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Original Research

Application of a Dual Force Sensor System to Characterize the Intrinsic Operation of Horse Bridles and Bits

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ABSTRACT

An equine bridle tension system, with electronic force gauges in both the line of the reins and that of the cheekpiece (CP) on one side of the horse, is used to study the dynamic response of the CP tension to rein tension in the ridden horse. The objective is to quantify so-called "poll pressure." Bits designed to give strong poll pressure using simple pulley or lever principles show a much attenuated transfer of the rein tension through the bit to the poll. The attenuation is readily understood when the equine mouth is recognized as a "floating" fulcrum degrading the otherwise required fixed pivot point of an ideal lever. Furthermore, any use of a curb chain diverts higher rein-induced CP tension to the chin rather than to the poll. Unexpectedly, however, a simple loose ring bit is found to give modest poll pressure, transferring rein tension through a pulley-like action. Finally, the curb bit of a double bridle is examined, and physical interference between the curb and bridoon mouthpieces is found. Standard, yet powerful computational signal processing of the dynamic time series tension data reveals that the poll pressure produced by the curb bit is predominantly due to tension in the bridoon reins and not the curb reins. Physical overlaying of the bridoon on the curb mouthpiece is implicated.

1. Introduction

It is generally thought that some horse bits can operate as levers of rein tension and thus amplify the forces transferred to the head (poll) or chin of the horse [1,2]. Popular discussions focus on poll pressure and how it might affect the training and behavior of the horse. Some even consider it a topic of horse welfare.

The great interest in this subject has not, however, been served satisfactorily by experimental verification of the ideas. It is normally accepted that any lever action operates as predicted, but in one exception, Swales [3] noted that the horse's mouth provides a "floating" fulcrum rather than the ideal fixed fulcrum. This recognizes that the mouth is not the ideal fixed point of restraint that the ideal lever requires. As such, significant changes to current thinking must be made, and these are readily substantiated through the present work.

Swales' notion of a floating fulcrum explains the observations presented here which show a significantly suppressed pressure on the poll than that predicted by the lever action otherwise expected from bits.

The method of study uses one force gauge in the cheekpiece (CP) of the bridle as well as one in the reins of the bridle on the same side of the horse. The dynamic driven response of the CP tension to the dynamic driving tension in the reins is studied. The characteristic operation of the cheek of the bit in transferring rein tension via the CP to the poll is therefore measured. This is distinctive to all previous related work where pairs of gauges are simply inserted in the left and right reins [4–6] and where the objective has been to identify rider effectiveness or horse "laterality."

This subtle yet important experimental distinction has also enabled us to identify a physical interference between

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the bridoon and curb bits when using a conventional double bridle. The dual gauge system reveals that the action on the poll measured by the system is due not to the lever-like curb bit but to the action of the bridoon mouthpiece which pushes down on the curb mouthpiece that lies trapped beneath it. This important finding clearly has significant consequences not only for effectiveness in training but also for considerations of horse welfare. The height available between the upper and lower mandibles in the average horse or pony is currently known to be around 34 mm ([7], 47 equine cadavers studied). The tongue completely fills the oral cavity and with bit mouthpiece thicknesses often around 14–16 mm or greater the potential stacking of two mouthpieces in a mouth, perhaps constrained to be closed by additional bridlework, ought to raise urgent questions.

2. Methods

SMA mini S-beam force gauges (Interface, Scottsdale, Arizona) [8] calibrated to 60 N capacity (with 150% overload capability) were inserted into the line of the CP and reins (Fig. 1) on one side of the horse. These force gauges are resistive wire strip strain gauges whose changes in potential difference, produced with strain, are transferred to transmitters which send the data by the Bluetooth protocol to a receiver connected to a USB port of a personal computer or laptop. Data transfer rates are up to 200 samples per second (5-ms intervals), and the typical range of reliable line-of-sight data transfer is well in excess of 40 meters. The transmitters are held inside modified camera cases attached to a breastplate on the horse. The rider is therefore not carrying any of the electrical equipment. Before the data are collected and after the CP is pretensioned, the force gauges are tared to zero. This therefore makes it possible in some cases to see negative net values for CP tension when rein tension is applied to the cheek. Typical pretensioning of the CP is in the order of a few hundred grams. The rider takes a normal contact on both reins and performs ridden exercises in the three lower gaits, and the natural resistive counter-contact from the body of the horse provides pairs of force data from the rein and CP. Because the CP is directly attached to the headpiece, we can assume that forces seen in the CP are those that are applied to the poll of the horse.

Fig. 1. S-beam mini force gauges (inset) included in the line of the reins and that of the leather strap cheekpiece (CP), here installed on the offside of the horse. The wireless transmitters are contained in adapted camera cases attached to the breastplate. The bit cheek shown is of the type B depicted in Fig. 2, and the mouthpiece is of a double jointed design.

For a lever design, the rein tension must act some distance, r, below the level of a fulcrum, assumed to be in the corners of the horse's mouth. The load (compression acting at the poll or the chin) must be connected to an attachment made some distance, r', above the fulcrum. The amplification factor (for the transfer of rein tension through to the poll) is then readily calculated to be

$$MA = r/r' \qquad (1)$$

with MA the engineer's "mechanical advantage." When r is greater than r', amplification is possible.

The bits chosen for the study (Fig. 2) included two where lever action might be expected and one where it is not.

Bit cheek A is a simple 70-mm loose ring. Bit cheek B is a loose ring design with the option of attaching the reins to a ring below the level of the mouthpiece. If the CP is attached at the upper ring as is usual, this bit can in principle act as a simple lever with the mouth acting as the fulcrum. The approximate distances between the two points of bridlework attachment and the expected position of the fulcrum (half way up the bit cheek) are equal, giving a theoretical mechanical advantage (MA) of 1 as a design parameter. Bit cheek C is a typical lever action curb cheek. The reins are attached to the lower ring and CP attached to the upper ring. The ratio of distances between the points of attachment of the bridlework and the level of the solid bar mouthpiece (the fulcrum point) provides MA = 1.5.

Various horses and riders each of differing levels of training and ability undertook the tests, but unlike previous studies specifically designed to correlate dynamic force data with ridden quality or horse behavior [9], this simpler study of the correlation between dynamic tension in the CP with that in the reins does not require any of this information. The intrinsic operation of the bits could in principle be discovered on the laboratory bench. But in practice of course, the equine mouth is expected to provide the fulcrum. Within the real experimental system comprising the rider's hands, the horse's mouth, and the bit, the elasticity of the equine mouth provides a "floating" fulcrum and a potential source of time-lag and decoherence between the dynamic rein and CP tensions.

2.1. *Data Capture and Analysis*

The data are to be presented in a number of formats as follows: