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Review

Surface electromyography in animal biomechanics: A systematic review

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ABSTRACT

The study of muscle activity using surface electromyography (sEMG) is commonly used for investigations of the neuromuscular system in man. Although sEMG has faced methodological challenges, considerable technical advances have been made in the last few decades. Similarly, the field of animal biomechanics, including sEMG, has grown despite being confronted with often complex experimental conditions. In human sEMG research, standardised protocols have been developed, however these are lacking in animal sEMG. Before standards can be proposed in this population group, the existing research in animal sEMG should be collated and evaluated. Therefore the aim of this review is to systematically identify and summarise the literature in animal sEMG focussing on (1) species, breeds, activities and muscles investigated, and (2) electrode placement and normalisation methods used. The databases PubMed, Web of Science, Scopus, and Vetmed Resource were searched systematically for sEMG studies in animals and 38 articles were included in the final review. Data on methodological quality was collected and summarised. The findings from this systematic review indicate the divergence in animal sEMG methodology and as a result, future steps required to develop standardisation in animal sEMG are proposed.

Contents

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1. Introduction

In humans, the study of muscle activity using surface electromyography (sEMG) is widely used for investigations of the neuromuscular system. Not only is it applied in healthy populations to assess the role and interactions of muscles during functional tasks (Cuesta-Vargas and González-Sánchez, 2013; Iida et al., 2012; Lee et al., 2013) and sport and exercise (Kavcic et al., 2004; Martens et al., 2015; Park et al., 2014; Serner et al., 2014), it is also used in clinical groups to understand muscle (mal-) adaptations and dysfunctions in musculoskeletal injury, pain and pathology (Castelein et al., 2015; Falla et al., 2014; Gardinier et al., 2012; van der Hulst et al., 2010). sEMG has made considerable technical advances in the last few decades, however, divergence in sEMG methodology between many research groups led to limitations in direct comparisons between studies. In order to standardise sEMG, the SENIAM project (Surface Electromyography for the Non-Invasive Assessment of Muscles) was established which provides guidelines for sensor placement and signal processing (Hermens et al., 1999). Furthermore, the International Society of Electromyography and Kinesiology (ISEK) has produced standards for sEMG reporting.

Although an interest in animal biomechanics has existed for centuries (van Weeren, 2012), the use of sEMG in animal populations is considerably less often reported compared to the human literature. The nature of capturing sEMG data in animals poses many challenges for researchers in this field. These are not limited to, but include, how to prepare densely hairy, woolly or greasy skin for optimal electrode adhesion whilst achieving minimal electrode-skin impedance, and where to place the electrodes. Added to this are behavioural constraints, e.g. how can I encourage the animal to perform a movement accurately and consistently? As a result, certain techniques commonly used in human sEMG data collection such as obtaining an isometric maximal voluntary contraction (MVC) for the purpose of sEMG data normalisation, are impossible in animals. Despite these challenges, the number of studies on sEMG in animals is steadily growing, with the majority of work having been carried out in equines (Garcia et al., 2014; Kienapfel, 2015; St. George and Williams, 2013; Williams et al., 2014, 2013; Zsoldos et al., 2014). The advent of wireless sEMG in particular has been a positive step in opening the doors to research questions which would otherwise have been very difficult to obtain using a wired system in animal populations.

Although the body of knowledge in animal muscle function through the use of sEMG is growing, this area of research is plagued by the same lack of standardisation in sEMG methodology which human sEMG studies faced prior to the development of SENIAM and ISEK recommendations. Before standards in animal sEMG can be proposed however, an overview of past and present research practices in animal sEMG needs to be gained. To our knowledge, no attempts have been made to summarise the scientific literature in animal sEMG. An overview which compares the methodologies utilised in animal sEMG studies would allow aspects such as agreement or disparity in electrode placement and approaches to signal processing to be identified. It might also suggest how one major challenge, the normalisation of sEMG in animals, can be best managed.

Therefore, the aim of this review is to systematically identify and summarise the literature in animal sEMG focussing on two aspects: the first is to summarise the species, breeds, activities and muscles which have been investigated in animal sEMG studies, and the second is to identify methodological practices in animal sEMG studies based on electrode placement and normalisation approaches. Although it is not the purpose of this review to propose standardised protocols in animal sEMG, it will suggest where animal sEMG methodology is divergent and highlight the challenges that the field is facing. From there, ways in which steps can be taken to develop standardisation in animal sEMG are suggested, to bring it in line with what has been achieved in human sEMG thus far.

2. Methods

2.1. Search strategy

A systematic literature search of sEMG studies in animals was conducted by two assessors between 12/5/15 and 9/6/15. The databases PubMed, Web of Science, Scopus, and Vetmed Resource were included. The key terms used were:

(1) "surface electromyography" AND animal AND exercise
(2) "surface electromyography" AND animal AND locomotion
(3) "surface electromyography" AND animal AND gait
(4) "surface electromyography" AND animal AND "muscle activity"
(5) "surface electromyography" AND equine OR "surface electromyography" AND horse
(6) "surface electromyography" AND canine OR "surface electromyography" AND dog
(7) "surface electromyography" AND bovine OR "surface electromyography" AND cow
(8) "surface electromyography" AND ovine OR "surface electromyography" AND sheep
(9) "surface electromyography" AND feline OR "surface electromyography" AND cat
(10) "surface electromyography" AND caprine OR "surface electromyography" AND goat
(11) "surface electromyography" AND rodent OR "surface electromyography" AND rat OR "surface electromyography" AND mouse
(12) "surface electromyography" AND bird
(13) "surface electromyography" AND rabbit

Inclusion criteria were full publications in English from 1990 to the present of studies which included animals and surface electromyography. Publications were considered from all research disciplines (e.g. basic science, applied and clinical biomechanics, veterinary science), however only studies where muscle activity was measured during the performance of an active voluntary movement or task were included, to make the findings informative to animal biomechanics, performance and rehabilitation. This is similar to the most common applications of sEMG in humans. Observational cross sectional studies, intervention studies, and case studies were considered. Abstracts from conference proceedings, studies which evoked a muscular contraction by stimulation in either an alert or anaesthetised animal, studies in humans, primates or aquatic animals, studies which only reported sEMG at rest, and studies where either intramuscular EMG or supramuscu-