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Original Research

Influence of Increased Intraarticular Pressure on the Angular Displacement of the Isolated Equine Distal Interphalangeal Joint

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A R T I C L E I N F O

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A B S T R A C T

The equine distal interphalangeal joint (DIPJ) is commonly affected by palpable joint distension and degenerative joint disease, with microinstability considered a contributory factor. The aim of this kinematic study was to investigate DIPJ angles during axial compression loading (ACL) in a material testing machine with and without increased intraarticular pressure (IAP) due to joint distension. Our hypothesis was that increased IAP would lead to an increased speed of angular displacement of the DIPJ during ACL and that this would become more apparent with the hoof placed on an uneven surface. Bone markers were placed on the second and third phalanx of six left and right isolated forelimbs from adult Warmblood horses. Limbs were placed in a material testing machine, and synchronous measurements of the kinematics and the pressures within the DIPJ during loading were obtained. With the hoof in neutral position, as well as with 3° lateral and 3° medial elevation, the proximal articular surface of the second phalanx was preloaded with 100 Newton (N), and angles and IAPs were measured during loading to 6,000 N at 600 N/s, with and without joint distension. Joint distension in combination with lateral/medial hoof elevation increased flexion, lateromotion/mediomotion, and axial rotation. The finding that moderate joint distension increases the effect of a relatively mild mediolateral foot imbalance on speed of joint movement during loading has the potential for clinical relevance in the development of osteoarthritis.

1. Introduction

Intraarticular pressure (IAP) is primarily dependent on the volume of synovial fluid; in a healthy, unloaded joint, IAP is below atmospheric pressure levels. An increase in synovial fluid volume is the consequence of more permeable subsynovial capillaries, with the watery plasma ultrafiltrate component of the synovial fluid and thus the total volume increased; subsequently, this stretches the joint capsule [1]. Over time, because of the elasticity of the joint capsule, relatively large volumes of synovial fluid can be tolerated. Joint capsule laxity is detrimental for joint health, as it is a major component of joint stability; and even microinstability may lead to supraphysiological cartilage loading and gradual degeneration; this was shown, for example, for the human ankle [2]. Therefore, two major symptoms of degenerative joint disease, that is, joint distension and cartilage degeneration may well be causative for each other, thus accelerating the development of osteoarthritis (OA).

The association of increased IAP with joint injury has been documented in the equine metacarpophalangeal joint (MCPJ) in live horses [3]. Synovial effusion of the equine distal interphalangeal joint (DIPJ) is also commonly seen

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with OA [4], septic arthritis [5], or following trauma and collateral desmopathy [6]. However, in the equine DIPJ, an inflammatory reaction of the synovial membrane may be also present without any clinical signs of pain [4]. The equine DIPJ of the forelimb is one of the joints most commonly affected by degenerative joint disease in sport horses [7], and the forces acting on the equine DIPJ are directly related to hoof placement and limb orientation, both of which is markedly influenced by trimming and shoeing. This has been documented in a study by Denoix [8], where asymmetrical elevation of the lateral and/or medial quarter of the hoof with axial compression (2,000 N–10,000 N) led to rotation of the second phalanx over the third phalanx toward the elevated side in isolated equine forelimbs.

After the landing of the hoof, the equine DIPJ initially undergoes mainly flexion (F) peaking in the first half of the stance phase; this is followed by extension (E) as the body mass moves forward over the standing limb. During locomotion in a straight line, additional motions outside the sagittal plane such as lateromotion/mediomotion (LM) and axial rotation (AR) occur at the beginning and end of the stance phase due to changes in the mediolateral orientation of the hoof [9]; greater alterations in LM and AR are thought to be induced mainly by asymmetric weight bearing, either by uneven ground or by poor mediolateral balance of the hoof [8,10].

In vivo, IAP values up to 20 mm Hg have been measured in clinically healthy equine DIPJ in a weight bearing position [11,12], whereas values of ≥40 mm Hg are considered to be pathologic [11,13]. During axial loading compression with 1,000 N and 2,000 N, the effect of raising both heels by 5° increased the IAP of the equine DIPJ in isolated limbs to supraatmospheric IAPs, whereas subatmospheric IAPs were documented with the hoof in a balanced position [14].

Our hypotheses were (1) that DIP joint distension due to additional fluid volume increase speed and magnitude of angular displacement in all movement directions (F, LM, and AR) during axial compression loading (ACL) and (2) that this effect is exacerbated with the hoof medially or laterally raised. The aim of the present in vitro study on isolated equine forelimbs was therefore investigate the effect of DIPJ distension with and without medial or lateral elevation of the hoof on changes in the angular movement of the equine DIPJ during ACL.

2. Materials and Methods

2.1. Materials

In the present study, 12 equine forelimbs from six Warmblood horses, euthanized for reasons other than lameness, were used. The horses' age ranged from 12 to 31 years (mean 18.4 years; standard deviation ±6.4 years) and the body mass from 469 to 646 kg (mean 539.43 kg, ±60.56 kg). On the day of euthanasia, the limbs were separated in the intercarpal joint and stored at −20°C.

2.2. Specimen Preparation

The specimens were removed from the freezer 24 hours before testing and fully thawed at room temperature. Lateromedial and dorsopalmar radiographic views of each specimen were taken and evaluated for gross pathologies using iQ-View 2.5.0 (Image Information Systems Europe GmbH, Germany). All hooves were uniformly trimmed by a qualified farrier to create a level weight bearing surface, and thereafter, the specimens were dissected at the level of the pastern joint, resulting in the second (P2) and third phalanx (P3), the intact DIPJ and all adjacent soft tissues including the hoof being used for further testing. One screw was placed into P2 through stab incision, and a second screw was placed in P3 through a small circular horn defect created with a core drill bit (diameter 1 cm). In left forelimbs, the screws were placed on the medial aspect of P2 and P3 and on the lateral aspect in right forelimbs. Two tripods each with three reflective markers (diameter 1 cm) were attached to these screws to allow measurement of the 3D kinematics of the bone movement. Additionally, three markers were attached on the hoof wall, one on each heel and one in the middle of the dorsal hoof wall, to document the stability of the hoof position during ACL (Fig. 1). After testing, specimens were dissected and the DIPJs were macroscopically assessed for pathology (e.g., full or partial thickness cartilage lesions, presence of osteophytes/enthesophytes, reduced elasticity of the cartilage, structural changes in the collateral ligaments).

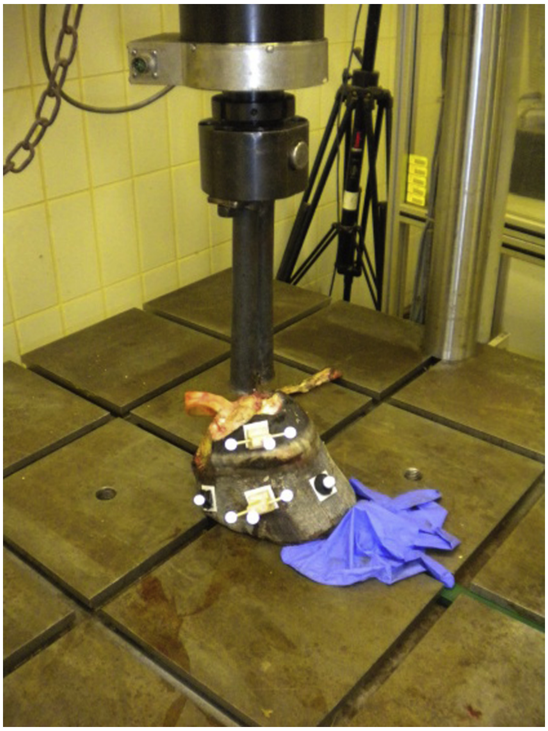

Fig. 1. Specimen (horse 2, right forelimb) in the material testing machine. Tripods with the reflective markers attached to the lateral sides of the second and third phalanx. The base of the third phalanx tripod is covering the defect in the lateral hoof wall. In addition, one marker on the heel and one dorsal on the hoof wall are visible. The marker on the opposite heel is obscured. The glove in front of the dorsal hoof wall is covering an adjusting screw that would have caused reflection errors during kinematic measurement. The adjusting screw was necessary to keep the specimen in its position during load measurement.