PROPRIOCEPTION

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INDEX

1. INTRODUCTION

1.1. Proprioception and sport

The scientific evidence available to date gives great importance to proprioceptive parameters as a tool for predicting and preventing injury.

Sport is a protagonist, since there is a great deal of scientific evidence on sports practice, as a method that improves the input of proprioceptive information and motor responses. It has been shown that a warm-up prior to sports practice increases the sensitivity and functioning of the proprioceptive system.

Athletes are often exposed to a great potential risk of injury due to excessive stimulation of the proprioceptors during sports practice and the consequent temporary proprioceptive deterioration. In this part, an increase in the sensitization of the proprioceptors against the aforementioned deterioration is carried out. This regulatory faculty allows obtaining benefits from the performance of physical activity and sport at all levels (Romero, 2013).

2. THEORETICAL FRAMEWORK

2.1. Proprioception

Proprioception was first defined by Sherrington in 1906 as “The sense of the position of one's body parts.”

According to the above, proprioception is responsible for providing the body with information about the position of body parts. In addition, it regulates the direction and range of movement, allows automatic reflex reactions and responses, contributes to the development of the body scheme and image, and supports the performance of motor actions (Tarantino, 2017).

Proprioception can also be defined as the body's ability to discover the position and movement of the joints. In addition, it is essential in everyday movements and especially in sports movements that require greater demands in terms of coordination.

“Posture is the external manifestation of the proprioceptive, vestibular and tactile process” (Jean Ayres).

With this phrase, Jean Ayres highlighted the importance of three internal sensory systems, which provide information about our body in relation to the environment.

2.1.1. Proprioceptive System:

This is the one that provides us with information about the harmonious functioning of muscles, tendons and joints: it participates in regulating the direction and range of movement; it allows automatic reactions and responses that are important for survival; it intervenes in the development of the body scheme and in the relationship with space and supports planned motor action.

2.1.2. Vestibular System:

This responds to body movements through space and changes in head position. Together with the proprioceptive system, it maintains muscle tone, automatically coordinates the movement of the eyes, head and body, maintaining a stable visual field and is fundamental in the perception of space and in the orientation of the body in relation to it.

2.1.3. Tactile System:

This is responsible for recording external information related to temperature, pain, touch, cold, heat; In this way, it allows us to discriminate stimuli from the environment and to react when they are threatening. It participates in body awareness and also in the development of emotional bonds and a sense of security. Together with the proprioceptive system, it supports planned motor action.

When these three sensory systems function efficiently and correctly, we see a regulated, organized and skilled person who can develop responses adapted to the demands of the environment. Sensory integration occurs automatically, unconsciously, without effort. For some others, this process is deficient and requires effort and attention, with no guarantee of precision, as can occur after a sports injury.

2.2. Proprioceptive system.

The proprioceptive system of the human body is composed of a series of nerve receptors that are in the muscles, joints and ligaments. Its operation is as follows: the proprioceptors send information to the spinal cord and the brain for processing; when the brain processes this information, it sends other information to the muscles so that they make the necessary adjustments in terms of muscle tension and elasticity in order to achieve the desired movement, whether it is a daily movement or a more complex sporting movement (Ruiz, 2004).

There are some structures of the peripheral nervous system that also intervene in proprioception, these are: sensory neurons, sensory fibers and mechanoreceptors (Vega, 2009). Some mechanoreceptors are also considered proprioceptors (Michelson & Hutchins, 1994).

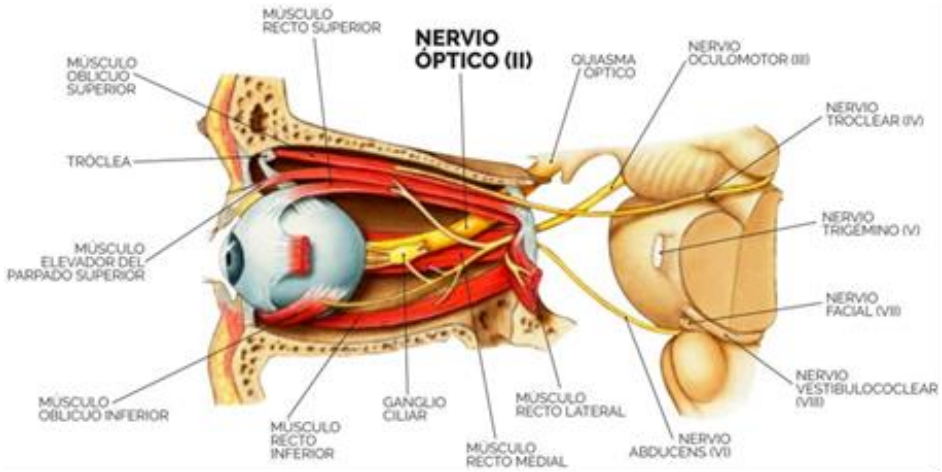
We can say then that proprioception is a very fast and reflex process (De la Torre, 2012), and it is possible to train the sensorimotor or proprioceptive system to produce faster and more coordinated responses to loads or unexpected movements of the joints (Ashton-Miller, et al., 2001).

The proprioceptive system consists of a series of elements called proprioceptors that provide us with information related to the position of the body, muscle tension and elasticity, and joint movement (Tortora & Derrickson, 2006).

Proprioceptors located in the muscles and tendons provide information about the degree of muscle contraction, tension, and position of the joints (Ávalos & Berrio, 2010). The inner ear tells us the orientation of the head in relation to the ground, both when moving and when stationary (Tortora & Derrickson, 2006). With all this data and other data provided by the rest of the proprioceptors in our body, humans know at all times the position they are in and where each limb is.

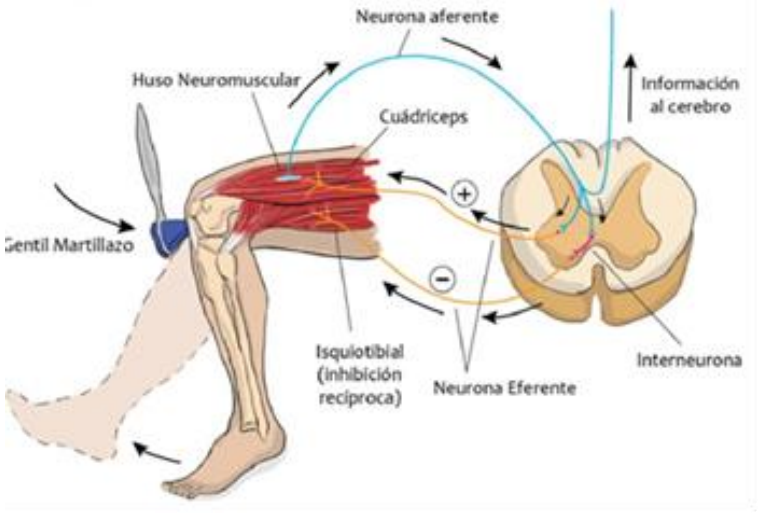
2.2.1. Proprioceptors in our body

- **Sensory Branch of the Oculomotor Nerve.**



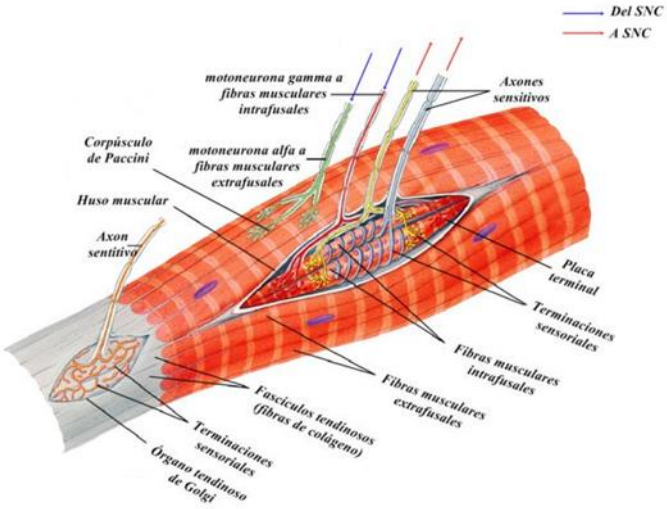
The sensory branch of the Oculomotor nerve is composed of afferent axons that send information from the receptors to the central nervous system and that come from proprioceptors of the extrinsic muscles of the eye. These axons provide information about proprioception, the non-visual perception of movements and the position of the body (Tortora & Derrickson, 2006)

- **Myotatic or Stretch Reflex.**



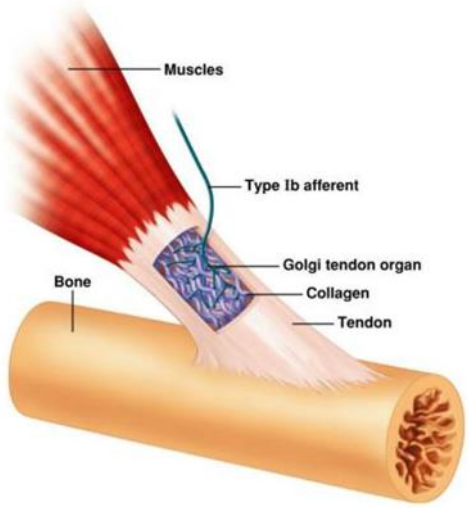
The Myotatic reflex is a protective reflex against sudden or excessive stretching. The most commonly used example is the tap on the patellar tendon that the doctor performs to check if we have normal reflexes (patellar reflex). The Myotatic reflex helps maintain posture. For example: "if a person who is standing begins to lean forward, the gastrocnemius muscle and other calf muscles stretch. Consequently, stretch reflexes are initiated in these muscles, which contract and restore the erect posture of the body. A similar type of reflex is observed in the muscles of the anterior region of the leg when a person who is standing begins to lean backward" (Tortora & Derrickson, 2006).

- **Muscle Spindle.**



The muscle spindle is located in skeletal muscles and gives us information about changes in muscle length and participates in the stretch reflex (Barroso, 2014). It sends information to the central nervous system where the information is used to coordinate movement (Tortora & Derrickson, 2006). The muscle spindle helps us control movement. There are more muscle spindles where finer movements are performed, such as the fingers of the hand. The muscle spindle also helps maintain joint stability (Needle et al., 2013).

- ***Golgi* Tendon Organs.**



"Golgi tendon organs are located at the junction of tendon and muscle" (Tortora & Derrickson, 2006). "Some researchers have hypothesized that the muscle spindle system may be the most significant component of the neuromuscular system during normal activities of daily living." (Ávalos & Berrio, 2010). Tendon organs respond to increases and decreases in muscle tension, meaning that Golgi tendon organs protect tendons and muscles from damage caused by excessive tension. Their activation produces relaxation of stretched agonist muscles and contraction of antagonist muscles.

This is because joint receptors contribute sensory information at the end of available joint movement, positions that do not occur during activities of daily living, muscle feedback (Ávalos & Berrio, 2010). This system is especially activated during walking to achieve progression despite the pendular variation of the center of gravity. The Golgi tendon organs play a more

significant role in athletic performance when more extreme movements are performed. The Golgi organs require a stimulation period of about 6-8 seconds (Edin & Vallbo, 1987).

- **Receptors of the Joint Capsule and the Joint Ligaments.**

The load that these structures bear in relation to the muscular tension exerted also activates a series of mechanoreceptors capable of detecting the position and movement of the joint involved. They are relevant proprioceptors when the structures are damaged.

- **Skin receptors.**

They provide information on the muscular tonic state and on movement, contributing to the sense of position and movement, especially in the extremities, where they are very numerous.

- **Other sensitive proprioceptors in the human body.**

• Mechanoreceptors: They are sensitive to mechanical stimuli such as deformation or stretching. They provide the sensations of touch, pressure, vibration, proprioception, hearing and balance.

• Thermoreceptors: Detect changes in temperature.

• Nociceptors: Respond to painful stimuli.

• Photoreceptors: Detect light. They are located in the eye.

• Chemoreceptors: Detect chemicals in the mouth (taste), nose (smell) and body fluids.

• Osmoreceptors: Detect the osmotic pressure of body fluids.

3. PROPRIOCEPTION. POSTURAL CONTROL AND BALANCE

Proprioception is important for maintaining balance, controlling limb movements and joint stability (Roberts, 2003).

3.1. Postural control

Postural control is the relationship between the neural and musculoskeletal systems when performing a task. These interactions of systems for postural control arise from a relationship between the person and the environment when performing a certain job, in which certain inherent postures are required. These actions are essential to achieve good stability and orientation in space.
In this way, postural control is made up of postural orientation (relationship between body segments), one's own body, environment and postural stability or balance (Santos, 2016).

In relation to the above, postural stability is synonymous with balance and is the ability to control the center of mass in relation to the support surface. Postural control and stability or balance are aspects that are considered equal, but they are different (Santos, 2016).

3.2. Balance

Balance is the individual's ability to maintain the stability of his or her body, another body or a certain position, in which certain body adjustments must be made to allow the maintenance of said posture by means of compensatory movements that face external forces that can generate an imbalance (Bolaños, 2010).

There are two types of balance: static and dynamic. Static balance seeks a postural and proprioceptive adjustment when the subject is not in a locomotor action. Dynamic balance makes a rebalancing adjustment to return to its base of support, when the subject undertakes a movement and moves outside the vertical axis of the body (Rigal, 2006).

The proprioceptive system together with the visual apparatus and the vestibular system plays a main role in maintaining balance in any movement or posture. These systems and apparatus are responsible for providing information to the central nervous system regarding the state of the body in relation to space in order to establish feedback (Díaz et al, 2020).

3.2.1. The importance of balance

Balance is a very important factor in everyday life, because it is responsible for maintaining a certain position and making relevant body adjustments to counteract gravity and remain standing (with one or two feet supported) and this is crucial to carry out daily tasks.

Within sports activities, balance plays a fundamental role in maintaining posture and performing tasks, due to a close relationship between balance and the ability to perform motor tasks (Davlin, 2004). This ability becomes more relevant in sports, especially in those disciplines that have a great load of movement and displacement on the ground, such as those required in Taekwondo. This ability is considered very important, since the correct execution of the technical sports gesture and the correct optimization of energy depend on it (Vallejos at al, 2019).

The ability to balance can be applied to a static condition, standing on a support surface with minimal movement, and to a dynamic situation, maintaining a controlled posture and performing techniques (Bressel et al, 2007).

In this way, static and dynamic balance are related to each other as they improve sports performance (Paillard et al, 2006).

4. BENEFITS DERIVED FROM PROPRIOCEPTION TRAINING

Through proprioceptive training, the athlete learns to take advantage of reflex mechanisms, improving facilitating stimuli that increase performance and decreasing inhibitions that reduce it. Thus, reflexes such as stretching, which may appear in an unexpected situation (for example, losing balance) can manifest themselves correctly (helping to recover posture) or incorrectly (causing a greater imbalance). With proprioceptive training, incorrect basic reflexes tend to be eliminated to optimize the response. (Ruiz, 2004)

4.1. Proprioceptive Training and Strength

Any increase in strength is the result of neuromuscular stimulation. When it comes to strength, we tend to immediately think of muscle mass, but we must not forget that this is under the orders of the nervous system. In short, it is known that for the improvement of strength through training there are functional adaptations (based on neural or nervous aspects) and structural adaptations (based on structural aspects: hypertrophy and hyperplasia, the latter without clear evidence of existence in people).

The reflex processes that include proprioception would be linked to functional improvements in strength training, together with the improvements that can be achieved through intermuscular coordination and intramuscular coordination.

- **Intermuscular Coordination**: It would refer to the interaction of the different muscle groups that produce a certain movement.

- **Intramuscular Coordination**: It would refer to the interaction of the motor units of the same muscle.

- **Proprioception (Reflex Processes)**: These refer to the processes of nerve facilitation and inhibition through better control of the stretch or myotatic reflex and the inverse myotatic reflex, mentioned above, which can produce adaptations at the level of inter-intramuscular coordination.

4.2. Proprioceptive Training and Flexibility

The stretch reflex triggered by the muscle spindles when excessive stretching causes a muscle contraction as a protection mechanism (myotatic reflex). However, in a situation in which we perform excessive stretching for a prolonged period, if we have slowly gone to this position and there we maintain the stretch for a few seconds, the reflex responses of the myotatic reflex are cancelled, activating the reflex responses of the Golgi apparatus (muscle relaxation), which allow improvements in flexibility, since by achieving greater muscle relaxation we can increase the range of movement in stretching more easily.

4.3. Proprioceptive Training and Coordination

Coordination refers to our ability to resolve unexpected and variable situations and requires the development of several factors that we can undoubtedly improve with proprioceptive training, since they depend largely on the somatosensory (proprioceptive) information that the body collects in these unexpected situations, in addition to the information collected by the visual and vestibular systems.

These coordination factors that we can improve with proprioceptive training are:

• **Regulation of the Spatio-Temporal Parameters of Movement**: This involves adjusting our movements in space and time to achieve effective execution in a given situation. For example, when a ball is thrown to us and we have to catch it, we must calculate the distance from which it is thrown to us and the time it will take to arrive based on the speed of the throw in order to adjust our movements. Good exercises for improving spatio-temporal adjustments are throwing or passing objects of different sizes and weights.

• **Ability to Maintain Balance**: In both static and dynamic situations, we eliminate small balance alterations by means of reflexive muscular tension that makes us move quickly to the stable support zone. Once we train the proprioceptive system to improve balance, we can even anticipate possible balance alterations so that they do not occur (anticipation mechanism). Exercises to improve balance include one-legged support, vertical supports, cones, swings and turns of the upper limbs and trunk with support on one leg, maintaining postures or movements with limited support or on irregular surfaces, exercises with the eyes closed.

• **Sense of Rhythm**: Ability to vary and reproduce force-speed and space-time parameters of movements. Like the previous ones, it depends largely on the somatosensory, visual and vestibular systems. In the sports field, we can break down complex motor actions specific to a sport into isolated elements to improve the perception of movements and then integrate them into a single action. It is important to follow a logical order when separating the elements of a technical action. For example, in a volleyball kick, we can separate the gesture into the steps of approach – lowering the centre of gravity by bending the legs while pulling the arms back – take-off – arming – final hit to the ball.

• **Ability to Orient Oneself in Space**: This is carried out fundamentally on the basis of the visual system and the proprioceptive system. We could improve this ability through voluntary attention training (choosing the most important stimuli).

• **Ability to Relax the Muscles**: This is important, since excessive tension in the muscles that do not intervene in a certain action can reduce the coordination of the movement, limit its amplitude, speed, strength. Using exercises alternating periods of relaxation-tension, trying to consciously control these states. At a high level of sport, voluntary relaxation is sought in situations of great stress that can later be transferred to competitive activity.

5. HOW DO WE WORK ON PROPRIOCEPTION?

We mainly work on proprioception through balance, coordination and surface changes exercises. These exercises usually start off simple, and as we gain skill they become more complicated, introducing a series of materials such as hoops, benches, balls, platforms…

To work on proprioception, we must provoke external stimuli that favour reflex muscular reactions, progressively increasing the difficulty.

5.1 What material can I use for proprioception?

There is a wide variety of materials used in proprioception exercises:

Bosu: A semi-sphere with one rigid part and one inflatable part. It can be used with the rigid, flat part facing up or with the inflatable part facing up. Historically, the bosu has been used as a material for training ankle, knee and hip proprioception in physiotherapy. Today it is used for other joints such as the shoulder or wrist.

Swedish ball or fitball: Inflatable ball of different sizes with which you can work a wide variety of proprioception exercises for the ankle, knee, hip, shoulder, etc. However, it has been used mainly to improve proprioception of the trunk (back).

The standard sizes are 55 cm, 65 cm and 75 cm. To know which size is appropriate for you, you can follow these recommendations: the 55 cm Swedish ball for people up to 1.57 m tall, the 65 cm for people between 1.58-1.82 m and the 75 cm for people taller than 1.82 m.

For many proprioception exercises, these measurements will not have to be taken into account, since the size of the ball would be chosen taking into account other parameters. An example could be doing squats against the wall with the ball in the middle, the size of the ball would not matter.

Balance board or unstable platform: A board, usually made of wood, that comes into contact with the ground using a material whose shape makes it unstable (hemisphere).

Wobble cushion, inflatable disc or unstable disc:

It is a kind of inflatable cushion that allows us to make it more or less unstable depending on how much air we put in it. It usually has plastic protrusions on one of its sides whose purpose is to include an extra stimulus.

Foam or balance pad: It is a kind of thick mat that causes instability because it is soft.

Proprioception is usually trained on stable planes, and unstable planes are more geared towards people who will be exercising on said unstable planes or those who want a greater challenge in their exercises.

5.2 What proprioception exercises should I do?

To work on proprioception, very complicated exercises are not necessary and their difficulty will increase progressively. They should be adapted to the person and the type of injury, with more intense exercises if they are trained at a sports level.

Proprioceptive exercises help to improve strength, coordination, balance and stability, and they will improve reaction time in certain situations, such as: allowing the correct posture to be recovered after stumbling unexpectedly.

Proprioceptive capacity can be trained through specific exercises, which are recommended after any injury, as well as a preventive method. One way to improve it, for example, is to do exercises on uneven and unstable surfaces, such as those seen above, under the supervision of a professional.

5.3. Example of Proprioceptive Exercises

5.3.1. Ankle Injury Prevention Protocol

Posición Inicial. Lanzamiento de balón medicinal

Posición Final. Lanzamiento de balón medicinal

Posición Inicial. Salto con disco

Posición Final. Salto con disco

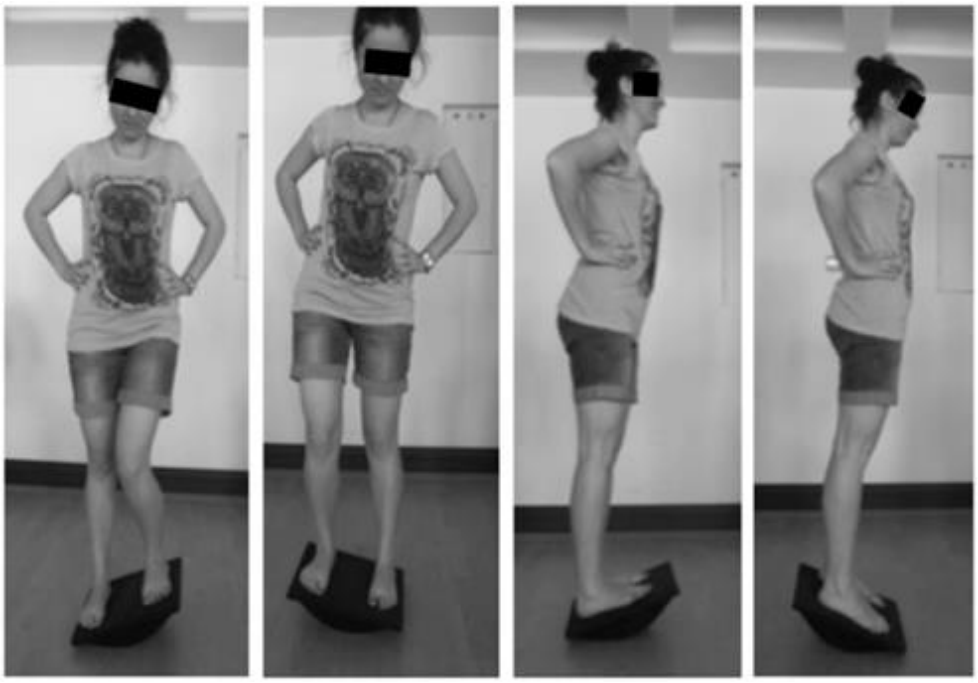
Posición Inicial. "Reloj"

Posición Final. "Reloj"

Posición Inicial. "Sueperman"

Posición Final. "Superman"

5.3.2. Balance board exercises



5.3.3. Core with proprioception

If you notice, these exercises also require certain levels of strength from the core muscles, the so-called functional block of the “core”. So you can start replacing your classic abdominals on the floor with this type of exercises where, in addition to improving your stability, you will achieve an improvement in the strength of the core muscles.

1. For better control of the roll with the trunk, stabilize your arms with the help of a pike and with your feet separated on the ball, rotate to both sides. Keep your hips elevated, without supporting the lumbar área.

2. Balancing on the ball, support the minimum weight on your hands and perform a crawl kick while maintaining balance.

3. The most challenging exercise. With your feet on the bosu, place your arms in a cross position alternately. Try to keep the bosu parallel to the ground.

5.3.4. Stability exercises.

1. With your hands on the ball, change your support. This will force you to activate your core and shoulder girdle stability.

2. Balance yourself with four supports on the ball, you will feel the neuromuscular activity with continuous muscular adjustments.

3. In the deep position, remove the supports. Go from four to three and, if possible, to two supports. More than strength, balance is needed to maintain this position.

5.3.5 Exercises for safety in running

1. To improve balance in the hip and spine, while sitting on the ball, clap your hands under your leg. It is not as easy as it seems.

2. Perform the dumbbell rowing exercise but with support from one leg. By shifting the center of gravity, motor control is more demanding on the supporting foot, check it out.

3. The bosu is a versatile and very useful element. Perform exercises on it systematically; two and one support, pliés, jumps, etc.

5.4. The 3 basics of proprioception

1. With support from one leg, align your arms, trunk and leg, maintaining balance.

2. On a mat, maintain balance on one foot. Try with your eyes closed, the difficulty and stimulation will be greater.

3. Sitting on a fitball, alternate supports from one foot to the other by moving your arms, you will be able to stimulate the receptors of the spine.

CONCLUSIONS

The purpose of this work is to show the importance of proprioception training to maintain, improve and enhance postural control, balance and coordination.

Three essential factors in the practice of Taekwondo, since, through them we use them for the good execution of the different techniques of this martial art. Techniques such as Tuls, jumps, kicks, turns, etc.

Knowing this concept will make us more aware that improving our practice of Taekwondo depends largely on our proprioceptive system being properly trained, which in turn will allow us to perform with greater security, confidence, certainty, forcefulness, efficiency, precision... everything that this sport demands of us, both at the beginning and as we progress in its teaching.

As a physiotherapist, I also wanted to do this work to highlight the importance of proprioception as a preventive measure, not only in sports injuries but also in our daily lives.

A good functioning of our proprioceptive system is essential for our neuronal and musculoskeletal system to stay in shape, allowing us agility, dexterity, good reflexes... throughout our lives.

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