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Radiographic analysis of the lower limbs using the hip–calcaneus line in healthy individuals and in patients with varus knee osteoarthritis

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ABSTRACT

Background: Several recent reports define the line from the centre of the femoral head to the lowest point of the calcaneus. The purpose of this study was to comparatively examine the usefulness of the hip–calcaneus (HC) line and hip–ankle (HA) line for the evaluation of lower-limb alignment in healthy individuals and in patients with osteoarthritis (OA).
Methods: Participants included 34 healthy individuals (mean age, 26.4 years) and 34 patients with OA (mean age, 74.2 years). Frontal radiographs of the entire lower limb were taken in single- and double-leg stances. For each group, the hip–knee–ankle (HKA) and hip–knee–calcaneus (HKC) angles were assessed and compared within and between stances. In addition, the HA line and HC line were assessed as the passing line in the knee, and were similarly compared.
Results: Significant differences between the HKA and HKC angles, and between the HA line and HC line were observed in both groups during both stances. In addition, significant stance-related differences in the HKA and HKC angles, HA line, and HC line were found in the OA group, but not in the healthy group.
Conclusions: Our results suggest that the HC line of the lower limb differs from the HA line. Furthermore, single- and double-leg stances should also be considered, especially in patients with OA. These considerations may affect preoperative planning for high tibial osteotomies and TKA.

1. Introduction

The mechanical axis, which is traditionally used to assess the degree of limb deformity, is defined as the line from the centre of the femoral head to the centre of the ankle joint (i.e., hip–ankle (HA) line) [1–4]. In addition, this axis is frequently used for the preoperative planning of procedures such as high tibial osteotomy and total knee arthroplasty (TKA). However, several recent reports use the hip–calcaneus (HC) line, defined as the line from the centre of the femoral head to the ground reaction point at the bottom of the calcaneus [5–7]. Guichet et al. [5] described the importance of the hindfoot in evaluating the loading axis of the lower limb in paediatric patients. Using the centre of the ankle and the ground reaction point to plot two mechanical axis lines, they reported a difference between the mechanical axis deviation based on conventional measures (MADC) and the mechanical axis deviation incorporating the ground reaction point (MADG). Similarly, Desai et al. [6] observed that the ground mechanical axis, rather than the conventional mechanical axis, may be a better measure of overall limb alignment. Recently,

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Haraguchi et al. [7] reported that lower-limb alignment should be measured based on the line from the hip centre to the lowest point of the calcaneus (i.e., HC line), and not to the centre of the ankle. This new method involves evaluating full-length standing posteroanterior radiographs that include the calcaneus (i.e., hip-to-calcaneus radiographs), where the calcaneus is elevated on a radiolucent platform. Regarding the hindfoot alignment, Norton et al. used standing long-leg anteroposterior radiographs and Saltzman hindfoot views, and reported that varus knee deformity is correlated with valgus hindfoot position in patients undergoing primary TKA [8]. Importantly, none of these previous studies have examined the mechanical axis and limb alignment of the entire lower extremity in healthy subjects and in patients with osteoarthritis (OA). Therefore, we hypothesised that the HC line of the lower limb differs from the HA line. In the present study, we aimed to comparatively examine the usefulness of the HC and HA lines for the evaluation of lower-limb alignment in healthy individuals and in patients with OA. To this end, we performed a detailed assessment of frontal radiographic images of the entire lower limb.

2. Methods

2.1. Patient information

The study included 68 patients stratified into two groups for the comparison of radiographic measurements. Informed consent was obtained from all individual participants included in the study. The healthy group comprised 34 patients (12 men, 22 women; mean age, 26.4 years) who received treatment for anterior cruciate ligament (ACL) or meniscial injury. The patients in the healthy group were examined in their healthy limbs pre-operatively. The OA group comprised 34 patients (five men, 29 women; mean age, 74.2 years) who received TKA for varus type OA at our hospital between July 2015 and January 2016. In the healthy group, the height, weight and body mass index were 1.67 ± 0.09 m, 64.6 ± 15.7 kg and 22.9 ± 3.9 kg/m^2, respectively (data presented as mean ± standard deviation); in the OA group, these values were 1.52 ± 0.06 m, 59.2 ± 10.4 kg and 25.7 ± 4.2 kg/m^2, respectively (Table 1). The non-operated side was evaluated in the healthy group (34 legs), while the affected side was evaluated in the OA group (34 legs), and all measurements were taken in the pre-operative stage. A power analysis was performed using G*Power version 3.1, and indicated that a sample of 34 patients in each group is required to obtain a power of 0.8 for an effect size of 0.5 and alpha of 0.05.

2.2. Measurement of limb alignment and angles

Frontal radiographic images of the entire lower limb (from the hip joint to the calcaneus) in single- and double-leg stances were taken. The hip–knee–ankle (HKA) and hip–knee–calcaneus (HKC) angles were assessed for both single- and double-leg stance in order to simulate the gait cycle. The HA line and HC line were assessed as the lines passing through the centre of the knee (i.e., medial edge as 0% and lateral edge as 100%). These radiographic measurements are shown in Figure 1.

2.3. Radiographic assessments

Full-length single-leg and double-leg standing posteroanterior radiographs that included the calcaneus (i.e., hip-to-calcaneus radiographs) were taken for the evaluation of the mechanical axis of the lower limb and hindfoot alignment, as described previously [7]. The subject maintained a bipedal and unipedal stance on a radiolucent platform and faced the long film cassette. For the lowest point of the calcaneus to be visualised on the radiograph, the cassette was slid into position with its lower edge passing the edge of the platform. The patient's patella was placed forward, with neutral position of the ankle. The X-ray beam was centred on the knee of the imaged leg, from a distance of two metres (voltage, 200 mA; current, 85 kV). We used three cassettes (17 × 17 in., flat panel detector) for the full-length radiographs. On the radiograph, the patella was confirmed to be centred between the femoral condyles and the ankle was confirmed to be placed in a neutral position.

In line with current convention, the HKA and HKC angles were expressed as angular deviation from 180°, with negative values for varus alignment and positive values for valgus alignment (i.e., HKA = −3° in varus alignment). To assess the deviation of the HA and HC lines from the axis of the limb, the medial and lateral edges of the tibial plafond were taken as 0% and 100%, respectively.

To determine the intra- and inter-observer reliabilities of the radiographic assessment, two investigators performed all radiographic assessments twice on 20 randomly selected radiographs. The intra- and inter-observer reliabilities of all radiographic

Table 1
Demographic data of healthy individuals and patients with knee osteoarthritis.

	Healthy group	OA group
Age (years)	26.4 ± 7.8	74.2 ± 8.4
Sex (female/male)	22/12	29/5
Height (m)	1.67 ± 0.09	1.52 ± 0.06
Weight (kg)	64.6 ± 15.7	59.2 ± 10.4
BMI (kg/m^2)	22.9 ± 3.9	25.7 ± 4.2

Unless otherwise specified, data are given as mean ± standard deviation. BMI, body mass index; OA, osteoarthritis.

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