Radiological Assessment of the Maximal Dorsiflexion Position of the Ankle in Healthy Persons

Kingma JJ1*, Mechielsen J1, Cobben LPJ2, and Van Veldhoven PLJ2

1Practice for Physical and Manual Therapy, The Hague, The Netherlands
2Haaglanden Medical Center, The Hague, The Netherlands

Abstract

**Background:** Dorsiflexion in the ankle can be impaired by certain disorders. Knowing that values of maximal dorsiflexion in healthy subjects vary widely, it is difficult to judge the decrease of dorsiflexion in patients. At present maximal dorsiflexion are calculated using different instruments and reference lines. The purpose of this study is to determine if in the full weight bearing dorsiflexion position an anterior impingement of the ankle is reached on X-ray images.

**Method:** Maximal dorsiflexion position (MDP) of the left and right ankle was determined on an X-ray in fifteen healthy subjects. Mean values of MDP and SDs were calculated.

**Results:** With an average distance between the anterior distal part of the tibia and the head of the talus of 1.4 mm, it is very likely that in this maximal dorsiflexion position the articular end position of the talocrural joint for dorsiflexion for these healthy subjects is reached. In this position the goniometric outcome of angle gamma (γ): were 105.2 (6.1) degrees.

**Level of Evidence**

- Study Design: Cohort monitoring study; Level of evidence, 4.

**Conclusion:** Radiological assessment of the ankle MDP of healthy adults in a full weight bearing position showed anterior impingement of the tibia against the talus.

INTRODUCTION

Dorsiflexion in the ankle can be impaired by multiple disorders, like muscular dystrophy, Achilles tendon disorders, neurological problems, osteoarthritis and other anatomical abnormalities. Widely varying values of maximal dorsiflexion of the talocrural joint in healthy subjects are reported and this causes difficulties in judging a decrease of dorsiflexion in a patient. According to the literature, maximal dorsiflexion varies from -0.6 to 118.5 degrees. This variation may be caused by the use of different ways of measuring (e.g., different subject position), calculating (different reference lines used) and/or using different types of instruments (Table 1). At this moment, no standardized method of assessment of maximal ankle joint dorsiflexion position exists [1-7].

Dorsal and plantar flexion is believed to represent motion in the talocrural joint. In fact, motion between tarsal and metatarsal bones is also included. Visual or palpable parts of bones in the lower leg and the distal part of the ankle are used as reference points in the assessments. Aforementioned, added to the fact that the bony landmarks ‘project’ through the skin, which stretches and moves during dorsiflexion, we propose that the maximal dorsiflexion position in only the talocrural joint cannot be measured accurately during physical examination. For an assessment of the position of the bony elements of the body, a radiological examination seems indispensable [8-20].

In some studies a neutral position has been used from which dorsiflexion is measured [1-7,9,11,12,14-19]. Such a neutral/zero position may vary widely between subjects (and studies). In the supine subject it is the angle of 90 degrees between the sole and the longitudinal midline of the fibula [2-4,7,9,11,12,15,16,19,20]. In the standing subject it is the angle between the floor and the longitudinal midline of the fibula [3,5,13,19], or the angle between the line from the lateral malleolus to the fibular head and the line from the center of the lateral malleolus to the tuberosity of the fifth metatarsal [12-14]. Besides this, the manual mount, direction and force used by the observers during the non-weight bearing goniometer measurements, towards a maximal articular position influences the measurement outcome strongly. For an accurate assessment of the maximal dorsiflexion position we need a clear view on the bony elements of the talocrural joint.
and the surrounding anatomical bony elements. We investigated if X-ray images will help us to measure and confirm whether the anatomical maximal dorsiflexion position by the bony elements of a talocrural joint is achieved in weight bearing position. We measured the angle in the extreme position of the ankle with respect to the lower leg: the maximal dorsiflexion position (MDP). The values of this angle in healthy subjects may serve as basic references to diagnose patients and to evaluate their improvement during and after therapy. Also the distance between the distal anterior part of the tibia and the head of the talus is calculated in millimetres.

Although in most ROM studies all subjects are healthy persons, their gender, age, body composition and especially the anatomy of the ankle and lower leg may vary, resulting in a large variety in flexibility of tarsal and metatarsal joints. These inter-subject differences may influence the magnitude of mean and standard deviations. Also the influence of the spatial position of adjacent bone structures in the subject is studied.

**MATERIALS AND METHODS**

All participants were informed about the purpose and procedure of the study before giving their written consent to participate.

**Subjects**

Fifteen healthy adults (4 males, 11 females), mean (SD) age 31.6, (2.9) years, height 174.1 (9.8) cm, weight 74.1 (14.2) kg volunteered to participate in this study. Prior to taking the X-ray images participants completed a health history form and an informed consent form. In both legs any motion was pain free. Exclusion criteria were: leg length discrepancy (>2 cm), genu varum/valgum/recurvatum, pes planus/cavus or hallux valgus. Also a history of arthritic or neuromuscular disorders, major trauma, fractures or surgical treatment or complaints were reason for exclusion.

**Technical equipment**

The Röntgen equipment was made by Siemens Yzio, Erlangen, Germany.

**Observers**

All measurements were independently carried out by the authors with technical supervision.

**Procedure**

One of the observers applied three metal bullets (diameter 3 mm) with stickers to the skin over the most prominent part of the tuberosity of the fifth metatarsal, the lateral malleolus and the

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### Table 1: Instruments, subject position and reference lines used by various authors.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Subject position</th>
<th>Reference lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodburn [20]</td>
<td>Video</td>
<td>Supine, knee extended</td>
</tr>
<tr>
<td>Baggett [3]</td>
<td>Tractograph**</td>
<td>Weight bearing, knee extended</td>
</tr>
<tr>
<td>Baggett [3]</td>
<td>Tractograph**</td>
<td>Non-weight bearing, knee extended</td>
</tr>
<tr>
<td>Nigg [12]</td>
<td>Infrared sensor</td>
<td>Seated, knee 90 degrees flexed</td>
</tr>
<tr>
<td>Hogeweg [7]</td>
<td>Universal goniometer</td>
<td>Supine, knee slightly flexed</td>
</tr>
<tr>
<td></td>
<td>2. Fluid goniometer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Universal goniometer</td>
<td></td>
</tr>
<tr>
<td>Dijkstra [5]</td>
<td>Perspex goniometer, with 180 degrees scale</td>
<td>Weight bearing on bench</td>
</tr>
<tr>
<td></td>
<td>50 cm arms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Univ. goniometer</td>
<td>X-ray: Midline fibula X line which divides the trochlea from the rest of the talus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Goniometer: Midline fibula X parallel to sole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Prone, hip, knee extended</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Sitting, hip 90°flexed, knee extended</td>
</tr>
<tr>
<td>Meyer [15]</td>
<td>Mechanical equinometer*</td>
<td>Anterior surface tibia X plantar surface of the ankle</td>
</tr>
<tr>
<td>Joaquin [8]</td>
<td>Univ. goniometer</td>
<td>Weight bearing lunge</td>
</tr>
</tbody>
</table>

*Tool of two mobile parallelograms both connected with a hinge and angular scale
**Goniometer

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### Table 2: Distance measurements between tibia and talus.

<table>
<thead>
<tr>
<th>N</th>
<th>Minimum (mm)</th>
<th>Maximum (mm)</th>
<th>Mean (mm)</th>
<th>SD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.10</td>
<td>7.10</td>
<td>1.44</td>
<td>1.83</td>
</tr>
</tbody>
</table>

### Table 3: Angle measurement in the MDP position.

<table>
<thead>
<tr>
<th>N=30</th>
<th>Mean (sd) degrees on the röntgen photo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle Gamma (γ)</td>
<td>105.2 (6.1)</td>
</tr>
</tbody>
</table>
fibular head. This was carried out on both legs. The participants were asked to stand on the platform (20 cm height) with a handlebar only for safety balance. The distance from the röntgen equipment to the subject’s lateral malleolus was standardized at 1.8 meter. At this distance all three reference points were visible on the röntgen images. The participant had to stand in this weight-bearing position four times already before holding this position for the X-ray to get familiar with the maneuver. The röntgen images were taken from the lateral to the medial side of the ankle.

All subjects were asked to stand on one leg and adopt a maximal dorsiflexion position of the ankle with a flexed knee. While standing on one leg the balance was kept by holding a handlebar with both hands. In this position a sagittal X-ray photo of the lower leg, ankle and foot was made (Figure 1). After the X-ray of the left leg was taken, the same procedure was carried out on the right leg. All X-ray images were taken by the same radiology assistant. The photos were, after a quick check by the observers, stored on a hard disc.

**MEASUREMENTS**

**Angles of the maximal dorsiflexion position**

The röntgen images were uploaded with the software package HOOKE MATE (developed at Maastricht University). The position of five points on the display was analysed by the computer in a fixed order, two points on the floor underneath the ankle (1 and 2) and the three metal bullets (3, 4 and 5). Subsequently angle γ was calculated (Figure 1). Reference lines were used to measure angle gamma (γ): the angle between the reference line from the center of the lateral malleolus to the fibular head and the reference line from the center of the lateral malleolus to the base of the fifth metatarsal bone. This angle was measured with the ankle in MDP (Figure 2).

**Distance between the talus and the tibia**

The observers also measured the distance between the ventral distal aspect of the tibia and cranial aspect of the talar neck measured in millimetres.

**RESULTS**

**Distance measurements between tibia and talus**

The space between the ventral distal part of the tibia and cranial aspect of the talar neck is calculated in millimetres (Table 2). With an average distance of 1.44 mm, it is very likely that in this maximal dorsiflexion position the articular end position of the talocrural joint for dorsal flexion for these healthy subjects is reached.

**Results of the goniometric measurement**

The angle gamma of the MDP was calculated in degrees (Table 3).

**DISCUSSION**

In the world of sports medicine and physiotherapy there is need for standardized physical measurement methods. In our knowledge this is the first study to measure the MDP in the ankle, by taking X-rays. With this study we want to measure and confirm that the anatomical MDP in the talocrural joint is achieved in a weight bearing position. The results show, with an average distance of 1.4 mm between the tibia and the talus, that it is very likely that the MDP is reached in a weight-bearing position. The participant had to hold still for a few seconds before the X-ray was taken. So fatigue and imbalance might have resulted in some participants not reaching their ‘real’ MDP.

Second, we measured the angles in the MDP on X-ray images. The values of these angles in healthy subjects may serve as basic references. The results show that there is a standard deviation of 5.2-7.3. The inter-subject variability is too big to create basic reference values. Age, body composition and especially the anatomy of the ankle and lower leg vary, resulting in a large variety in flexibility in tarsal and metatarsal joints. A standardized measurement method with good reproducibility will benefit follow-up after ankle trauma and inter-clinician communication.

**LIMITATIONS OF THE STUDY**

A limitation of this study is that there was only made one X-ray of each ankle. Therefore the reproducibility was not tested. For other study goals more measurements were carried out in both ankles, inducing fatigue. Only 15 participants took part, resulting in measurements being carried out in 30 ankles. This might have compromised the power of the study.
FUTURE RECOMMENDATIONS

To prove if the maximal dorsiflexion in the ankle is reached, more X-rays should be made at different moments to test the reproducibility. Future assessment of weight bearing dorsiflexion, as the tibia and fibula move around the arcus of the talus, is recommended.

REFERENCES