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Original Research

Effect of Different Head-and-Neck Positions on Nuchal Ligament Dimensions in Fetal Foals

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ABSTRACT

Controversy surrounds certain head-and-neck positions (HNPs) in sport horses and their potential impact on the nuchal ligament (NL). This study measured the effects of six different HNPs on NL dimensions in five fetal cadavers, specifically funicular length, lamellar width at C4, and the lengths of the five individual lamellar bands. Normalized mean percentage changes in NL dimensions in HNP-2 to HNP-6 were compared with the NL dimensions in HNP-1. The lengths of the funicular and lamellar bands (C2–C6) decreased when the head and neck were raised (HNP-2, HNP-3, and HNP-5), in proportion to the degree of elevation, and increased when the head and neck were lowered (HNP-4 and HNP-6). Not all cervical segments were affected in the same way nor to the same degree. Lamellar width significantly decreased an average of 46% with HNP-4 (rollkur) and 29% with HNP-6 (long and low). Exaggerated poll flexion, as in HNP-3 and HNP-4, showed uneven stretching suggesting that the NL was not working as an integrated unit in these postures. Overall, the results suggest that certain HNPs impose limitations on the cycling of strain energy from head and neck movements during locomotion. Some positions may be associated with an increased chance of damage to either the NL or associated muscles.

1. Introduction

Some of the head-and-neck positions (HNPs) required of sport horses during training and competition differ from those usually observed in horses during unrestricted movement. Unrestrained horses may briefly place their heads and necks in unusual and even extreme positions. However, imposing the more extreme HNPs on performance horses, such as the extreme hyperflexion of “rollkur” used as a training aid by some dressage riders, may alter tension in the nuchal ligament (NL) in a way that negatively affects its function. This extreme posture has also been documented to have negative physical and psychological effects on the horse [1].

Correct HNP in the riding horse has been discussed in the equestrian literature for centuries [2–4]. According to the current rules of dressage dictated by the Fédération Equestre Internationale, in all work, even at the halt, the horse must be “on the bit,” a posture in which the neck is raised and arched, the poll is the highest point of the neck, and the head (specifically, the bridge of the nose) is slightly in front of the vertical [5]. Even so, what constitutes “correct” or beneficial posture during training continues to be a source of controversy, as there is little published data concerning the potential effects of different HNPs on locomotory or support structures, including the NL.

The NL consists of two distinct yet interconnected elements. The cord-like funicular part spans the occiput and the dorsal spinous processes of the second through fourth thoracic vertebrae (T2–T4) like a bowstring; caudal to the wither it continues down the thoracolumbar (TL) spine as the supraspinous ligament. The sheet-like lamellar part of the NL consists of a series of short bands that run cranioventrally from T2–T4 to the dorsal spinous processes of the

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sixth to the second cervical vertebrae (C6–C2), the funicular and lamellar parts are united to C3 [6,7].

The NL is thought to play an important role in locomotion by cycling strain energy during head and neck movement, and thereby doing much of the mechanical work at the cervicothoracic junction [7,8]. It has been estimated that the NL in the horse contributes a little over half of the oscillatory work at the walk and approximately one-third of the work at the trot and canter, reducing the metabolic cost of locomotion accordingly [8].

However, those studies involved either cadavers or live horses moving with their heads and necks unrestricted. They did not investigate potential changes in NL dimensions, and thus the tensions, with the different HNPs commonly employed by riders and trainers or by horses evading bit pressure. Six common and reproducible HNPs have been described and studied in relation to the biomechanics of the TL spine and to locomotory forces and patterns in the moving horse [9–11]. As yet, the effects of these different HNPs on NL dimensions have not been investigated in detail.

The purpose of our study was to bridge that gap by documenting the effects of these six different HNPs on NL dimensions, specifically funicular length, lamellar width, and the lengths of the individual lamellar bands. We used equine cadavers to precisely measure each of these elements in the different HNPs. Because of the practical challenges of working with adult equine cadavers, we used late-term fetal foals, based on a study which showed that the NL in late-term fetal calves has the same fundamental structure–mechanical relationships as it does in adults [12]. As a precocial species, equine foals are born sufficiently advanced in their development that all the different normal postures and patterns of movement may be demonstrated within a half hour of birth. As the body grows after birth, these postures and movements are retained, and hence, the connections of the NL would remain similar even if their size and significance may vary according to many different environmental factors. This study uses the near-term equine fetus as a model of the complex attachments and relationships of the NL in equine anatomy to investigate potential postural effects on its dimensions. Our hypothesis was that changes in HNP from the unrestricted position observed in the freely moving horse would result in measurable changes in NL dimensions that would have clear implications for equine locomotion.

2. Materials and Methods

2.1. Subjects

Five late-term fetal foals were collected from pregnant mares that were euthanized for reasons unrelated to this study. The recently expired foals in their amniotic sacs were stored at −20°C until study. In preparation for dissection, each frozen cadaver was thawed at 4°C for 4–7 days, depending on its size. Once the foal was thawed, the skin and musculature overlying the NL were dissected away on one side of the neck to expose the NL for its entire funicular length and lamellar width (Fig. 1). Between sets of measurements, foals were wrapped in remaining skin and covered with moistened cotton sheets and plastic bags before being stored at 4°C. When significant drying out of the tissues occurred, measurements on that foal were discontinued.

Fig. 1. Head and neck of a cadaveric equine fetus, positioned in lateral recumbency. The overlying tissues were removed to expose the nuchal ligament. (In this specimen, the lamellar portion has been partially dissected for reasons unrelated to this study.) Head and neck angles were measured as shown, using a protractor and goniometer at the throatlatch and wither, respectively.

2.2. Head-and-Neck Positions

In each foal, measurements of NL length and width were made, as detailed in the following, with the head and neck serially positioned to mimic each of the six HNPs previously described [9–11] and illustrated in Fig. 2. The first position, HNP-1, is taken to be the horse's natural posture when the head and neck are unrestrained. The head angle, defined here as the angle between vertical and the long axis of the mandible, is approximately 60°. The neck angle, defined as the angle between horizontal and the dorsum of the neck as it extends cranially from the wither, is approximately 159°. For this study, HNP-1 was the neutral or control position against which the other five HNPs were compared.

In HNP-2, the head and neck are moderately elevated, and the poll is moderately flexed such that the bridge of the nose remains slightly in front of the vertical. The resulting head angle is approximately 50° and the neck angle 136°. In HNP-3, the head and neck are likewise moderately elevated, but the poll is markedly flexed such that the bridge of the nose is well behind the vertical. Because of the amount of poll flexion in this position, the head angle is measured as the angle between vertical and the bridge of the nose. In HNP-3, the head angle is approximately −20° and the neck angle 136°.

In HNP-4, the head and neck are lowered, but the poll is in hyperflexion; as a result, the bridge of the nose is profoundly behind the vertical. As with HNP-3, the head angle in this position is measured by gauging the angle between vertical and the bridge of the nose. In HNP-4, the head angle is approximately −50° and the neck angle 170°. This position represents the hyperflexion of rollkur.

In HNP-5, the head and neck are markedly elevated (a position of "absolute elevation"), and the poll is moderately extended, so the bridge of the nose is well forward of the vertical. The resulting head angle is approximately 70° and the neck angle 120°. In HNP-6, the head and neck are