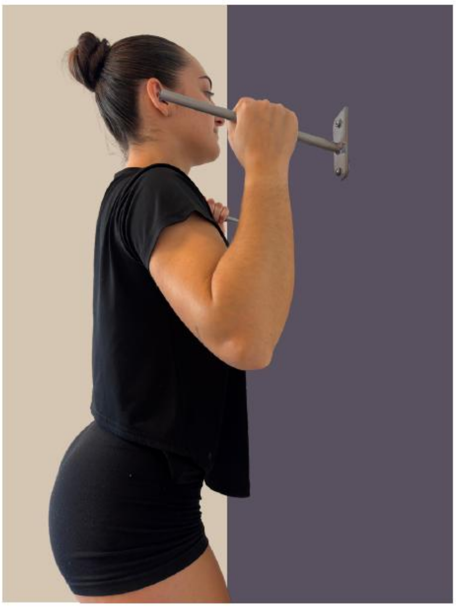
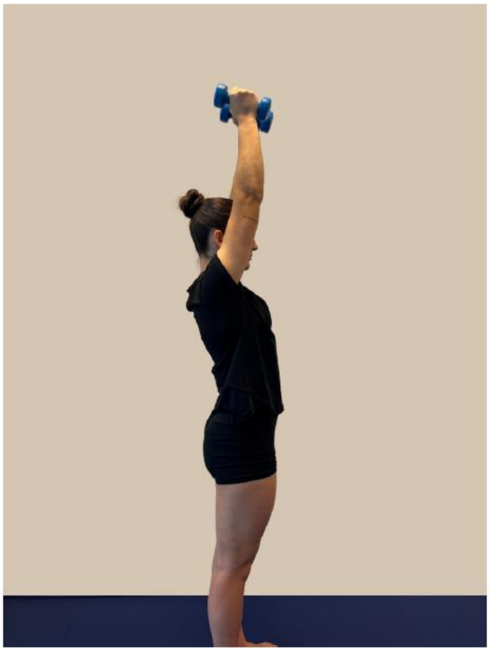
MAIN WRIST AND HAND MUSCLES

MUSCLE	FUNCTION
First radial	Extension + Radial Inclination (wrist)
Second radial	Extension + Ulnar Inclination (wrist)
Common extensor of the fingers	Extension (wrist and phalanges)
Extensor of the fifth finger	Extension (wrist and fifth finger) + Abduction (fifth finger)
Posterior ulnar	Extension + Ulnar Inclination (wrist)
Large abductor of the thumb	Abduction + Antepulsion (thumb)
Large extensor of the thumb Short extenbsor of the thumb	Extension (wrist and thumb) + Abduction (thumb)
Palmar major	Flexion + Radial Inclination (wrist)
Palmar minor	Flexion + Ulnar Inclination (wrist)
Anterior ulnar	Flexion + Ulnar Inclination (wrist)
Common flexor superficialis	Flexion (wrist and phalanges)
Large flexor of the thumb	Flexion (wrist and thumb)

GRIPS

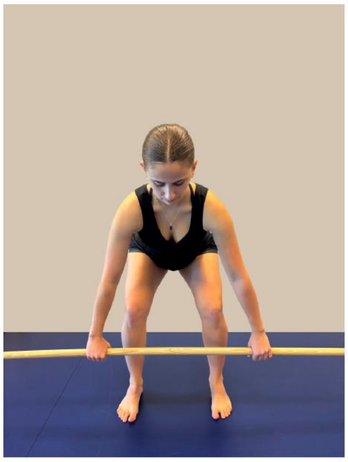
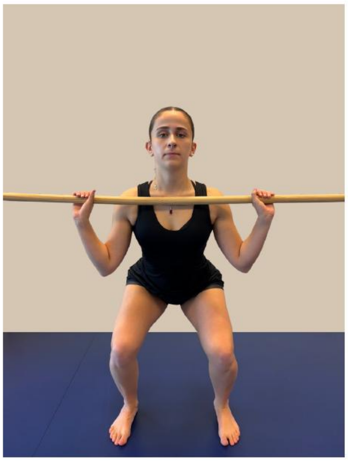
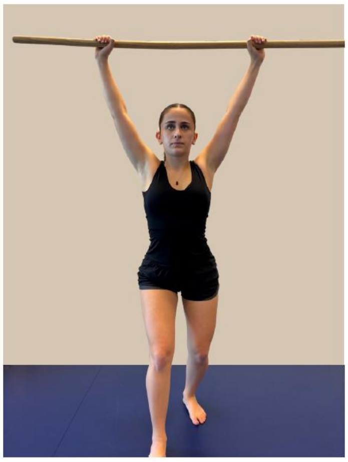
NEUTRAL GRIPS

Useful for pull-ups and exercises that work the triceps.

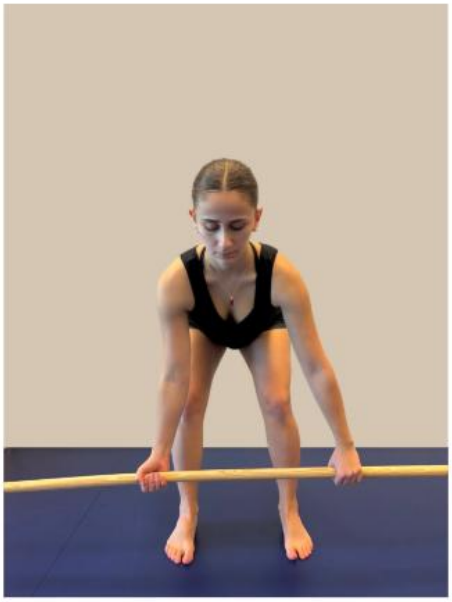

PRONE GRIP

Useful for split jerk.

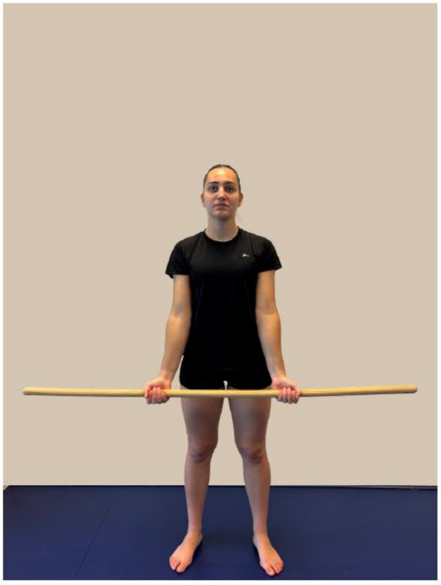
MIXED GRIP

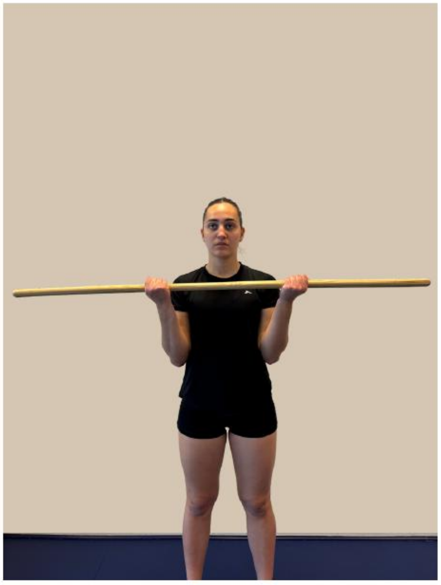
Useful for deadlift.

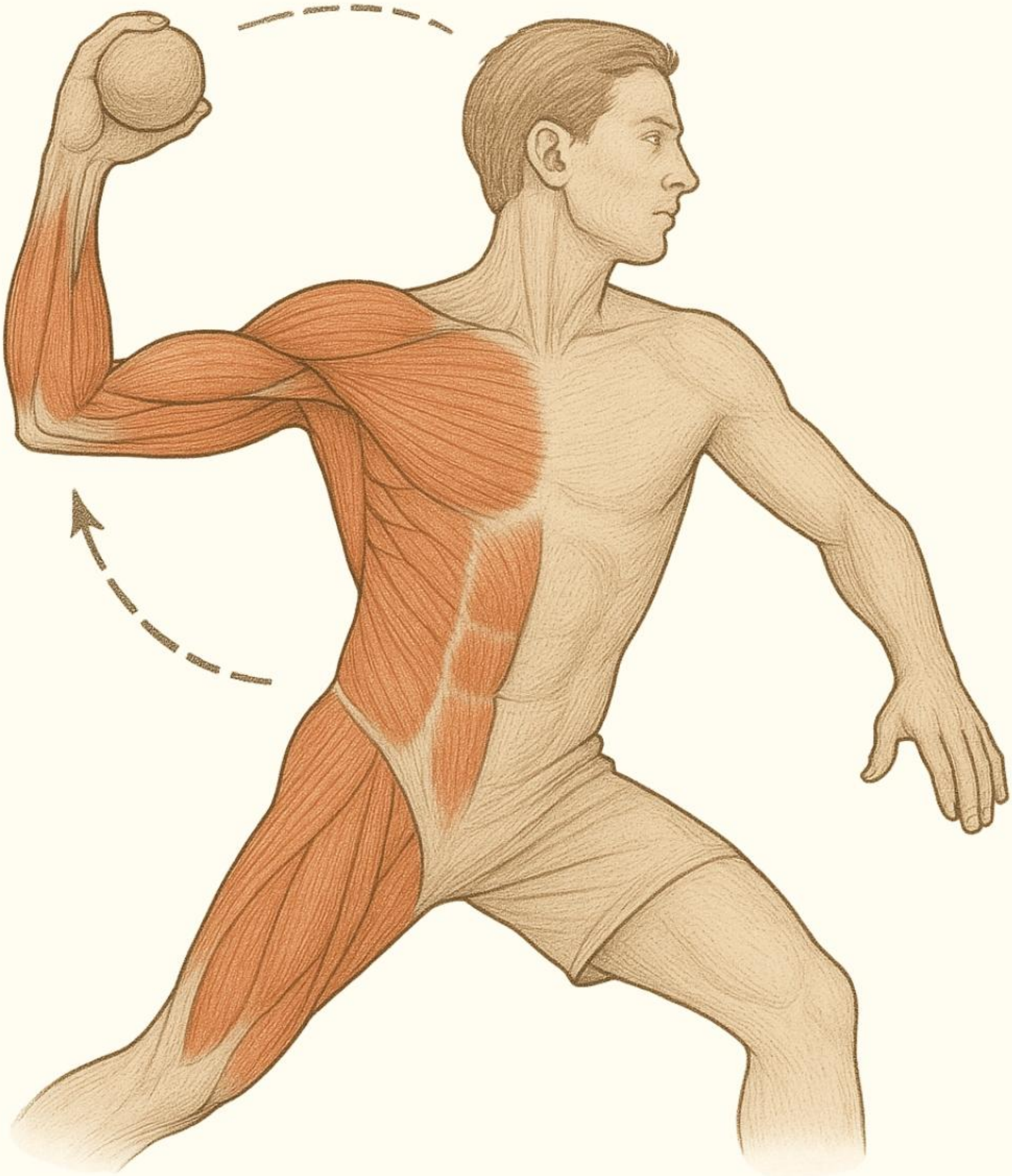



SUPINE GRIP

Useful for biceps curl and wrist curl.







BIOMECHANICS OF THROWING

BIOMECHANICS OF THROWING

PREPARATORY PHASE

We place the parts of our body in a predisposition to throw, while our brain activates an anticipatory reaction to the movement that is going to be performed.

MAIN PHASE

We perform all the gestures that are necessary to complete the movement. It is the phase in which more different movements occur, so neuromuscular coordination is essential.

FINAL PHASE

The thrown object has just left our hand and the body makes a series of movements as a result of the residual kinetic energy that has been accumulated during the gesture.

BASEBALL

WIND-UP-PHASE

- Opposite knee to chest.
- Concentric contraction of the rotator cuff (compression and rotation).

STRIDE PHASE

- Anterior lunge.
- Abduction and external rotation of the shoulder.

ARM COOKING PHASE

- Trunk bending.
- Adduction and internal rotation of the shoulder.

ARM ACCELERATION PHASE

- Trunk bending.
- Adduction, internal rotation and extension of the shoulder.
- Ball release.

ARM DECCELERATION PHASE

- Trunk bending.
- Eccentric contraction of the rotator cuff to avoid instability.
- Acceleration of the fast extension of the elbow.

FOLLOW-THROUGH PHASE

- The complete body follow the trajectory of the movement until almost touching the ground with the hand.

BASKETBALL

PREPARATION PHASE

- Dominant foot forward.
- Hands keeping the ball.
- Visual information is received before starting the action.

ACCELERATION PHASE

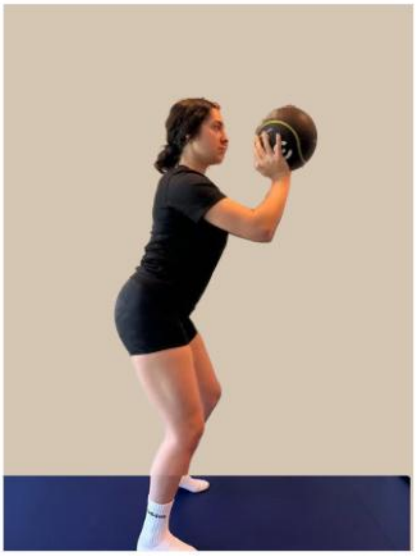
- Semi-extension of the knees.
- Flexion of the shoulder and elbow, placing the ball in front of the forehead.

SHOOTING PHASE

- Extension of the knees.
- Extension of the elbows.
- Ball release.

FLIGHT PHASE

- Flexion of the dominant wrist.
- The rest of the body recover its normal position due to the gravity and the kinetic energy that has been accumulated during the gesture.



FOOTBALL

PREPARATION PHASE

- Bring the ball up using one hand.
- One foot forward.

FOOT PLANT AND ARM COOKING PHASE

- Big forward strip with the opposite foot.
- Ball cooked back behind the head as far as possible.
- Arch the back.

TOE DRAG PHASE

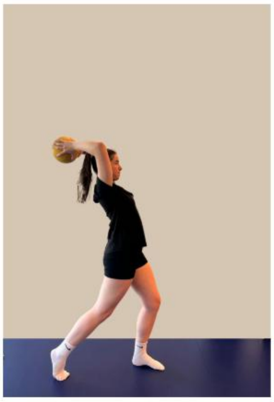
- Bring the arms forward.
- Drag the trailing foot across the ground.
- Keep the front foot planted.

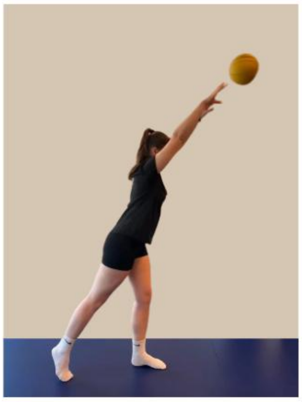
BALL RELEASE PHASE

- Straight the trunk.
- Extend the arms forward and release the ball.

FOLLOW THROUGH PHASE

- Follow the movements until the kinetic energy runs out.





GLOSSARY OF TERMS

- Asynchronous (“asíncrona”) means that the events don’t occur in a simultaneous way.
- Bone marrow (“médula ósea”) is a soft, spongy tissue located in the center of most long bones. It produces leukocytes, red blood cells, and platelets.
- Bradykinesia (“bradicinesia”) refers to the slowness of the voluntary movements.
- Capillarization (“capilarización”) refers to the process in which the muscle tissue increases the number of vessels to improve the blood flow.
- Dyskinesia (“discinesia”) refers to the lack of neuromuscular coordination, with the appearance of involuntary movements.
- Hematopoietic origin (“origen hematopoyético”) refers to the cell that comes from blood cells.
- Heterodimeric (“heterodímero”) refers to a molecular complex formed by two proteins that bind together to create a functional unit.
- Hinge region (“región de bisagra”) refers to the zone of the globular head of the myosin which allow the interaction with the actin.
- Hypertrophy (“hipertrofia”) refers to the increase of the size of the muscle due to the increase of the size of the muscle cells.
- Hypotonia and hypertonia (“hipotonía e hipertonía”) refers to a decrease or increase of the tension of the muscles when they are relaxed.
- Mesenchymal origin (“origen mesenquimal”) means that the cell comes from the mesenquima, a tissue derivated from the mesoderm, which is one of the three layers into which embryonic tissue is divided.
- Mesodermal origin (“origen mesodermal”) means that the tissue comes from the mesoderm, one of the three layers into which embryonic tissue is divided.
- Motor plate (“placa motora”) is the neuromuscular union, where the motorneuron reach the muscle fiber.
- Osteoblastic lineage (“linaje osteoblástico”) refers to those cells that comes from the reproductive line of the osteoblasts.
- Osteoclastic lineage (“linaje osteoclástico”) refers to those cells that comes from the reproductive line of the osteoclasts.
- Polymer (“polímero”) is a chemical, natural or synthetic compound formed by a series of repetitive structural units.
- Vasoconstriction and vasodilatation (“vasoconstricción y vasodilatación”) refers to the narrowing and widening of the blood vessels.

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BIBLIOGRAPHIC REFERENCES

Abat González, F., Turmo-Garuz, A., Campos Moraes, J., & Capurro Soler, B. (2022). Fisiología y mecanobiología del tejido tendinoso y muscular. *Revista Española de Artroscopia y Cirugía Articular*, *29*(1). https://doi.org/10.24129/j.reaca.29175.fs2107024

Beel, J. A., Stodieck, L. S., & Luttges, M. W. (1986). Structural properties of spinal nerve roots: Biomechanics. *Experimental Neurology*, *91*(1), 30–40. https://doi.org/10.1016/0014-4886(86)90023-3

Belogianni, K., & Baldwin, C. (2019). Types of Interventions Targeting Dietary, Physical Activity, and Weight-Related Outcomes among University Students: A Systematic Review of Systematic Reviews. *Advances in Nutrition*, *10*(5), 848–863. https://doi.org/10.1093/advances/nmz027

Bennasar-Veny, M., Yañez, A. M., Pericas, J., Ballester, L., Fernandez-Dominguez, J. C., Tauler, P., & Aguilo, A. (2020). Cluster Analysis of Health-Related Lifestyles in University Students. *International Journal of Environmental Research and Public Health*, *17*(5), 1776. https://doi.org/10.3390/ijerph17051776

Biomechanics of Tendons and Tendon Failure. (2003). *Seminars in Musculoskeletal Radiology*, *07*(1), 059–066. https://doi.org/10.1055/s-2003-41085

Bohannon, R. W. (2019). Grip Strength: An Indispensable Biomarker For Older Adults. *Clinical Interventions in Aging*, *Volume 14*, 1681–1691. https://doi.org/10.2147/CIA.S194543

Borga, M., West, J., Bell, J. D., Harvey, N. C., Romu, T., Heymsfield, S. B., & Dahlqvist Leinhard, O. (2018). Advanced Body Composition Assessment: From Body Mass Index to Body Composition Profiling. *Journal of Investigative Medicine*, *66*(5), 1–9. https://doi.org/10.1136/jim-2018-000722

Buckthorpe, M. (2019). Optimising the Late-Stage Rehabilitation and Return-to-Sport Training and Testing Process After ACL Reconstruction. *Sports Medicine*, *49*(7), 1043–1058. https://doi.org/10.1007/s40279-019-01102-z

Burnett, M. G., & Zager, E. L. (2004). Pathophysiology of peripheral nerve injury: A brief review. *Neurosurgical Focus*, *16*(5), 1–7. https://doi.org/10.3171/foc.2004.16.5.2

Burton, I. (2022). Interventions for prevention and in-season management of patellar tendinopathy in athletes: A scoping review. *Physical Therapy in Sport*, *55*, 80–89. https://doi.org/10.1016/j.ptsp.2022.03.002

Caeiro, J. R., González, P., & Guede, D. (2013). Biomecánica y hueso (y II): Ensayos en los distintos niveles jerárquicos del hueso y técnicas alternativas para la determinación de la resistencia ósea. *Revista de Osteoporosis y Metabolismo Mineral*, *5*(2), 99–108. https://doi.org/10.4321/S1889-836X2013000200007

Camarero-Espinosa, S., Rothen-Rutishauser, B., Foster, E. J., & Weder, C. (2016). Articular cartilage: From formation to tissue engineering. *Biomaterials Science*, *4*(5), 734–767. https://doi.org/10.1039/C6BM00068A

Cohen, S., Gianaros, P. J., & Manuck, S. B. (2016). A Stage Model of Stress and Disease. *Perspectives on Psychological Science*, *11*(4), 456–463. https://doi.org/10.1177/1745691616646305

Doherty, C., Bleakley, C., Delahunt, E., & Holden, S. (2017). Treatment and prevention of acute and recurrent ankle sprain: An overview of systematic reviews with meta-analysis. *British Journal of Sports Medicine*, *51*(2), 113–125. https://doi.org/10.1136/bjsports-2016-096178

Escriche-Escuder, A., Cuesta-Vargas, A. I., & Casaña, J. (2021). Effect of a common exercise programme with an individualised progression criterion based on the measurement of neuromuscular capacity versus current best practice for lower limb tendinopathies (MaLaGa trial): A protocol for a randomised clinical trial. *BMJ Open*, *11*(8), e046729. https://doi.org/10.1136/bmjopen-2020-046729

Esther Díaz-Mohedo. (2015). *Manual de Fisioterapia en Traumatología*. Elsevier B.V.

Fisiología del ejercicio (4ª ed) (with López Chicharro, J., & Fernández Vaquero, A.). (2023). Editorial Médica Panamericana.

Follis, S. L., Bea, J., Klimentidis, Y., Hu, C., Crandall, C. J., Garcia, D. O., Shadyab, A. H., Nassir, R., & Chen, Z. (2019). Psychosocial stress and bone loss among postmenopausal women: Results from the Women's Health Initiative. *Journal of Epidemiology and Community Health*, *73*(9), 888–892. https://doi.org/10.1136/jech-2019-212516

Fort Vanmeerhaeghe, A., & Romero Rodriguez, D. (2013). Rol del sistema sensoriomotor en la estabilidad articular durante las actividades deportivas. *Apunts. Medicina de l'Esport*, *48*(178), 69–76. https://doi.org/10.1016/j.apunts.2012.09.002

Garcia, M. B., Ness, K. K., & Schadler, K. L. (2020). Exercise and Physical Activity in Patients with Osteosarcoma and Survivors. In E. S. Kleinerman & R. Gorlick (Eds.), *Current Advances in Osteosarcoma* (Vol. 1257, pp. 193–207). Springer International Publishing. https://doi.org/10.1007/978-3-030-43032-0_16

García-Gomariz, C., Igual-Camacho, C., Hernández-Guillen, D., & Blasco, J. M. (2019). Efectos de un programa de ejercicio combinado de impacto, fuerza y resistencia en la prevención de osteoporosis de mujeres posmenopáusicas. *Fisioterapia*, *41*(1), 4–11. https://doi.org/10.1016/j.ft.2018.11.001

Gill, T. M., Williams, C. S., Richardson, E. D., & Tinetti, M. E. (1996). Impairments in Physical Performance and Cognitive Status as Predisposing Factors for Functional Dependence Among Nondisabled Older Persons. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *51A*(6), M283–M288. https://doi.org/10.1093/gerona/51A.6.M283

González, A. (1985). *Bases y principios del entrenamiento deportivo*. Stadium.

Hadders-Algra, M. (2018). Early human motor development: From variation to the ability to vary and adapt. *Neuroscience & Biobehavioral Reviews*, *90*, 411–427. https://doi.org/10.1016/j.neubiorev.2018.05.009

Hess, G. W. (2010). Achilles Tendon Rupture: A Review of Etiology, Population, Anatomy, Risk Factors, and Injury Prevention. *Foot & Ankle Specialist*, *3*(1), 29–32. https://doi.org/10.1177/1938640009355191

Hoeger, W. W. K., Hoeger, S. A., Fawson, A. L., & Hoeger, C. I. (2019). *Fitness & wellness* (13th edition). Cengage Learning.

John E. Hall & Michael E. Hall. (2021). *Guyton y Hall. Compendio de fisiología médica* (14th ed.). Elsevier B.V.

Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2005). *Lehninger principles of biochemistry* (4th ed). W.H. Freeman.

Levin, M. F., & Piscitelli, D. (2022). Motor Control: A Conceptual Framework for Rehabilitation. *Motor Control*, *26*(4), 497–517. https://doi.org/10.1123/mc.2022-0026

Lum, D., & Barbosa, T. M. (2019). Brief Review: Effects of Isometric Strength Training on Strength and Dynamic Performance. *International Journal of Sports Medicine*, *40*(06), 363–375. https://doi.org/10.1055/a-0863-4539

Mora Bautista, G. (2008). EL ENVEJECIMIENTO Y LA ACTIVIDAD FISICA. *Movimiento Científico*, *2*(1). https://doi.org/10.33881/2011-7191.mct.02109

Nancy Stella Landínez-Parra, Juan Carlos Vanegas-Acosta, & Diego Alexander Garzón-Alvarado. (2011). *Aplicaciones de mecanobiología computacional*. Universidad Nacional de Colombia.

Navarrete-Muñoz, E. M. (2015). UNA MENOR ADHERENCIA A LA DIETA MEDITERRÁNEA SE ASOCIA A UNA PEOR. *NUTRICION HOSPITALARIA*, *2*, 785–792. https://doi.org/10.3305/nh.2015.31.2.7874

Portal-Núñez, S., Lozano, D., De La Fuente, M., & Esbrit, P. (2012). Fisiopatología del envejecimiento óseo. *Revista Española de Geriatría y Gerontología*, *47*(3), 125–131. https://doi.org/10.1016/j.regg.2011.09.003

Potthoff, M. J., Olson, E. N., & Bassel-Duby, R. (2007). Skeletal muscle remodeling. *Current Opinion in Rheumatology*, *19*(6), 542–549. https://doi.org/10.1097/BOR.0b013e3282efb761

Quadrilatero, J. (2023). Mitochondria: Key modulators of skeletal muscle remodeling. *Seminars in Cell & Developmental Biology*, *143*, 1–2. https://doi.org/10.1016/j.semcdb.2022.10.004

Ribeiro, D. K. D. M. N., Lenardt, M. H., Lourenço, T. M., Betiolli, S. E., Seima, M. D., & Guimarães, C. A. (2018). O emprego da medida de independência funcional em idosos. *Revista Gaúcha de Enfermagem*, *38*(4). https://doi.org/10.1590/1983-1447.2017.04.66496

Rodríguez-Camacho, D. F., & Correa-Mesa, J. F. (2018). Biomecánica del cartílago articular y sus respuestas ante la aplicación de las fuerzas. *Revista Médicas UIS*, *31*(3). https://doi.org/10.18273/revmed.v31n3-2018005

Saló i Orfila, J. M. (2016). Estructura de los ligamentos. Características de su cicatrización. *Revista Del Pie y Tobillo*, *2016*, 1–6.

Sato, S., Yoshida, R., Murakoshi, F., Sasaki, Y., Yahata, K., Kasahara, K., Nunes, J. P., Nosaka, K., & Nakamura, M. (2022). Comparison between concentric-only, eccentric-only, and concentric–eccentric resistance training of the elbow flexors for their effects on muscle strength and hypertrophy. *European Journal of Applied Physiology*, *122*(12), 2607–2614. https://doi.org/10.1007/s00421-022-05035-w

Smith, J. J., Eather, N., Morgan, P. J., Plotnikoff, R. C., Faigenbaum, A. D., & Lubans, D. R. (2014). The Health Benefits of Muscular Fitness for Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine*, *44*(9), 1209–1223. https://doi.org/10.1007/s40279-014-0196-4

Średniawa, A., Drwiła, D., Krotos, A., Wojtaś, D., Kostecka, N., & Tomasik, T. (2019). Insomnia and the level of stress among students in Krakow, Poland. *Trends in Psychiatry and Psychotherapy*, *41*(1), 60–68. https://doi.org/10.1590/2237-6089-2017-0154

Thom, G., & Lean, M. (2017). Is There an Optimal Diet for Weight Management and Metabolic Health? *Gastroenterology*, *152*(7), 1739–1751. https://doi.org/10.1053/j.gastro.2017.01.056

Topp, K. S., & Boyd, B. S. (2006). Structure and Biomechanics of Peripheral Nerves: Nerve Responses to Physical Stresses and Implications for Physical Therapist Practice. *Physical Therapy*, *86*(1), 92–109. https://doi.org/10.1093/ptj/86.1.92

Ulrich Welsch. (2008). *Sobotta Histología* (2th ed.). Editorial Médica Panamericana.

Universidad Autónoma del Estado de México, & García-Lirios, C. (2019). Dimensions of human development theory. *Ehquidad Revista Internacional de Políticas de Bienestar y Trabajo Social*, *11*, 27–54. https://doi.org/10.15257/ehquidad.2019.0002

Vasconcelos Raposo, A. (2019). *La fuerza*. Paidotribo.

Vega, J. A. (1999). Propioceptores articulares y musculares. *Biomecánica*. https://doi.org/10.5821/sibb.v7i13.1632

Wang, J. H.-C., Guo, Q., & Li, B. (2012). Tendon Biomechanics and Mechanobiology—A Minireview of Basic Concepts and Recent Advancements. *Journal of Hand Therapy*, *25*(2), 133–141. https://doi.org/10.1016/j.jht.2011.07.004

Wavreille, G., Baroncini, M., & Fontaine, C. (2011). Anatomía, histología y fisiología del nervio periférico. *EMC - Aparato Locomotor*, *44*(1), 1–9. https://doi.org/10.1016/S1286-935X(11)70975-3

Xiao, J. (Ed.). (2020). *Physical Exercise for Human Health* (Vol. 1228). Springer Nature Singapore. https://doi.org/10.1007/978-981-15-1792-1

Yoo, J., Ma, X., Lee, J., & Hwang, J. (2021). Research Update on Stress Riser Fractures. *Indian Journal of Orthopaedics*, *55*(3), 560–570. https://doi.org/10.1007/s43465-020-00291-4

Zebis, M. K., Andersen, L. L., Brandt, M., Myklebust, G., Bencke, J., Lauridsen, H. B., Bandholm, T., Thorborg, K., Hölmich, P., & Aagaard, P. (2016). Effects of evidence-based prevention training on neuromuscular and biomechanical risk factors for ACL injury in adolescent female athletes: A randomised controlled trial. *British Journal of Sports Medicine*, *50*(9), 552–557. https://doi.org/10.1136/bjsports-2015-094776