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Review

The horse–saddle–rider interaction

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ABSTRACT

Common causes of poor performance in horses include factors related to the horse, the rider and/or the saddle, and their interrelationships remain challenging to determine. Horse-related factors (such as thoracolumbar region pain and/or lameness), rider-related factors (such as crookedness, inability to ride in rhythm with the horse, inability to work the horse in a correct frame to improve core strength and muscular support of the thoracolumbar spine of the horse), and saddle-related factors (such as poor fit causing focal areas of increased pressure) may all contribute to poor performance to varying degrees.

Knowledge of the horse–saddle–rider interaction is limited. Traditionally, saddle fit has been evaluated in standing horses, but it is now possible to measure the force and pressure at the interface between the saddle and the horse dynamically. The purpose of this review is critically to discuss available evidence of the interaction between the horse, the rider and the saddle, highlighting not only what is known, but also what is not known.

Introduction

Back pain and dysfunction are common causes of poor performance in horses (Zimmerman et al., 2011a,b). One recent large-scale study of British dressage horses demonstrated that 25% had a history of back-related problems (Murray et al., 2010). Reasons may include primary thoracolumbar osseous pathology (Gillen et al., 2009; Girodroux et al., 2009; Meehan et al., 2009; Zimmerman et al., 2011a,b), or back muscle soreness developed secondarily to lameness, incorrect training, a poorly skilled rider, a saddle not fitting the horse and/or a saddle not fitting the rider. However, there is a lack of scientific data relating directly to riders. Both experimentally-induced forelimb or hindlimb lameness (Gómez Alvarez et al., 2007, 2008) and back pain/stiffness have been shown to alter the biomechanics of the spine and shift the centre of gravity (Wennerstrand et al., 2004, 2009). This may predispose to rider back pain or stiffness (Lagarde et al., 2005; Symes and Ellis, 2009) and abnormal saddle movement, such as saddle slip consistently to one side (Greve and Dyson, 2012). Saddle slip may induce focal areas of increased pressure beneath the saddle (deCocq et al., 2006).

Rider pain or stiffness may induce rider crookedness and can diminish the ability of the rider to follow the movement of the horse (Lagarde et al., 2005; Symes and Ellis, 2009). In turn, this may cause exacerbation of equine thoracolumbar region pain and/or lameness. Such a vicious circle may occur in many horses, making it clinically challenging to determine whether altered biomechanical function of the spine is caused by primary thoracolumbar region pain (Wennerstrand et al., 2004, 2009), sacroiliac joint region pain (Dyson and Murray, 2003; Dyson, 2008) or primary lameness (Landman et al., 2004; Gómez Alvarez et al., 2007, 2008), because the conditions often co-exist (Zimmerman et al., 2011b). However, to date, there is little quantitative biomechanical evidence linking lameness and function of the thoracolumbar region.

The purpose of this review is to discuss critically available evidence of the interaction between the horse, the rider and the saddle, highlighting not only what we do know, but also what we do not know.

Measurement technology

A variety of pressure mats which can be placed underneath or on top of saddles to measure applied force have been used historically, including the Saddle Tech (Harman, 1997) and FSA (Jeffcott et al., 1999; deCocq et al., 2006). There are two commercially available pressure mats in current scientific use, CONFORMat (Tekscan) and Pliance (NOVEL) but there have been no objective comparisons between the two mats. Nonetheless, bench testing to determine accuracy, hysteresis, repeatability, stability, creep, rate of loading, response and mat artefacts, environmental effects, calibration stability and contoured loading performance is important to ensure validity of data from any pressure mat (Nicholson et al., 2001).

Ideally, standardised testing should insure that the total force measured is within ±10% of a known applied force (Ferguson-Pell

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et al., 2001). The CONFORMat contains more sensing elements per unit area (0.5 sensels/cm^2) than the Pliance system (0.1 sensels/cm^2) and has a significantly higher sampling rate. The CONFORMat has resistive sensing elements, whereas the Pliance has capacitive sensing elements. There are advantages and disadvantages of the two types of sensing elements, which are discussed in-depth elsewhere (Ashruf, 2002). The CONFORMat is usually used with one sensor overlying the spinous processes; the pressure applied to the spinous processes can therefore be measured. However, stretching of the mat over the back may lead to erroneous readings. Tekscan also produce a mat with two sensors on each side of the back similar to the Pliance. Whichever mat is used, for consistent results of measurement of the forces applied to a horse's back, the mat should be left in place on the horse's back throughout measurements, the position of the mat should be marked on the horse's hair coat, the rider should mount from a high mounting block or via a 'leg-up', the girth should be tightened, one hole at a time, by alternating the right and left sides and daily calibration is essential (deCocq et al., 2006, 2009a; Belock et al., 2012).

The pressure data acquired is surrounded by a lot of 'noise', with considerable variations in the pressure patterns and, unless specific scientific questions are asked, there is a risk of subjective over-interpretation of the data (Holmes and Jeffcott, 2010). Each sensing element measures the peak pressure within the sensor, so they have a tendency to overestimate the force. The mat shapes to the contour of the body and registers the force-component applied perpendicular to its surface. The forces measured that act vertically on a sloping border is an underestimation of the true vertical force. In areas where the back contour comes close to vertical, such as the wither area, the underestimation is considerable. Thus, data collected will be influenced by the shape of the horse's back and the incident angle of the transmitted forces: the total measured force recorded for a rider on a horse with a narrow, sloping back may be less than that for a horse with a broad, flat back. The pressure data cannot distinguish between the effect of the rider, the saddle and the movements of the horse (Bystrom et al., 2009, 2010a,b). The resulting multidimensional data and analysis requires consideration of force magnitude, its spatial distribution and temporal changes (Belock et al., 2012). In some studies focal areas of pressure have been assessed using either the mean pressure value over the entire measurement period or the maximum pressure value; mean values were more repeatable (deCocq et al., 2006: von Peinen et al., 2010). The area over which the measurements were acquired has varied among studies, which may account for variability in results (Meschan et al., 2007; von Peinen et al., 2010).

Currently, data have mainly been presented by normalising a number of strides into one stride, usually compiling total force divided into six areas (left, right; cranial, middle and caudal) (Bystrom et al., 2009, 2010a,b), but although there are many possible variables it is not known which method gives the most valid and useful information. Nonetheless, these mats do provide an objective way of measuring either the force applied to a horse's back via the saddle or the force applied to a saddle by a rider. They also provide an objective way of assessing the stability of the rider's position in the saddle by calculating the excursion of the centre of pressure (Peham et al., 2010). There are descriptions of correlating pressure mat data with the phase in the stride cycle (Bystrom et al., 2010b, 2011). There is the potential to extract more data, such as quantifying peak pressures in space, time and magnitude; specialised analysis tools may be required to maximise the usefulness of the acquired data.

Traditionally, the gold standard method for collecting equine back kinematic data (Faber et al., 2001, 2002), limb movement data (Keegan, 2007), and rider movement data (Bystrom et al., 2009, 2010a) has been by the use of optical motion cameras. These measurements are best accomplished by using force-measuring treadmills and therefore the technology is principally restricted to gait laboratories (Buchner et al., 1994). Optical motion systems can also be used overground, but there are two major drawbacks of these systems for the study of horse–rider interaction. Firstly, the field of view is limited. This can be solved by using more cameras, but this is expensive. Secondly, it is not possible to study movement of parts of the body that are blocked from view and an important part of the back of the horse cannot be viewed directly because of the saddle. It is, however, possible to measure the movements in front and behind the saddle and to predict the movements beneath the saddle.

Several groups around the world are working on the development of body sensor-based objective movement examination systems, with wireless transmission of data. Inertial measurement units (IMUs) have recently been validated as a reliable and repeatable method to collect objective equine movement data (Keegan, 2007; Keegan et al., 2004, 2011; Pfau et al., 2005; Warner et al., 2010; Halling-Thomsen et al., 2010). Poll and croup mounted sensors have been used to objectively quantify forelimb and hindlimb lameness (Keegan et al., 2004). However, the IMUs can be mounted on any subject and therefore not only have potential for assessment of horse and rider movement outside gait laboratories, but also for the investigation of the biomechanical relationship between equine back movement and limb movement and the changes that occur with injury. By combining the use of back pressure measurements and IMUs mounted on the saddle, the rider and the horse, the measurement technology might provide the answers which will help increase our understanding of how back movement varies in normal or diseased horses and identify the key differences.

The saddle

Saddle design

The saddle must fit both the horse, whose shape is continually changing at different gaits, and the rider, enabling them to remain in balance at a variety of paces (Dyson, 2012). Coupling these two complex dynamic forms through the medium of a saddle is extremely challenging and the study of this is complex. Traditionally saddle designs were made by rote, lore, feel and experience. It is only relatively recently that technologies have become available that permit detailed study of this complex dynamic system.

Saddle designers traditionally started from a rigid frame (the tree) which, when well-fitted, can spread load, but cannot adapt to the changing shape of the horse's back as it moves. A variety of methods have been used to mitigate this problem (flocking, padding, air bags, flexible trees and others). More recently some saddle designers have introduced designs with no tree or vestiges of the tree (pommel arch or head plate, for example), which allow flexibility to adapt to the changing shape of the horse's back, but might be expected to spread load less well. Efforts to mitigate this problem include partial trees and stiffer flexible materials. Additional pads and numnahs are often used in an attempt to improve saddle function, but although the manufacturers make sweeping claims about reduced concussion and altered force distribution, these have not been validated by scientific studies and in some instances additional pads may actually be detrimental by increasing focal pressure (Kotschwar et al., 2010a,b).

So-called treeless saddles are flexible and are suggested to fit a wider range of back shapes than a conventional treed saddle, by providing an adaptable interface between the horse and the rider (Belock et al., 2012). However there are a number of different designs, several of which are not free of rigid parts, and are therefore not truly treeless saddles. Two studies concluded that the tested