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Original Research

# Preliminary Evaluation of Toe–Heel and Mediolateral Hoof Balance at the Walk in Sound Horses With Toed-In Hoof Conformation

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ABSTRACT

Empirically, toed-in hoof conformation has been associated with an increased risk of lameness and reduced longevity of equine athletes, presumably linked with changes in hoof balance. Therefore, toe–heel and mediolateral hoof balance of the vertical ground reaction force and limb-loading symmetry were objectively evaluated in five clinically sound, toed-in warmblood horses using a pressure plate. Five measurements of each forelimb were recorded at walk, and toe–heel and mediolateral hoof balance of the vertical ground reaction force were calculated throughout stance (126 Hz). Peak vertical force (PVF) and vertical impulse (VI) symmetry were calculated as lowest or highest mean value × 100%. All horses presented higher loading of the lateral zone at impact, rather equivalent loading of the medial and lateral zones at midstance, and increased lateral loading at the end of the stance phase in both forelimbs. Unexpectedly, left and right fore toe–heel balance in four of the five toed-in horses revealed higher loading of the toe zone at impact, whereas one horse presented higher loading of the heel zone at impact in both forelimbs. Limb-loading symmetry was 83.1 ± 8.7% and 84.1 ± 7.9% for PVF and VI, respectively, which was lower than expected in sound horses. It is unclear if the distinct difference in toe–heel balance compared with previously reported data in horses with normal distal limb conformation is actually predisposing to or is a consequence of pathology, but it may be associated with distal limb lameness, as increased loading of the toe early in the stance phase has been associated with navicular disease.



## 1. Introduction

Toed-in or pigeon-toed conformation is a frequently observed conformational fault of the front limbs in horses [1,2]. It is caused by an internal rotation of the distal limb and is often seen in combination with a base-narrow stance [3,4]. Toed-in conformation has been associated with a paddling forelimb motion [3,4] and with an alteration in the breakover point being located more to the lateral side of the toe [5]. Internal rotation of the distal limb and the ensuing abnormal movement pattern is believed to induce excessive stress to the lateral part of the hoof and uneven wear of the hoof wall, ultimately resulting in a lower lateral hoof wall [5–7]. Hoof wall height asymmetry has been linked with pathology of the distal interphalangeal joint [8,9]. This may be either due to an abnormal intraarticular pressure [10] or to abnormal stress on the collateral ligaments, the distal part of the deep digital flexor tendon, and the distal part of the annular ligament [11]. In the studies by Caudron et al [12,13], cadaver limbs were fixed to a rotational platform and the effects of distal limb rotation and hoof wall asymmetry were evaluated radiographically. It

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was concluded that horses with a rotational deformity, such as toed-in conformation, present abnormal loading of the interphalangeal joints [12,13].

Although mild toed-in deviations have been reported not to impair soundness or performance [1], severe toed-in conformation has been empirically linked with an increased risk of injury and a reduced longevity of the equine athlete. However, there is a lack of objective information regarding the biomechanical effects of toed-in conformation during locomotion. New insights into this matter could lead to a better understanding of the eventual predisposition of injury and provide evidence-based guidelines for corrective farriery.

Pressure plate analysis has recently been used for the dynamic evaluation of toe–heel and mediolateral hoof balance of the vertical ground reaction force in sound warmblood horses with normal distal limb conformation [14], and therefore, this technique would be exceptionally suited for the study of toed-in horses.

The aim of this study was to dynamically evaluate the toe–heel and mediolateral hoof balance of the vertical ground reaction force and limb-loading symmetry at the walk in a sample of warmblood horses with clinically obvious toed-in hoof conformation. The hypothesis was that toed-in horses would present distinct differences in hoof balance compared with horses with normal distal limb conformation as described previously [14]. It was presumed that the major differences would occur in the mediolateral plane.

**Fig. 1.** Representative example of a toed-in horse included in this study.

## 2. Materials and Methods

### 2.1. Animal Selection

Five unshod, toed-in warmblood geldings were used (mean ± standard deviation [SD] body mass 556 ± 94 kg; wither height 1.61 ± 0.06 m). Only horses with severe toed-in conformation and associated hoof capsule distortions (e.g., longer medial hoof wall) were included, and this was based on clinical or visual evaluation of their distal limbs when standing squarely on a flat surface (Fig. 1). Horses with other important and possibly confounding conformational deficits (e.g., carpal valgus, bench knee, and so forth) were excluded. No quantitative measurements of the severity of the condition were performed. All horses were part of the teaching herd of Ghent University and were regularly used for pleasure riding by the students' riding club; they had no history of lameness and were clinically sound based on a standard clinical evaluation performed by the first author at walk and trot on a hard and on a soft surface in a straight line and while lunging clockwise and counterclockwise on hard and soft surfaces in a circle with a diameter of 10m. All horses were trimmed by an experienced farrier 2 weeks before the start of the study. However, it was not the aim to correct the toed-in conformation. Adequate measures were taken to address the welfare of the horses involved; the experiment was carried out in accordance with legislation on the protection of animals used for scientific purposes. Because of the sampling or data collection in this study was not invasive, nor harmful for the participating animals, institutional ethics committee approval was not deemed necessary by the committees chairperson.

### 2.2. Measurement System and Data Collection

The horses were walked over a pressure plate embedded between high-density polyethylene plates on a 20 × 2 m concrete walkway and covered with a 5-mm rubber mat, as described previously [15,16]. The pressure plate consists of 16,384 force-sensitive resistors in an active measuring surface of 1.95 × 0.32 m (2.6 sensors/cm$^2$) (Footscan 3D 2m-system; RSscan International, Paal, Belgium) and connected to a portable computer equipped with the Gait Scientific software version 7 (RSscan International, Paal, Belgium).

After 5 minutes of warming up, the horses were led from their left side over the measuring system by an experienced handler, on a long lead rope, without interfering with horse's velocity or head motion. The average velocity over the pressure plate was measured using two gates of photoelectric sensors with a 2-m interval centered over the measuring area. Although acceleration was not measured, the 20-m-long track ensured that the effect of acceleration and deceleration at the start and end of each trial was minimized over the central measuring area. A trial was considered valid if the horse moved at a constant pace, looked straight ahead, the gait velocity was within a narrow preset range, and the hoof of at least one forelimb fully contacted the plate surface. Five valid measurements of each forelimb were collected.