

International Diploma Equine Osteopathy

Int'l DipEO

Can proprioception be improved by exercise?

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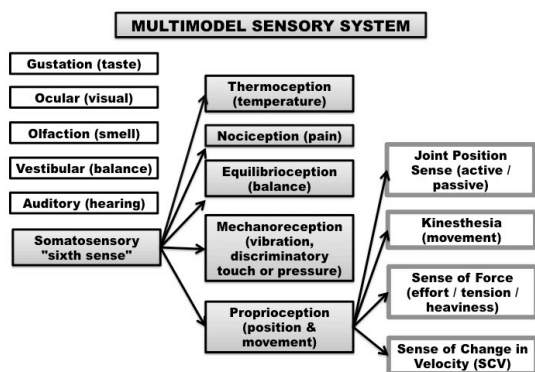
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2 Introduction

The word *proprioception* is originated from “the Latin (*re*)*ceptus* (the act of receiving) and *proprius* (one’s own)”. (Ashton-Miller, Wojtys, Huston, & Fry-Welch, u.d.)

Proprioception can be described as awareness of the body’s position and movement in space, i.e. if a person holds out one arm and at the same time holding its eyes closed, the person still knows where the arm is positioned. It is sometimes referred to as the “sixth sense” (Nickolls, 2020) after taste, visual, smell, balance and hearing.



Picture from (Proprioception, u.d.)

Proprioception plays an important role and is significant for moving the body while maintaining balance and body posture. (Ferlinc, Fabiani, Velnar, & Gradisnik, 2019)

This paper will go through the fundamentals of proprioception, proprioceptors and exercises recommended for proprioceptive training.

In chapter 3 more details about proprioception will be covered. What is proprioception, what is it good for and why is it necessary?

In chapter 4 the different main proprioceptors and their functions and locations are covered.

In chapter 5 the tools and training aids for proprioceptor training and/or rehab training are covered.

The focus of this paper is to understand how proprioception works, what it consists of and how, or if, it can be altered. Does proprioception improve with exercise or is it merely skill, coordination and/or perhaps body awareness that improves?

3 What is proprioception?

Proprioception is the body's "sixth sense," providing a continuous, unconscious awareness of the body's position, movement, and the effort it takes to perform different actions. It is important for everything from maintaining balance to performing movements like walking without looking at the feet (or hoofs in this case). (Cleveland Clinic, u.d.)

There are different sensory receptors (proprioceptors) located in the muscles, tendons, and joints that provide the brain with information about the body's position, movement, velocity and force being used. (Proske & Gandevia, 2012) This sensory information is important for coordination, balance, and motor control, enabling the horse to move without constantly having to rely on its vision. (Cleveland Clinic, u.d.)

The main proprioceptors are listed below and will be described in more detail in the next chapter.

- *Muscle Spindles*

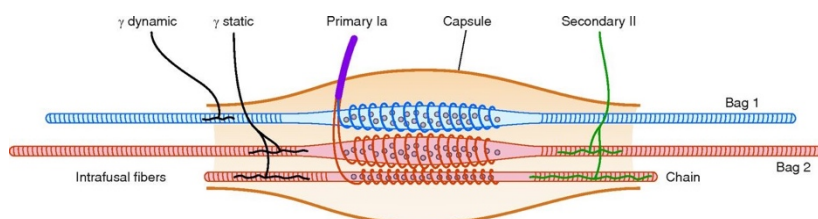
- *Golgi Tendon Organs*
- *Joint Receptors*

In short, these proprioceptors work together to provide the central nervous system with continuous sensory feedback, enabling the individual (horse or human) to perform coordinated movements, maintain balance, and adapt to surroundings and different grounds or surfaces.

4 Main proprioceptors

4.1 Muscle Spindle

A muscle spindle is a specialised sensory receptor located within the muscle belly of a skeletal muscle. (Santuz & Akay, 2023) It senses stretch and provides vital information to the central nervous system (CNS) about changes in muscle length and velocity. This information is important for proprioception, motor control, and reflex actions. (Mechanoreceptors Specialized for Proprioception, u.d.)



“Diagrammatic representation of the mammalian muscle spindle. The intrafusal fibers include the large nuclear bag 1 and bag 2 fibers together with the smaller nuclear chain fibers. Ends of the bag fibers extend beyond the capsule while chain fibers lie within the limits of the capsule. Large, group Ia afferent fibers terminate as primary endings, making spiral terminations around the nucleated portions of all three intrafusal fiber types. Smaller,

group II afferent fibers terminate as secondary endings, lying to one side of the primary endings and supplying bag 2 and chain fibers. Gamma dynamic (γ dynamic) fusimotor fibers innervate bag 1 fibers, while gamma static (γ static) fusimotor fibers innervate bag 2 and chain fibers.” (Proske & Gandevia, 2012)

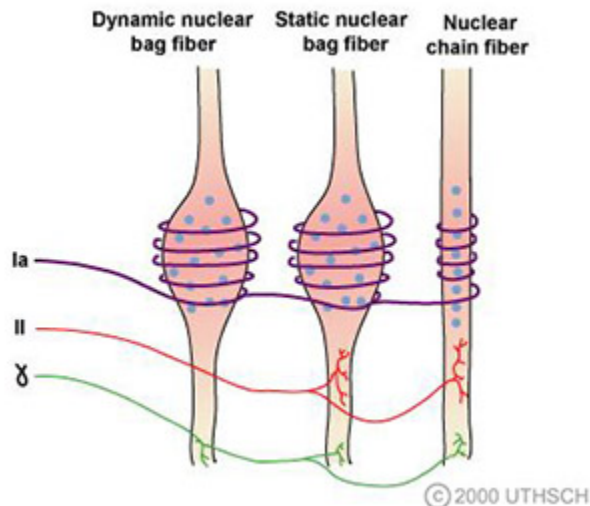
4.1.1 How is the Muscle Spindle structured?

The skeleton muscle consists of *extrafusal* muscle fibres and *intrafusal* muscle fibres. The extrafusal fibres connect the muscle to bones and are responsible for movement. The intrafusal muscle fibres are enclosed within a connective tissue capsule and they run parallel to the contractive extrafusal fibres. These fibres are proprioceptors and will tell the position of the muscle, joints, ligaments and tendons. (Spinal Cord: Stretch Reflex I Muscle Spindle, u.d.)

“Spindles are scattered throughout each muscle in numbers that vary with the function of the muscle and the delicacy of its control. The greater the spindle density, the finer the control” (Korr, 1975)

There are two main types of intrafusal muscle fibres:

- *Nuclear bag fibres* - these fibres have nuclei clustered in a central thicker region and are larger than the nuclear chain fibres. They are sensitive to length and velocity.
- *Nuclear chain fibres* – these fibres have nuclei arranged in a single row. They are sensitive only to stretch, and not velocity like the nuclear bag fibres.



Picture (Knierim, 2020)

Different innervations (Knierim, 2020):

- *Sensory Innervation (Afferent fibres)* – these sensory afferent neurons transmit signals from the muscle spindle to the CNS.
 - *Type Ia afferent fibres* – these fibres are wrapped around the mid-section of the intrafusal muscle fibres. They provide information about length (degree of stretch) and velocity (speed of stretch).
 - *Type II afferent fibres* – these fibres innervate the ends of the nuclear chain fibres and provide information about muscle length.

- *Motor Innervation (Efferent fibres)* – the intrafusal muscle fibres, which only have a little contractive ability at the ends, are innervated by gamma motor neurons (γ -motor neurons).

4.1.2 How does the Muscle Spindle detect stretch?

Since the muscle spindles are arranged in parallel with the extrafusal muscle fibres, the intrafusal muscle fibres within the muscle spindle are stretched whenever the extrafusal muscle fibres are stretched. (Muscle Spindles, u.d.)

When the intrafusal muscle fibres are stretched, the type Ia and type II sensory fibres are activated. This leads to an action potential with a signal to the CNS. The frequency of these action potentials increases with the degree and speed of the stretch. (Kröger & Watkins, 2021)

4.1.3 How does the Muscle Spindle become slack?

When a muscle contracts, the extrafusal fibres shorten, and the muscle spindle will become slack. During muscle contraction, the alpha motor neurons (which innervate the extrafusal fibres) and the γ -motor neurons are working together, this is called the “alpha-gamma coactivation”. (Knierim, 2020) The γ -motor neurons cause the ends of the intrafusal fibres to contract, taking away the slack in the muscle spindle. This is important for maintaining proprioceptive feedback during movement.

4.1.4 Stretch Reflex

When a muscle suddenly is stretched, the Ia afferent fibres send signals to the spinal cord. In the spinal cord, these Ia afferents form a monosynaptic connection (a direct synapse) with alpha motor neurons that innervate the same muscle that was being stretched. This causes the stretched muscle to contract reflexively, resisting the stretch and helping to prevent

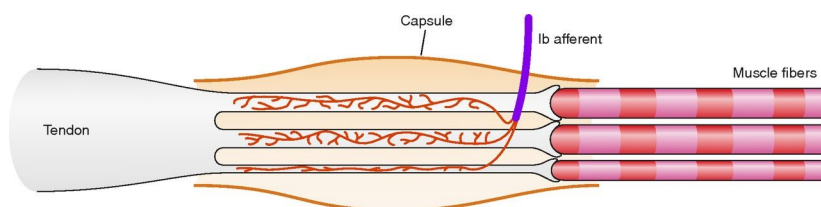
overstretching and injury. A classic example is the "knee-jerk" reflex where the patellar tendon is tapped. (Knierim P. D., 2020)

“when a muscle is stretched it is reflexly stimulated by its spindles to contract, and thereby to resist stretching. Conversely, shortening of the muscle decreases the afferent discharge, reduces the excitation of the motoneurons, thus favoring relaxation (that is, lengthening) of the muscle. The influence of the muscle spindle, therefore, is to cause the muscle to resist change in length in either direction.” (Korr, 1975)

In other words, the muscle spindles are essential for providing feedback to the nervous system to enable movement, detecting stretch and preventing overstretching.

4.2 Golgi Tendon Organ

The Golgi tendon organ (GTO) is another important proprioceptor. While the muscle spindle primarily senses changes in muscle length and velocity, the GTO senses degree of tension within the tendon. (Spinal Cord: Golgi Tendon Organ Reflex (GTO), u.d.)



“Diagrammatic representation of the mammalian Golgi tendon organ. The Group Ib axon penetrates the receptor capsule and branches, each branch terminating on a tendon strand that is attached to a muscle fiber. A typical tendon organ has 10 or more muscle fibers attached to it, each fiber belonging to a different motor unit. Contraction of a motor unit

supplying a tendon organ stretches the tendon strand to which its muscle fiber is attached, generating activity in the Ib axon.” (Proske & Gandevia, 2012)

The GTOs are found within the tendon between the skeletal muscle and the bone. When a muscle contracts it will create tension and pull on the tendon and the GTO. The GTO is located in a capsule within the tendon. Inside the capsule, collagen fibres of the tendon are intertwined with the afferent nerve fibre (type Ib afferent fibre). (Spinal Cord: Golgi Tendon Organ Reflex (GTO), u.d.)

4.2.1 How does the Golgi Tendon Organ detect tension?

As previously mentioned, when a muscle contracts, it will pull on its tendon, increasing the tension in the collagen fibres of the tendon. Because the GTO is in series with the extrafusal muscle fibres, this tension compresses the collagen fibres within the GTO capsule. This tension will cause the afferent fibres to depolarise which will lead to an action potential to signal the tension to the CNS. (Knierim, 2020)

The frequency of these action potentials is directly proportional to the amount of tension in the tendon. The higher the tension, the higher the firing rate of the Ib afferent. (Contento, Dalton, & Power, 2019)

4.2.2 Golgi Tendon Reflex:

One important function of the Golgi tendon organ is to act as a safety mechanism, preventing muscles and tendons from being injured (like a tear or rupture) due to too much force. It does

this primarily through the Golgi Tendon Reflex, also known as the *inverse stretch reflex*.
(Spinal Cord: Golgi Tendon Organ Reflex (GTO), u.d.)

When the tension in a muscle and its tendon is at a high level, risking doing damage to the muscle and tendon, the GTO fires strongly. The type Ib afferent fibres from the GTO enter the spinal cord and synapse with an inhibitory interneuron. This inhibitory interneuron then synapses with the alpha motor neurons that innervate the same muscle that is generating the excessive tension.

The inhibitory signal from the interneuron inhibits the alpha motor neurons, causing the muscle to relax and reduce the tension.

At the same time, the Ib afferent fibres can also excite motor neurons of antagonist muscles, leading to their contraction – this is sometimes called reciprocal activation or autogenic inhibition.

A common example is the biceps and triceps coactivation. If a weightlifter tries to lift a weight that is too heavy, the GTOs in the biceps will detect the dangerously high tension. They will then trigger the inverse stretch reflex, causing the muscles to relax and forcing the weightlifter to drop the weight, preventing a muscle or tendon tear.

To summarise, the Golgi tendon organ is important to sense tension, and its reflex is crucial for preventing injuries (such as tears to muscles and tendons) when too much tension is put to a muscle and tendon.

4.3 Joint receptors

The third type of proprioceptors are the joint receptors. Joint receptors are mechanoreceptors, and they are sensitive to stretch, pressure and compression. This information (nerve impulses or action potentials) is then sent to the central nervous system. (Banios, o.a., 2022) They are activated when the connective tissues in and around a joint are changed due to joint movement or changes in joint position. Different types of joint receptors are sensitive to different types of changes. As other proprioceptors, they provide information about limb position and joint movement but according to research, the function of these receptors are not well understood. (Mechanoreceptors Specialized for Proprioception, u.d.)

Different types of Joint receptors:

Ruffini Endings:

- The Ruffini Endings (sometimes called Golgi Type endings) are found in the joint capsule and ligaments.
- They are slowly adapting receptors and sense stretch of the capsule, and it is only at extreme angle that the capsule is stretched. (Proske, A reassessment of the role of joint receptors in human position sense, 2023)

Pacinian Corpuscles:

- Pacinian Corpuscles are found in subcutaneous tissues beneath both hairy and smooth skin. (Pacinian Corpuscles, u.d.)
- They are rapidly adapting mechanoreceptors and they are highly sensitive to high frequency vibrations.

Free Nerve Endings:

- The free nerve endings are found throughout the body, in both superficial and deep tissues.
- They are primarily pain receptors (nociceptors), but they also sense thermal, chemical and mechanical changes. (Free nerve endings, u.d.) Whether or not they are part of the proprioceptors seems to be different opinions about. According to an article by Patrick Dougherty, Ph. D. (Dougherty, 2020) they should not count as proprioceptors “As mentioned above, free nerve endings of 1° afferents are abundant in muscles, tendons, joints, and ligaments. These free nerve endings are considered to be the somatosensory receptors for pain resulting from muscle, tendon, joint, or ligament damage and are not considered to be part of the proprioceptive system.”

Interestingly, in the past, slowly adapting receptors in the joints were thought to be the primary receptor for detecting position sense. In recent days, this view has changed, and the muscle spindle is now believed to be the primary sensor of position. (Proske, A reassessment of the role of joint receptors in human position sense, 2023)

4.4 Summary of information - proprioceptors:

To summarise the chapter above, it is important to understand that the sense of proprioception is not retrieved from a single type of receptor. Instead, the brain retrieves and integrates information from:

- *Muscle Spindles* – provides information about changes in muscle length and velocity.
- *Golgi Tendon Organs* – provides information about muscle tension.
- *Joint Receptors* – provides information about joint position, movement and articular limits.

5 Exercises and tools for improving proprioception

When researching online, several equine professionals claim that various exercises improve proprioception. Please note that the listed examples of exercises below are not retrieved from research but from different equine articles.

As mentioned in previous chapters, proprioception is the horse's awareness of its body's and limbs position and movements in space, including where the horse places its hoofs. It is important for balance, coordination and movement.

5.1 How could exercise improve proprioception?

If it is possible to improve proprioception with exercise, then how could it (supposedly) be done?

- *Stimulates proprioceptors:* Exercise activities that are focused on balance and coordination, stimulates the proprioceptors located in muscles, joints, tendons, and ligaments. (Martin, 2024) As mentioned in previous chapters, these receptors, or rather proprioceptors, send continuous feedback to the brain about the body's position and movement.
- *Improves neuromuscular pathways and muscle activation patterns:* Varied training and learning new skills and movements require body awareness. The horse needs to process the information received from the different proprioceptors. The neuromuscular pathways are developed and with repetition the new skill and movement can be performed faster with less effort. (Han, Waddington, Adams, Anson, & Liu, 2015)

- *Build core strength and stability:* Some proprioceptive exercises (i.e. elastic resistance band) also engage the horse's core muscles, which are important for spinal stability, posture, and overall body control. (Jessie Bengoa, u.d.)

5.2 Different exercises to improve proprioception:

- *In-hand pole work:* When a horse walks over poles, it enhances the sense of body position and coordination. The horse needs to be aware of where it places its hoofs to avoid the obstacle. (In-Hand Polework - The Powerful Tool to Boost Your Horse's Health and Well-being, 2024)
- *Ground poles and raised poles:* Walking or trotting over poles improves proprioception since it needs to work on its hoof-eye coordination. For better effect, the poles should be placed at different heights, angles and distances. (Proprioception and Strength Training Techniques for Horses, 2024)
- *Elastic resistance band (i.e. Equiband® Pro):* Using an elastic band under the abdomen and behind the hindquarters are supposed to make the horse aware of and activate its abdominal and hindquarter muscles and to build strength but also to enhance proprioception. (Equicore Concepts/About, u.d.)
- *Uneven terrain/varied surfaces:* Walking or riding on varied surfaces like sand, gravel, grass or asphalt provides different sensory input to the hooves and limbs and making the horse adjust its steps accordingly. (Proprioception and Strength Training Techniques for Horses, 2024)
- *Balance pads:* Standing on soft, unstable surfaces forces the horse to both contract and relax the small stabilising muscles to maintain balance. This will improve both proprioception and strength. (Proprioception and Strength Training Techniques for Horses, 2024)

- *Weight shifting*: Similar exercise as balance pads. Gently leaning into the horse while it is standing, or lifting one hoof at a time, encourages the horse to shift its weight. (Proprioception and Strength Training Techniques for Horses, 2024)
- *Backing up*: Asking the horse to back up requires significant proprioception as it changes the horse's visual field. (Proprioception and Strength Training Techniques for Horses, 2024)
- *Backing uphill*: To make the backing up activity a bit more difficult, the horse could be asked to be backing uphill. This requires both proprioception and balance and works as a strengthening activity for the pelvic limbs. (Haussler & Paulekas, 2009)
- *Walking uphill*: Slowly walking uphill, or even walking uphill over an obstacle, encourages the horse to contract the abdominal muscles and iliopsoas muscles and is good for proprioceptive and balancing training. (Haussler & Paulekas, 2009)
- *Walking downhill*: Slowly walking downhill, especially over an obstacle, is good for balance and proprioception. The horse needs to engage its abdominal muscles and core stabilising muscles and also work on resisting gravity. (Haussler & Paulekas, 2009)
- *Carrot stretches*: Encouraging the horse to reach for treats in various positions (i.e. between front legs or low to the side) helps improve flexibility, core strength, and body awareness. (Pilates for Horses - Part 1: Carrot Exercises, 2020)
- *Tail pulls and pelvic tucks*: Gently pulling on the horse's tail to either side can help activate core and muscles around the stifle. The horse can also be asked to do a pelvic tuck by running the fingers on either side of the tail. (Proprioception and Strength Training Techniques for Horses, 2024)

- *Heat*: Using a heating pad (or similar) increases the blood flow to the muscles and can improve proprioception and strength. (Proprioception and Strength Training Techniques for Horses, 2024)

6 Can proprioception improve with exercise?

Researchers seem to agree that proprioceptive training (for humans in this case) is very beneficial for preventing injuries, recover from injury (rehabilitation training) and in some cases even improve results within the different sports. (Yilmaz, Soylu, Kaplan, & Batalik, 2024)

Other research claim that other types of training could be damaging for proprioception.

“Exercise can disturb proprioception, and this has implications for musculoskeletal injuries. Proprioceptive senses, particularly of limb position and movement, deteriorate with age and are associated with an increased risk of falls in the elderly.” (Proske & Gandevia, 2012)

But the question remains, can proprioception improve with exercise? With training, is it perhaps skill and strength that improves and not proprioception per sei? “... the muscle spindle is the only receptor system whose peripheral gain can be modulated by central command. Evidence is still lacking that one can volitionally learn to increase fusimotor input to spindles. However, it would be logical to assume that the Olympic gymnast who trains for 10 years to balance motionless on a narrow beam has learned something in those years of training. No amount of training can increase her sensory receptor density, but she may learn (a) systematically to increase her fusimotor drive to the spindles in such challenging tasks, (b) systematically to increase the gain of the spinocerebellar and dorsal column-medial lemniscal networks receiving spindle afference,

and (c) to pay undivided attention to detect relevant afferent cues with greater probability and/or increase the somatosensory field for proprioception in the sensory cortex. If she uses any or all of these mechanisms she may be able more reliably to focus attention and detect smaller postural changes than 10 years previously. In other words, she undergoes successful proprioceptive training. If none of these effects occur, however, it is likely that her improvement is due to refined motor responses to the standard cues provided by the proprioceptive systems, and her improvement should not be ascribed to improvement in proprioception.” (Wojtys, Fry, Ashton-Miller, & Huston, 2001)

“More specifically, Ashton-Miller et al. have argued that if proprioception is only the afferent (hardware) part of the system, proprioception cannot be trained because there is no capacity to train a signal.” (Han, Waddington, Adams, Anson, & Liu, 2015)

7 Conclusion

Proprioception is an automatic subconscious activity where different kinds of proprioceptors in the body sends signals to the brain. On the contrary, body awareness is a conscious activity where the horse actively needs to adjust its movements in order to avoid obstacles (i.e. ground poles) or uneven ground. When doing this research most papers reviewed claim that proprioception can be improved with various exercises, but still, it seems that it is the strengthening of muscles, balance and coordination that improves. The conclusion is that proprioceptive training is very beneficial, i.e. to decrease risk of injuries and to improve strength and mobility in rehab training, but more research is needed to confirm that it is indeed proprioception that is improved and not only body awareness and coordination.

A special thank you to the YouTube channel Ninja Nerd which has been very helpful in the understanding of neurophysiology.

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