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Practical use of electromyography in veterinary medicine – A review

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Abstract: Electromyography (EMG) is a sophisticated electrodiagnostic-neurophysiological method, which serves to diagnose neuromuscular system diseases. It is based on the measurement of the electrical potentials created by the skeletal muscle activity. For this technique, surface electrodes and needle electrodes can be used, which read the action potential of a large number of motor units and read a small number of motor units, respectively. The wide-spectrum application of this method extends our diagnostic possibilities of the clinical examination in veterinary practice. Together with a clinical neurological examination and imaging methods, EMG forms a part of the diagnosis of nervous system diseases and it is a useful diagnostic technique for differentiating neuropathies, junctionopathies, and myopathies. The results of the neurophysiological examination inform us about the functional state of the peripheral and central nervous system; it can demonstrate subclinical diseases and monitor the dynamics of changes in the functional state of individual nervous systems over time. In this article, we review the electromyographic method and its use in veterinary practice.

Keywords: animal; electrodiagnostic study; neurologic patient

Introduction

Neurological and neuromuscular diseases are some of the most challenging clinical cases in veterinary practice. Diagnosis of the neuromuscular diseases consists not only of a thorough clinical and neurological examination, but also requires advanced diagnostics, such as ultrasonography, radiography (X-ray), computed tomography (CT), magnetic resonance imaging (MRI), electromyography (EMG), or a muscle and nerve biopsy (Dewey and Fossum 2019). Advances and better availability of imaging diagnostic methods, such as MRIs, have created better conditions for the diagnosis of cases (Platt and Olby 2014).

EMGs record the electrical activity in a muscle. They can detect the presence of abnormalities, such as a chronic denervation or fasciculation, in a clinically normal muscle and they can distinguish a myopathic disease from a neurogenic disease.

In human neurology, a variety of electrodiagnostic methods, including encephalography, are used to aid the diagnosis of neuromuscular disorders. However, these techniques are complex, require sophisticated equipment, and the patient must be cooperative. Since an EMG is a relatively non-invasive

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technique, it can be performed in a conscious animal and can be used during locomotion to study normal or pathological muscle work. EMGs have become a useful extension of the clinical examination (Van Wessum et al. 1999).

The action potentials that arise during depolarisation of the muscle membrane can be captured by needle or surface (contact) electrodes adhered to the skin. The information from the contact electrodes or from the EMG needle is processed in a PC and converted into an EMG curve or a sound. Needle electrodes are most often used; they allow for the examination of the surface and deeper structures. During the examination, specially modified needles are inserted into the muscle (or in some cases around the nerve fibre).

With this method, the patient may experience mild pain at the insertion site, or may experience a slight hypersensitivity of the muscles being examined. In veterinary medicine, sedation is, therefore, used. When using surface electrodes, the electrodes adhere to the skin with no need of sedation. This method is absolutely painless. Spontaneous activity is recorded from the muscles in pathological conditions, no electrical activity can be detected from a healthy muscle at rest. In the case of a muscle contraction, any individual action potentials, their shape, duration, number of phases and amplitude are evaluated.

Electromyography

Electromyography is an electrodiagnostic method in which the electrical activity (potentials) of the patient's muscle fibres and nerves are detected and recorded (Kimura 2001). Electromyography (EMG) is the recording of insertional, spontaneous, and voluntary electric activity of muscle (Kimura 1989). Studies of individual muscles provide the possibility of directly identifying the affected muscle fibres (LeCouteur and Williams 2012) and EMG is one of the methods that can be used for the assessment of neuromuscular disorders (Kimura 1989). This diagnostic method is usually performed as a part of a complete neurological examination. In addition, to investigate the involvement of the central nervous system (CNS) or nerve root, EMGs and other neurophysiological studies can be used in conjunction with a CT or MRI (Cuddon 2002; LeCouteur and Williams 2012). Evaluation of the peripheral motor system, when the main clinical symptom is neuromuscular weakness, consists of electromyography itself, measurements of the motor nerve conduction velocity, evaluation of F-waves, and repeated stimulation of motor nerves (Poncelet and Poma 2012).

An electromyographic examination is widely used to record the typical electrical activity (action potentials), to identify denervated muscles and to characterise myopathies. Typical electrical activities, which is detected by the EMG can be divided into spontaneous activities that consists of potentials which are not dependent on the mechanical stimulation, and abnormal activities. During an EMG examination, three phases should be investigated. The first phase assesses the electric potentials associated with the insertion or movement of the needle electrode within the muscle. This muscle activity is called insertional activity. In the second phase, the resting activity in the muscle is evaluated with the needle stationary at different depths in the muscle. These two phases offer the most relevant information in the diagnosis of neuromuscular diseases. The third phase involves the assessment of electrical potentials (motor unit action potentials) occurring during (induced) muscle contraction (Van Wessum et al. 1999).

Within a healthy, pathologically unchanged muscle, spontaneous activity can be observed, but these waves must be distinguished from models indicating abnormal activity. Four types of normal spontaneous activity can be recognised: insertional activity, miniature potentials of end plates, end plate spikes and action potentials of motor units (LeCouteur and Williams 2012). The input or insertional activity is caused by the mechanical irritation of the muscle fibre, needle puncture or when the muscle is completely atrophied and might be replaced by connective or adipose tissue (also ossifying or fibrotic myopathies). This activity can be absent or reduced, when the electrode is not in the right muscle and it can be prolonged when the muscles are denervated. Increased insertional activity is most prominent 4 to 5 days after denervation and usually precedes the onset of other denervation-linked potentials. Increased or prolonged insertional activity can be a sign of early denervation atrophy, but it is also seen in myotonic disorders and myositis (Kimura 1984; Jaggy 2009; Aminoff 2012).

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Figure 1. A motor unit action potential is the action potential reflecting the electric activity of a single anatomic motor unit (Strain 2006)

It is the compound action potential of those muscle fibers within the recording range of an electrode

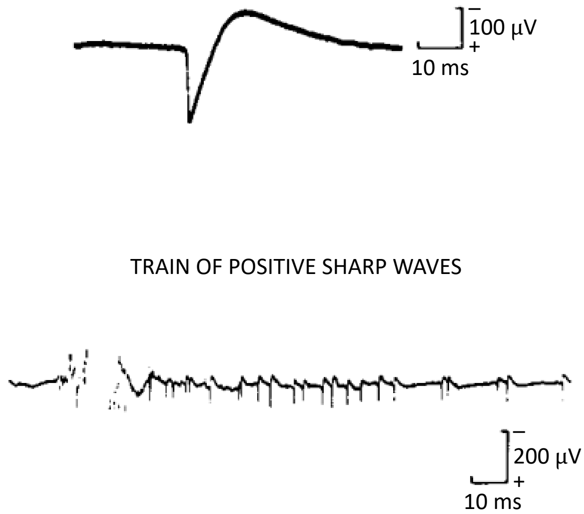

Figure 2. The top trace shows a single positive sharp wave (Strain 2006)

The bottom trace shows the pattern of initial discharge of a number of different positive sharp waves after movement of the recording needle electrode in denervated muscle

The motor unit action potential (MUAP) is a compound potential that is generated after the electrical stimulation of alpha-motor axons or after spontaneous activity by the motor fibres of the motor unit (Figure 1). These potentials are usually two- or three-phasic in shape, but they may also have more than four phases in shape, when they are referred to as multiphasic. Clinically, the number of phases and the duration of the MUAPs are of greater importance than their amplitude, because the amplitude is influenced by the electrode position, muscle fibre type, and the age of the animal (Sustronck 1994; Crone and Krarup 2013).

In addition to these spontaneous activities, the fibrillation potentials ("Fibs"), positive sharp waves ("PSWs") (Figure 2), myotonic discharges, complex repetitive discharges, which indicate the abnormal activity, can also be detected. All of these unusual electrical potentials suggest neuropathy or myopathy. These potentials, so called "Fibs" and "PSWs" arise from the spontaneous discharge and hypersensitivity of individual muscle fibres due to the destabilisation of the sarcolemma and they may occur secondarily due to diseases causing denervation (neuropathy) or as a result of a primary myopathy (LeCouteur and Williams 2012).

Fibrillation potentials are characterised as spontaneous, bi- or tri-phasic waves, which are represented by downward folding. Fibrillations are the most commonly observed abnormal electromyographic findings and they strongly suggest denervation. They can be detected after an acute nerve transection, when the nerve fibres degenerate distal to the lesion site. The muscle fibres remain viable, but they become supersensitive after 7–10 days. Acutely denervated muscles are not limited to neuromuscular junctions, but acetylcholine receptors are found throughout the membrane, and the fibre is supersensitive with the result of spontaneous discharge. Fibrillations are often seen in conjunction with positive sharp waves, which are presented as monophasic waves with a short positive phase followed by a longer very large negative phase. Initially, they increase in number and amplitude. When denervation persists and atrophy starts, the fibrillation potentials decrease in number and amplitude, and they finally cease when the muscle is completely atrophied (Kimura 1984; Podell et al. 1995; Van Wessum et al. 1999; Mills 2005; Dewey and Fossum 2019). Denervated muscle fibres are manifested by spontaneous depolarisation, which is the most common form of fibrillation (Poncelet and Poma 2012).

Complex repetitive discharges are referred to polyphasic potentials, but they do not appear as fibrillations or positive sharp waves. These complex potentials are thought to result from exposed muscle fibres. They are caused by repetitive MUAPs after insertion of a needle electrode or even by the percussion of a muscle. In contrast

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to myotonic discharges, they start and end abruptly, they are constant in amplitude, and have a shorter duration. They are relatively often associated with a chronic course (Van Wessum et al. 1999; Dewey and Fossum 2019). These high-frequency action potentials can sometimes be seen in patients with muscular dystrophy, metabolic disorders, inflammatory or hypothyroid myopathies (Fellows et al. 2003), lower moto-neuron diseases (Buchtal and Rosenfalck 1966) or in the lesions of nerve roots or peripheral nerves (Stalberg et al. 1983).

Nerve conduction and electromyography studies are useful electrodiagnostic methods in the clinical examination of the peripheral nervous system and striated muscles. Nerve conduction diagnostics provide an effective and rapid method for determining the motor nerve conduction velocity (MNCV) and the amplitude of both potentials, sensory nerve action potential (SNAP) and compound motor action potentials (CMAP) (Kane and Oware 2012; Chouhan 2016). Suspected peripheral nerve diseases (e.g., neuropathies) are examined by motor nerve conduction studies (Poncelet and Poma 2012).

Repetitive nerve stimulation (RNS) and a single-fibre EMG (SF-EMG) represent clinical electrophysiological techniques which give us exact information about changes in the transmission at the neuromuscular junctions (Yang et al. 2001). Repetitive nerve stimulation is an electrodiagnostic method in which repeated supramaximal nerve stimulation occurs when recording M-waves from muscles innervated by a given nerve (Dumitru 2001; LeCouteur and Williams 2012). In this test, the action potentials of a muscle mass (CMAP) are recorded during the repetitive motor nerve stimulation, which indicates the number of activated muscle fibres. When progressively fewer nerve fibres respond to the repeated nerve stimulation, a decremental (reduced) model occurs in the CMAP series. This is a typical finding when the released stocks are depleted and the number of blocked end plates increases during the repeated nerve stimulation (Sonoo et al. 2001). Every patient undergoing RNS should also undergo routine nerve conduction studies and electromyography (EMG).

The most sensitive electrodiagnostic test for the neuromuscular junction transmission is a single-fibre electromyography (Kane and Oware 2012). The SF-EMG is used to diagnose several types of data (Stalberg et al. 2010):

1. Variability in the neuromuscular junction transmission at the level of a single or pairs of junctions;
2. The relative fibre density of muscle fibres in the motor unit;
3. Macro-EMG – motor unit action potential, which represents the activity of all the muscle fibres in the motor unit using a single-fibre electrode modification.

The SF-EMG uses a special concentric needle electrode with a small recording area, which ensures the detection of action potentials from individual muscle fibres. Potentials are recorded from two muscle fibres in the same spontaneously activated motor unit, the time interval between these two potentials varies from discharge to discharge, which is a manifestation of the neuromuscular vibration (Stalberg and Trontelj 1997).

When the single-fibre action potentials are recorded, it can assess the shock waves during transmission through the neuromuscular junction. There are two ways to activate the transmission (Stalberg et al. 2010):

1. Intramuscular nerve branches are stimulated and the recording is based on the individual muscle fibres (called stimulatory SF-EMG);
2. Motor units are spontaneously activated and the values are recorded on pairs of muscle fibres of the same motor unit (called spontaneous SF-EMG).

Clinical use of EMG in veterinary medicine

Electrodiagnostics is a general term that includes several electrodiagnostic techniques, such as a needle electrode examination (NEE); motor and sensory nerve conduction (NCS) studies, delayed responses and evoked potentials (EP). Electrodiagnostic methods are very useful attributes in addition to the clinical examination of patients suffering from pain, weakness, or neurological deficits. Painful peripheral neuropathies, nerve trauma, radicular and multiradicular problems, lumbosacral stenosis, arachnoiditis and painful myopathies are among the conditions in which electrodiagnostic methods are very beneficial. When assessing neuropathic pain syndrome, thanks to the electrodiagnostic methods, it can be determined whether there is functional peripheral nerve damage before any attempt at therapy. One is also able to determine

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the relevance of the identified peripheral neuropathic lesion to subjective clinical therapy (Abrams and Waldman 2014). The EMG measures the electrical activity of a muscle during rest and during contraction. The muscle tissue does not normally produce any electrical signals during rest. When an electrode is inserted, a brief period of electrical activity is recorded, but after that, no signal should be present. The related procedure is the nerve conduction velocity, which is a measurement of the speed of conduction of an electrical impulse through the nerve. It can determine the nerve damage and destruction, and it is often performed at the same time with the EMG. Both procedures help to detect the presence, location, and the extent of a disease that damages the nerves and muscles.

In studies dealing with spinal cord disorders, such as the cervical myelopathy in dogs with clinical and radiographic symptoms, EMG examinations revealed the denervation potentials in the epaxial muscles of the caudal cervical region (Binzegger et al. 1976). The presence of denervation potentials in epaxial muscles in the lumbosacral region of dogs with paralysis of the hind legs caused by an acute disc herniation and subdural haematoma has also been detected (Binzegger and Heckmann 1977). Several positive waves have been recorded in the epaxial muscles of the thoracic spine of Afghan Hounds with necrotising myelopathy (Cummings and De Lahunta 1978).

Nes (1986) described the use of electromyography in peripheral nerve diseases, traumatic myelopathy, neoplasia, poly (radiculo) neuritis, as well as its use in neuromuscular diseases such as myasthenia gravis. Steinberg (1979) described the diagnoses of traumatic peripheral neuropathies; he confirmed the EMG symptoms of denervation in all 30 dogs with a brachial plexus trauma. Forterre et al. (2007) detected abnormal EMG findings in all patients with a peripheral nerve injury in their study focused on iatrogenic sciatic nerve injuries. The insertional activity included trains of positive waves and isolated fibrillation potentials.

EMG was used also in several scientific articles dealing with canine degenerative lumbosacral diseases. Sisson et al. (1992) used EMGs in their work to diagnose the abnormalities of the *cauda equina* syndrome. The chronic course of the most *cauda equina* neuropathies makes them suitable for detection with EMGs. EMG examinations were performed in 13 of 15 clinically positive dogs in this study. Eight dogs diagnosed with EMG abnormalities had a concurrent significant *cauda equina* compression detected during surgery. The EMG analysis was 100% accurate in predicting the presence or absence of *cauda equina* compression in this study which indicates the excellent ability of this technique to differentiate dogs suffering with motor unit diseases vs. orthopaedic diseases. Aleman et al. (2020) stated in their study on sidewinder-gait horses that an EMG can be used as a diagnostic aid to determine neurologic versus non-neurologic diseases and further localise those of neurologic origin (Aleman et al. 2020). In a study on shivering horses from Aman et al. (2018), the result provides a link between abnormal surface EMG (sEMG) patterns in shivering horses and cerebellar Purkinje cell dysfunction.

In a study performed by De Risio et al. (2001) in dogs with degenerative lumbosacral stenosis (DLSS), the authors used EMGs in addition to sensitive diagnostic techniques including MRI, CT, and epidurography. EMGs were useful because they provided additional information to the acquired results from the imaging studies. EMGs were performed on 22 dogs and abnormalities, such as fibrillation potentials and positive sharp waves in the tail and/or anal sphincter, were found in 19 (86%) dogs with DLSS (De Risio et al. 2001).

In another study, Abraham et al. (2003) described the use of an EMG in the diagnosis of peripheral nerve tumours. Sciatic nerve tumours were diagnosed in a crossbreed dog of a Staffordshire Terrier and in a Bichon Frisé dog, which both suffered chronic left pelvic limb lameness. In both cases, the neurological examination was consistent with the symptoms of left sciatic nerve incapability, as confirmed with the EMG and MRI studies. In the first case, spontaneous depolarisation and the presence of positive sharp waves in the left proximal part of the *m. semitendinosus* and the left part of *m. gluteus* were recorded. In the second case, it was not possible to measure the spontaneous muscle activity due to the muscle atrophy, but the additionally performed conduction velocity of the left sciatic nerve was delayed more than the right, unaffected, sciatic nerve (Abraham et al. 2003).

In one clinical study, Menchetti et al. (2020) measured the electrodiagnostic findings in 35 dogs and 14 cats with brachial plexus injuries. EMGs

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were performed from the *supraspinatus*, *infraspinatus*, *biceps* and *triceps brachii*, carpal extensor and flexor, and interosseus muscles. Their findings demonstrated spontaneous muscle activity, comprising positive sharp waves and fibrillation potentials in the affected limb of each animal. They also described that the radial and ulnar motor nerve conduction studies (MNCVs) were absent in 47% (radial) and 62% (ulnar) of the dogs and 57% (radial and ulnar) of the cats. This absence was significantly associated with the amputation of the affected limb in their study. This proves that conduction studies are an essential extension to the EMG examination.

Dokozeylul et al. (2013) used an EMG as a part of the neurological examination in a patient suffering from facial paralysis with hypothyroidism. The EMG of the main facial muscle groups was performed using a concentric needle electrode. They found a slightly abnormal spontaneous electrical activity, where fibrillation potentials and positive sharp waves were recorded. After the hypothyroidism treatment, the facial paralysis resolution and improvement of the patient's clinical findings were recorded. Re-examination of the EMG revealed some regenerative findings, poly-phasic potentials, and an increasing number of phases of the motor unit in the muscles of the head, indicating the patient's recovery (Dokozeylul et al. 2013).

Platt and Olby (2014) described that electromyography can be used as a diagnostic tool to confirm myotonia. Repetitive high-frequencies upon the needle insertion, which tend to wax and wane in amplitude and frequency can be seen in myotonic discharges. Nam et al. (2020) also used concentric needle electromyography on *biceps* and *triceps brachii*, *femoris* and *vastus lateralis* muscles, which presented random, spontaneous discharges of myotonic potentials with fluctuating amplitude and frequency, which were identical with the myotonic discharges.

Hajek et al. (2012) published a case study of two dogs and one cat with different neurological symptoms. Electromyographic examinations of the masseter muscles of the first dog confirmed preserved insertional activity. Furthermore, significant spontaneous activity was found in the form of positive sharp waves and fibrillation potentials. In the second dog, fast discharges of individual motor units with the formation of an interference pattern were recorded from the muscles of the pelvic limbs (*m. semitendinosus*, *m. semimembranosus*). In the cat, significant spontaneous activity, positive sharp waves (PSWs), was observed in the caudal muscles of the pelvic limbs, which was absent in the proximal muscles. These findings contributed to the diagnosis of the disease, together with the clinical findings, to confirm masseter myositis in the first dog and tetanus in the second dog. In the cat, based on the absence of the potential shape changes excluding the purely myogenic damage in combination with a lower measured conduction velocity in the *n. tibialis*, the authors pronounced a diagnosis of distal neuropathy of Bengal cats.

Electrodiagnostic findings in botulism affected dogs include normal motor nerve conduction velocity, decreased M-wave amplitude, increment of the M-wave with slow/rapid supramaximal repetitive nerve stimulation and increased, "jitter", with a single fibre EMG. On the other hand, tick paralysis causing an ascending flaccid paralysis occurs within a few days and may cause death through respiratory paralysis. However, no EMG evidence of denervation was observed and only the amplitude of the motor potentials were markedly reduced (Stanciu and Solcan 2016).

Electromyography of the thoracic limbs demonstrated the presence of "doublets" and simultaneous activity in both agonist and antagonist muscles in dog with tetanus. These abnormalities may be explained by defective glycinergic inhibition at the spinal cord level. Together with the history, clinical findings, and progression of signs, the EMG supported the presumptive diagnosis of focal canine tetanus in the study from De Risio et al. (2006).

Stanciu and Solcan (2016) used an EMG in their case report of acute idiopathic polyradiculoneuritis concurrent with acquired myasthenia gravis. They found mild to moderate insertional activity and spontaneous activity consisting primarily of fibrillation potentials, positive sharp waves and complex repetitive discharges in the *quadriceps femoris*, *tibialis cranialis*, *extensor carpi radialis* and plantar interosseous muscles in a dog with flaccid tetraparesis associated with weak reflexes supporting the diagnosis of acute idiopathic polyradiculoneuropathy (Stanciu and Solcan 2016). Electromyography revealed widespread abnormal spontaneous electrical activity consisting primarily of positive sharp waves and more occasional fibrillation potentials in most of the appendicular

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and paravertebral muscles in a cat with idiopathic polyradiculoneuropathy. The EMG of the head muscles was normal (Granger et al. 2008).

Twenty individual axial and appendicular muscles were examined in diabetic cats for the presence of insertional activity, fibrillation potentials, positive sharp waves, and complex repetitive discharges. The EMG evaluations revealed no abnormalities in many muscles, especially in diabetic cats with milder neurological dysfunction. Even in diabetic animals with severe neurological dysfunction, the changes were, at most, moderate in severity with a tendency towards a distal muscle distribution. However, again, many muscles demonstrated no abnormalities (Mizisin et al. 2002).

In addition, electromyography can be used to record activity from sets of muscles in awake, freely moving animals using implanted intramuscular electrodes. As a tool, EMG has a wide range of applications ranging from inferring neural processes to analysing movement. The amplitude of the rectified and filtered electromyogram can be used as an indirect measure of muscle activity. The EMG is a useful tool for kinesiologists to study muscle activation and for physiologists to infer neural processes. Although it would be preferable to directly record the contractile force and the length of the muscle when measuring the activity, this is usually not practical. The EMG provides a relatively simple, minimally invasive method for recording the activity of muscles. Information regarding the timing of the muscle activation that cannot be appreciated by visual inspection of the animal can be analysed using EMGs. As a technique, the EMG is best used in combination with other techniques, such as recording the ground reaction forces using force plates and video recordings of limb movement. This is because EMGs provide an indirect measure of the level of the muscle force. When recording an EMG, it must also be remembered that there is an appreciable electromechanical time lag between changes in the EMG signal and the contractile force in the muscle. For the soleus muscle in a walking cat, this lag can be as much as 70 ms (Whelan 2003).

Another area of the use of EMGs, in addition to the neurological and muscular diagnostics, is therapeutic exercise, which is an essential part of the rehabilitation of musculoskeletal and neurological diseases in veterinary medicine. Lauer et al. (2009) investigated the effect of a treadmill inclination on the electromyographic activity and pelvic limb kinematics in healthy dogs. Using EMG, they found a 5% inclined treadmill surface had no significant effect on the gluteal muscle and on the proximal and the distal part of the quadricep muscles during the stance and swing phases, when compared to walking on a flat surface. The EMG activity of *m. semitendinosus*, *m. semimembranosus* and *m. biceps femoris* was significantly higher during the first half of the stance phase when dogs walked on a 5% inclined treadmill, when compared to the EMG activity when dogs walked at a 5% declined treadmill. The authors also revealed that increasing or decreasing the inclination did not change the EMG activity in *m. gluteus* and *m. quadriceps.* Therefore, the authors rejected the hypothesis that the activity of the muscle groups – *m. gluteus* and *m. quadriceps* at the beginning of the posture phase should be increased at a 5% inclined surface.

McLean et al. (2019) evaluated the appearance of the muscle activity of *m. vastus lateralis* (VL), *m. biceps femoris* (BF) and *m. gluteus medius* (GM) during the posture, gait, trot, and during selected therapeutic exercises in clinically healthy dogs. A superficial EMG of the selected muscles was performed while standing, walking, trotting, raising the forelimb to the mat and with the pelvic limbs on an unstable mat, standing on a rocking plate, and backing up, getting up and walking over obstacles. The maximum and mean muscle amplitude (μV) reflecting the activity during several exercise cycles were compared between exercises. The mean *biceps femoris* amplitude was significantly higher in all the exercises ($P < 0.05$) compared to the posture. The mean *vastus lateralis* amplitude was significantly higher ($P < 0.05$) during walking, trotting, backing up, walking over an obstacle, and while trotting with an increased limb weight bearing when compared to the posture. The mean *gluteus* muscle amplitude was significantly higher ($P < 0.05$) during trotting, walking, getting on a raised mat, walking over an obstacle and backing up when compared to the posture. These results can help veterinarians choose specific exercises focused on specific muscles during conditioning, strengthening, and rehabilitation (McLean et al. 2019). Different results were found in dogs with hip osteoarthritis (OA). In all the investigated muscles, the mean activity was significantly decreased during the early swing phase in dogs with hip OA.

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The *vastus lateralis* and *gluteus medius* muscles of the clinically worse pelvic limb had a significantly higher activity than the contralateral pelvic limb during early stance (Bockstahler et al. 2012).

In addition, the EMG served as a useful research tool in athletic horses to assess the muscle activation patterns and the force of contraction during locomotion, to understand the role of the nervous and muscular systems in fatigue, and to describe the aetiology, diagnosis, and the treatment of myopathies of the limbs and back (Jones 1989).

Electrodiagnostic procedures are also an important part of the diagnostic regimen for characterising neural and neuromuscular disorders in exotic animal species. These techniques provide physiological information that is otherwise unavailable to the clinician (Sims 1996). Often EMG experiments in small animals, like small snakes, fish, birds, salamanders, and mammals are performed (Nuijens et al. 1997). The study from Quinlan et al. (2017) demonstrates that electromyograms obtained during locomotor activity in mice were effective for the identification of early physiological markers in amyotrophic lateral sclerosis (ALS). These measurements could be used to evaluate therapeutic intervention strategies in animal models of ALS. In particular, muscles that are predominately composed of the most vulnerable fast fatigable (FF) and fast fatigue resistant (FR) motor units may progressively carry less of the burden of force production, whereas an increased burden may be taken on by muscles that are predominantly composed of slow (S) fibres, and, thus, are more resistant. Such a compensatory shift in activity would not necessarily be observable from the gross locomotor kinematics, but requires EMG recordings.

Conclusion

Examination of the electrical activity of muscles is used in the diagnosis of muscular diseases, in nerve damage and in disorders of neuromuscular transmission. It helps to localise the lesion site within the nervous system and it has a special significance in biomechanics and also in rehabilitation. The work of muscles is controlled with the help of the nerves; the muscle and its nerves together form an inseparable team. Injury, excessive pressure, inflammation, toxic substances, or any congenital malformations can impair their proper function.

Electromyography reveals the presence, location and extent of such damage. Measuring the electrical activity of the examined muscles helps to reveal the cause of their weakness, paralysis, or the cause of involuntary muscle twitching. EMGs help to differentiate peripheral neurogenic and myogenic lesions as well as central paralysis, to demonstrate the impaired neuromuscular transmission in myasthenic syndromes, and to demonstrate myotonia and other diseases with spontaneous activity.

There are more and more data available suggesting that EMG studies are justified and could find increasing application in veterinary practice and especially in the field of veterinary neurology, so they should be given high attention and studies on some other diseases that are common, but poorly mapped, are suggested and needed.

Conflict of interest

The authors declare no conflict of interest.

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