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MINI REVIEW

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Basic background in reflex physiology

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ABSTRACT

Reflexes are a fundamental part of nervous system analysis. Various pathologies manifest themselves by disrupting the basic reflex functions inherent in the individual, and some of them are fully developed at birth. For a complete clinical analysis, knowledge of the basic mechanisms of its functioning is required. This review aims to demonstrate the mechanism of some of the main reflexes present in individuals in a simplified way, consolidating knowledge of great importance to the area. The focus is not on detailing the specifics of each reflex but on the use of recent advances in research to accurately determine its visual effects as well as its effects in the organism, observed through clinical examinations.

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Introduction

A reflex can be defined as an involuntary, qualitatively invariable nervous system response to a stimulus. A reflex arc is defined as the movement described from the stimulus to the central or peripheral nervous system and its return to the stimulus site, with a function. The reflex arc is a fundamental part of the physiology of posture and locomotion, as well as for the clinical examination of the nervous system [1,2]. Reflexes have the function of maintaining the homeostasis of the organism, as well as preserving the physical integrity of the individual [3]. We can quote from the increase in blood flow during exercise to coughing and sneezing. They are important survival mechanisms, and many of the mechanisms fully developed at birth.

Reflexes have five basic components involved in the physiological response: receptors, sensory nerves, synapses, motor nerves, and target organs. Receptors vary widely within the body, but they all share a common function: to translate some environmental energy received into the stimulus form into action potential so that they can propagate through the sensory nerves. For example, retinal receptors transduce light, and muscle spindle receptors transduce the stretch. Several types of receptors are known, with different capacities for stimulus transduction [4,5].

In transduction, action potentials are generated along the sensory nerves at a frequency proportional to the transduced energy [6]. This proportionality between the intensity, by which a receptor is stimulated, and the frequency of action potentials resulting in a sensory nerve is called the coding frequency and is how the receptor communicates to the nervous system about the intensity of light, heat, muscle stretch, and so forth, which he transduced [7].

The sensory nerve, also called as the afferent nerve, conducts the action potential generated at the receptor to the nervous system, penetrating the spinal cord through the dorsal roots. On entering the nervous system, synapses occur to generate a response to the stimulus. For most of the reflex arcs, more than one synapse occurs. Few reflexes are monosynaptic, such as those from muscle spindles. The response is driven by the motor nerve, or efferent nerve, bringing the action potentials of

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the nervous system to the target organ, an effector of the response. The motor nerves leave the spinal cord through the ventral roots [8,9].

It is in the target organ that the reflex response will be fulfilled, with variations in its activity according to its usual function. As an example, we can mention the quadriceps muscle of the leg, in the case of the patellar reflex (muscle stretch), and the smooth muscle of the iris when in the pupillary reflex, triggered by light [10,11].

Reflex Physiology

Reflexes can be segmental or intersegmental. A segmental reflex is one in which the reflex arc passes through a small segment of the nervous system [11]. In an intersegmental reflex, multiple segments of the nervous system are used [12]. The reflex analysis is very important for diagnosis, treatment, and prognosis of diseases of the nervous system, but a well-performed analysis can also determine pathologies in other systems, such as musculoskeletal systems [13].

The autonomous nervous system guarantees adequate responses to emergency or stress situations that require rapid and intense responses, being the main responsible for reflexes. It is the part of the nervous system responsible for regulating neurovegetative functions whose control is involuntary: respiratory, cardiovascular, renal, digestive, and endocrine systems. It plays a major role in maintaining homeostasis at all times in the face of different environmental situations and challenges, innervating various organs, glands, blood vessels, and smooth and cardiac muscles. It is divided into the sympathetic and parasympathetic autonomic nervous system [14,15].

The sympathetic system innervates all the viscera of the body, preparing the body for the fight-or-flight response. Among its functions, pupil dilation, increase in heart/respiratory rate and blood pressure, bronchodilation, and decrease in digestive peristalsis, among others, are highlighted. The parasympathetic system has a function contrary to the sympathetic system in a large part of the body, which can cite the functions of reducing heart/respiratory rate, emptying the bladder, and increasing the peristalsis of the digestive system. The balance of function between the two autonomous systems makes the body in an ideal health condition [14,16].

In the course of this review, we will present the basics fundamentals of the reflexes of the greatest clinical importance.

Muscle stretch reflex

To perform a response, receptors capable of detecting the result of the contraction of the muscles to the central nervous system, as well as their extension over the body, are required. The receptors involved are the muscle spindles and the Golgi tendon organ [17]. The spindles can contract and indicate muscle length as they have parallel skeletal fibers. The Golgi tendon organ is an encapsulated structure located at the muscle–tendon junction, where the collagen fibers of the tendon join the ends of the extrafusal muscle fibers. The stretching of the fibers also stretches the tendon organ. These compresses and stretches the nerve endings, causing their depolarization. Tendon organs are very sensitive to changes in muscle tension, unlike muscle spindles which are more sensitive to changes in muscle length. When the muscle contracts, the frequency of depolarization of the tendon organs increases markedly, whereas that of the muscle spindles decreases or even disappears [18,19].

The spindle is encapsulated and contains specialized skeletal muscle fibers, intrafusal muscle fibers, and extrafusal muscle fibers. The intrafusal fibers can contract at their polar end, whereas, at their apolar end, there is no contraction, being encased by the motor neuron itself and gamma motor neurons themselves. The extrafusal muscle fibers can physically shorten the muscle and receive nerve supply within their motor unit, which is the alpha motor neurons [18].

The way to generate an action potential is through muscle stretching, with stretching of the equatorial segment and opening of the ion channels, causing membrane depolarization, and generating the action potential [20]. The ability to send information to the central nervous system is determined through the muscle spindle, which informs the length of the muscle. Both the stretch receptors provide the nervous system with information on length and tension, which is essential for coordination in posture and locomotion [21].

This reflex can happen in any muscles of the body; however, some are more important for clinical analysis and diagnosis. The reflex mostly used in the analysis of the patient is the patellar reflex. In this reflex, the action potentials are generated in the spindle sensory nerve at a frequency proportional to the degree of stretching of the equatorial region of the spindle. Once transmitted to the central nervous system, a monosynaptic and excitatory connection occurs with the motor neuron that returns to the extrafusal fibers of the same muscle [13,22].

The patellar reflex is generated by percussion of the patellar tendon (quadriceps muscle insertion). The impact on it results in a longitudinal stretching of the entire muscle and also stretching of the muscle spindles. The spindle receptor action potentials are directed to the spinal cord, causing a postsynaptic excitatory potential in the motor neuron that returns to the quadriceps muscle. This causes the contraction of this muscle and extension of the knee joint [23].

If there are no abnormalities in this structure, the expected effect is that the leg will stretch forward or lift upward during the analysis. This can be a short or slightly larger movement depending on the stimulus performed. In some of the cases, the quadriceps can also move. The absence or decrease of this reflex even with an increase in the stimulus may indicate a pathology linked to the nervous system [24].

There are several causes, so it is necessary to identify its etiology. Disc herniation is an example that triggers a decrease or absence of the patellar reflex depending on the degree of severity of the herniation. In the presence of a herniated disc, it retracts outward and the nerves are anatomically modified and may overlap. Furthermore, there is a greater increase in pressure in the intervertebral disc that triggers the absence of the patellar reflex [25]. Another cause associated with the decrease of this reflex is Parkinson's disease, due to the damage of nerve cells. Parkinson's disease is a brain disease with no cure, and the patellar reflex may be permanently absent in these situations [26].

Lumbosacral radiculopathy can also trigger a reduction or absence of a patellar reflex, sometimes in one leg or both. This syndrome affects the nerve root in the spine, and it remains compressed. Symptomatologically, there is tingling, weakness, or loss of sensation in one or both legs. A herniation is often a direct cause of the development of this syndrome [27]. Other causes of failure of the patellar tendon reflex include damage by accident or trauma, surgery, use or ingestion of harmful substances, and birth defects, among others [28,29].

Pupillary reflex

The pupillary reflex is stimulated by light, so when the light is pointed at the eye, a series of processes occur. In the first, the light activates the photoreceptors present in the retina, occurring sensory potentials, which are transmitted to the brain stem through the optic nerve, where through various interneurons, and cholinergic parasympathetic neurons stimulate the muscle that contracts the iris, with a decrease in the pupil [30].

The pupil dilation process occurs through postganglionic neurons, which secrete acetylcholine, being a neurotransmitter to the muscle. There is a set of smooth muscle fibers that contract and cause the pupil to dilate around the pupil, which are innervated by the sympathetic nervous system [31].

The clinical examination of the pupillary reflex is extremely important, and it can present different variations, linked to pathologies or not, making it essential for many diagnoses. For its analysis, a light source is used, and the evaluation allows us to know the conditions of the retina, the optic nerve, and the group of neurons in the diencephalon and motor neurons of the oculomotor nerve [32,33].

A normal response to a direct light source should be a pupillary contraction in both the eyes. The pupillary constriction in the illuminated eye is called a direct pupillary response, and the constriction of the opposite pupil is called a consensual pupillary response. Several pathologies are responsible for changes in the pupillary reflex, such as optic nerve disorders, ocular cranial neuropathies, disorders with ocular motility dysfunction, visual field defects, and disorders in the retina [34–36].

Rectosphincteric reflex

The rectosphincteric reflex consists of the entry of the feces into the rectum accompanied by reflex relaxation of the internal anal sphincter, followed by peristaltic contractions of the rectum. This reflex often results in defecation although this effect can be blocked by voluntary constriction of the external anal sphincter. The rectosphincteric reflex has a great importance in defecation, necessary for its control [37].

Reflexes of the digestive system

The stomach has two main functions: the initial portion is to store food, whereas the final portion can grind and select. Each part of the stomach has a characteristic reflex. The reflex in the initial portion of the stomach is adaptive or receptive relaxation as it is necessary to relax the muscle for food intake. In the distal portion, mainly the process of peristalsis occurs, which are muscle impulses/contractions to release the digested food [38,39].

There is a difference in the way that the initial astral motility is controlled, but both are under endocrine and nervous control. Synapsing with nerve cell bodies through the extensive gastric is made up of vagus nerve fibers, which exert full control over the gastric activity. The parts of the stomach work in opposite ways, and the initial part relaxes, whereas the distal part makes peristaltic contractions by vagal stimulation in both the plexus [40].

The main neurotransmitter responsible for the peristalsis process, not only in the stomach but also throughout the gastrointestinal tract and in all organisms, is acetylcholine, synthesized in the liver, and stored in synaptic vesicles along the neurons [41]. When an action potential reaches an excitation threshold, the vesicles burst and release acetylcholine in the synaptic cleft. With an immediate function and rapid degradation, it is responsible for the constant movement developed by the smooth musculature [42].

The main inhibitory control of gastric emptying is mediated by an enterogastric reflex (a neural mechanism) and an enterogastrone (an endocrine mechanism), which consists primarily of sympathetic reflexes and cholecystokinin (CCK) hormone [43]. CCK receptors respond to fat in the duodenum and jejunum, and duodenum receptors for the sympathetic reflex monitor the chemical composition of digesta leaving the stomach. These two mechanisms inhibit emptying when the duodenum content is hypertonic, acidic, or irritating [44]. It is important to remember that the duodenal mucosa is much more permeable than the gastric mucosa and has no powerful barrier function. Thus, the hypertonic content may cause a large amount of fluid to be diverted from the plasma to the lumen of the gastrointestinal tract [45].

Osmotic-laden meal nutrients should also be slowly released into the duodenum to be mixed with pancreatic enzymes. The inhibitory mechanisms involved are: (1) too much Chimo in the small intestine, (2) excessively acidic Chimo, (3) Chimo with too much protein or unprocessed fat, (4) hypotonic or hypertonic Chimo, and (5) irritative Chimo [46].

Arterial baroreceptor reflex

The arterial baroreceptor reflex modulates circulation from hydrostatic pressure sensors present in the blood vessels or heart. There are receptors in high blood pressure territories, such as the aortic arch and carotid sinuses, and in low-pressure territories such as the great veins and some cardiac chambers [47].

Baroreceptor innervation transmits information to the central nervous system through the nucleus of the solitary tract. Information processing leads to increased parasympathetic system activity and decreased sympathetic system activity. The final events of this reflex arc are decreased heart rate and peripheral vasodilation [48].

Exercise reflex

The exercise reflex is composed of a group of actions responsible for cardiovascular regulation when the body is subjected to physical activities. It consists of a feedback system that perceives the work of the muscles, monitoring the contraction, and the accumulation of cellular waste in it, being a normal hemodynamic response to exercise in healthy individuals [49].

During physical activities, mechanical stimulation occurs in muscles associated with contraction, stimulates efferent nerve endings, and triggers a cardiovascular reflex, the mechanoreflex. This cardiovascular reflex stimulates afferent nerves that trigger an increase in heart rate. Along with the increase in heart rate, the reflex also causes an increase in sympathetic activity in the bulbar region and a decrease in vagal activity [50].

With a constant physical effort, the blood circulation is unable to remove all the muscle metabolites produced, triggering a new cardiovascular reflex, the metaborreflex, in which non-myelinated afferent fibers take the information of the accumulation of substances to the bulbar region, which in turn increases sympathetic activity and decreases parasympathetic activity, leading to increased pulmonary ventilation and causing vasoconstriction in muscles that are not in exercise, in addition to increased cardiac output. This results in a greater arrival of oxygenated blood to skeletal muscles in the activity and not to those that are not used, increasing the energy supply, removing toxic metabolites, and increasing the potential for time in exercise [5,50,51].

Similar to other smaller auxiliary systems, both are complementary and are extremely necessary for the constancy of physical effort.

Postulates in the Reflex's Physiology

From the knowledge obtained in the area of reflex physiology, postulates were established to explain the organism's response mechanism, dealing with the latency period, threshold mechanism, and intensity–magnitude mechanism [52–54].

The postulate on latency explains that there is an inversely proportional relationship between stimulus and latency, and in other words, the greater the stimulus, the faster response is generated. The generated interval is defined as latency time and lasts from the beginning to the end of the reflex arc [55]. Its clinical evaluation is extremely important, performed through electroneuromyography, which allows both the source and the location of a specific neuromuscular disease to be known for more accurate diagnoses. The changes in the latency time indicate some failure in the nervous system or musculoskeletal system [56]. The postulate that deals with the intensity–magnitude relationship establishes that the stimulus intensity is directly proportional to the magnitude of the response, i.e., the greater the stimulus, the more intense the organism's response [54]. The threshold postulate determines that there is a minimum stimulus to trigger a reflex response [57]. Reflexes related to the maintenance of life and proprioception have less latency time, lower action threshold, and less need for stimulus to generate a response, such as postural reflex, respiratory reflex, and reflexes generated by painful stimulus [58,59].

The knowledge of these postulates and parameters determined by them is essential for the clinical analysis of the patient. The delay or absence of a response, as well as hyperresponsiveness to a particular stimulus, may be the indications of neurological diseases or syndromes, as well as other pathologies that cause sensory modulation disorders, such as autism spectrum disorder [57,60,61].

The studies show that, in clinically healthy patients, as younger, the faster the reflex response is generated, with less need for stimulation, lower action threshold, and shorter latency time. However, it is difficult to establish an expected pattern between different individuals of the same age and clinical condition. Thus, routine monitoring and maintenance of the patient's history are paramount, especially in the cases of genetic predisposition, such as Parkinson's disease and Alzheimer's disease [52,62–64].

Conclusion

Reflex bows are everywhere in the nervous system and are the basis for many of the individual's subconscious responses in their environment. Numerous clinical examinations of the nervous system involve the evocation of reflex responses, such as the pupillary reflex, muscle stretch reflex (patellar reflex), and flexor reflex.

If any of the five fundamental components of malfunction, the expected reflex response does not occur. It is important to know the general anatomy, physiology, expected normal clinical response to the usual reflexes, to perform a neurological examination to locate any lesions.

Compliance with Ethical Standards

The authors declare that they have no conflict of interest. This article does not contain any studies with human participants or animals performed by any of the authors.

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