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Systematic review of ground reaction force measurements in cats

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ABSTRACT

Although orthopaedic abnormalities in cats are frequently observed radiographically, they remain clinically underdiagnosed, and kinetic motion analysis, a fundamental aspect of orthopaedic research in dogs and horses, is not commonly performed. More information obtained with non-invasive measurement techniques to assess normal and abnormal gait in cats would provide a greater insight into their locomotion and biomechanics and improve the objective measurement of disease alterations and treatment modalities. In this systematic review, 12 previously performed studies that investigated ground reaction force measurements in cats during locomotion were evaluated. The aims of these studies, the measurement methods and equipment used, and the outcomes of parameters used to assess both sound and diseased cats are summarised and discussed.

All reviewed studies used pressure sensitive walkways to gain data and all provided an acclimatisation period as a prerequisite for measurements. In sound cats during walking, the forelimb peak vertical force was greater than in the hindlimb and the peak vertical force in the hindlimb was greater in cats than in dogs. This review confirms that ground reaction forces can be used to evaluate lameness and treatment effects in the cat.

Introduction

Biomechanical motion analysis in dogs and horses has been a fundamental aspect of veterinary orthopaedic research for decades. Various motion analysis techniques have been used to describe normal and disturbed locomotion and to investigate the impact of treatment modalities. Commonly used motion analysis techniques include the measurement of ground reaction forces (GRFs), joint and spine kinematics, and electromyography (EMG).

The technique most frequently used to describe normal and disturbed locomotion is kinetic gait analysis, which provides information on the forces produced during the gait cycle. Various systems have been used to measure these forces; for example, single or multiple force plates have been placed in walkways (Nordquist et al., 2011; Voss et al., 2011) or on treadmills (Bockstahler et al., 2009; Fischer et al., 2013). These force plates are available in many different designs and exhibit various functions depending on the variable investigated. Studies have used force plates in the assessment of both normal and abnormal gait in dogs (Gillette and Angle, 2008). Pressure-sensitive walkways (PSW) with high numbers of pressure sensors have also been used. After coming into contact with the paw, these sensors quantify the high- and low-pressure areas, vertical forces, and temporal characteristics of the stance phase (Lascelles et al., 2006; Souza et al., 2013).

The parameters evaluated in kinetic gait analysis include orthogonal GRFs resulting from contact between the paw and the ground during locomotion, such as the mediolateral force, craniocaudal force, and vertical forces e.g. peak vertical force (PFz) and vertical impulse (IFz). Additional parameters evaluated include the rate of loading, temporal gait characteristics, and paw pressure distributions (Gillette and Angle, 2008). Among all of these parameters, the PFz and IFz are the most commonly evaluated (McLaughlin, 2001).

Kinetic gait analysis has been widely used in dogs and horses and is well established in these species. However, very little information on feline kinetics and kinematic biomechanics is available in the published literature, which is surprising considering that cats have been used for many years as experimental models for investigations of the neural control of locomotion (Abraham and Loeb, 1985; Abraham et al., 1985; Pratt and Loeb, 1991; Loeb, 1993) and the regenerative potential of the spinal cord in humans (Barbeau and Rossignol, 1987; Bouyer and Rossignol, 2003). Moreover, although orthopaedic disorders in cats are frequently observed on radiographs, they are often clinically underdiagnosed (Lascelles, 2010; Grierson, 2012).

More information on normal and abnormal gait obtained using non-invasive measurement techniques would provide greater insight into feline biomechanics and enhance our understanding of feline

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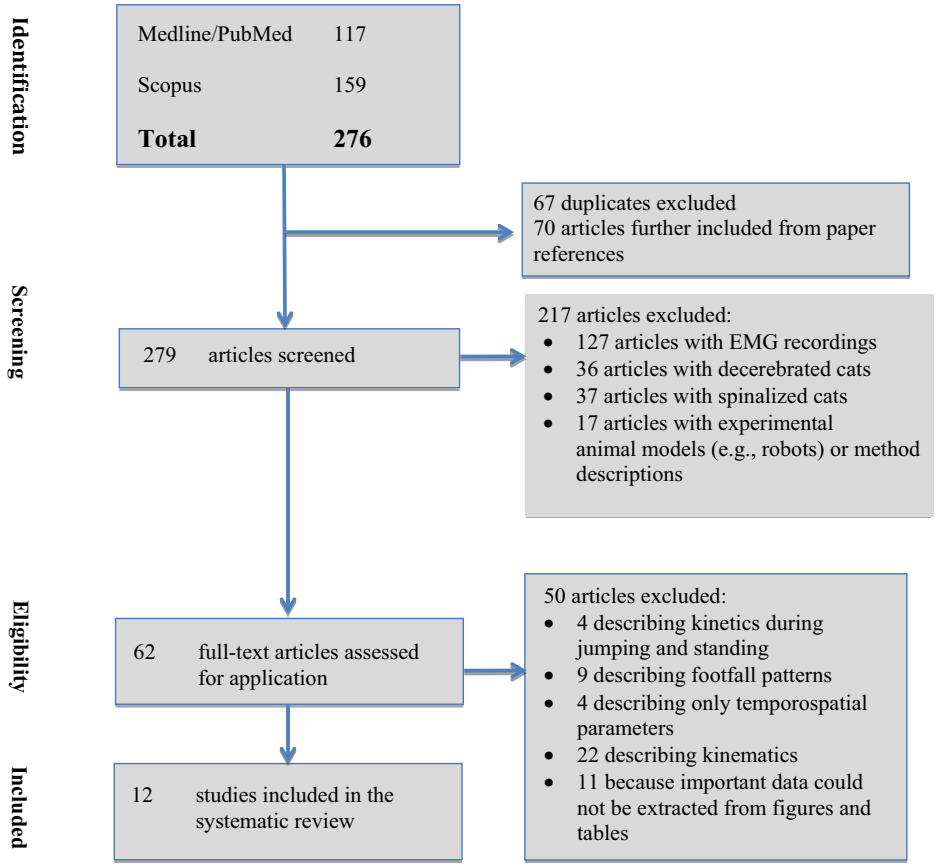

Fig. 1. Study flow chart. The numbers of identified articles and the exclusion process for this systematic review are described.

locomotion. Non-invasive measurement of GRFs would be particularly useful in predicting, describing and assessing gait disorders in cats with orthopaedic disease. It would also facilitate the objective evaluation of treatment outcomes, thereby helping to improve therapeutic modalities.

In this systematic review, we evaluated previously performed studies involving GRF measurements in cats during locomotion. The aims of these studies, the measurement methods and equipment used in each, and the outcome measures used to assess both sound and diseased cats are summarised and discussed.

Materials and methods

The published standard for reporting systematic reviews (Moher et al, 2009) was used in this analysis and data were collected by screening the PubMed/Medline and Scopus databases.

A PubMed/Medline search was undertaken on 2 September 2014. The combination search term 'gait OR locomotion' yielded 181,015 articles. The combination of those search terms with 'cat AND feline' yielded 805 articles. Further addition of 'walkway OR treadmill OR pressure platform OR ground reaction forces OR kinetic OR kinematic NOT spinal NOT cortical NOT denervation' narrowed the list down to 117 articles. In the Scopus search, the terms 'cat OR feline AND gait OR locomotion' yielded 2315 articles, and combination with 'kinetic OR kinematic OR ground reaction forces OR pressure plates OR treadmill OR walkway' produced 447 articles. The exclusion of several terms using 'NOT spinal OR cortical OR denervation OR decerebrated' narrowed the list down to 159 articles.

An additional 70 potentially relevant articles were identified from the reference lists of the previously mentioned papers. Upon completion of this initial search, a library was created using EndNote X7 software (Thomson Reuters), and all duplicate studies were excluded. The titles and abstracts of all papers were screened, and all articles that did not record kinetic data, only investigated EMG data (without investigating GRF), or involved cats that had been spinalised or decerebrated were excluded. After reading the full texts of all selected articles, we assessed the 12 studies included in the systematic review regardless of the number of cats recorded in each study. The numbers of identified articles and the exclusion process are described in Fig. 1.

Results

Study aims

Table 1 provides an overview of the aims of all studies included in this systematic review. Four studies involved basic kinetic research in sound cats during locomotion (Lascelles et al., 2007; LeQuang et al., 2010; Verdugo et al., 2013; Corbee et al., 2014), three addressed osteoarthritis (OA) (Guillot et al., 2012, 2013; Moreau et al., 2013), and three evaluated cats that had undergone onychectomy (Romans et al., 2004, 2005; Robinson et al., 2007). Apart from the study by Moreau et al. (2013), five studies dealing with diseased cats compared them to a sound control group. Of the two remaining studies, one was a comparative study (Demes et al., 1994) and one primarily involved EMG, but included an investigation of GRFs (Fowler et al., 1993).

Of all the studies reviewed, 10 measured GRFs while the cats walked, trotted, or galloped. Fowler et al. (1993) evaluated cats while standing, when level walking, and when slope walking, while Lascelles et al. (2007) evaluated cats under both walking and jumping conditions (Table 2). In addition to these studies, which focused mainly on the evaluation of feline GRFs, we identified two studies in which the GRF data of sound cats were also investigated, but not as the main research topic. The goal of one of these two studies was the elucidation of internal force production in selected skeletal muscles (Fowler et al., 1993). The other study compared GRF data between primates and cats (Demes et al., 1994). Both studies were