# Correlation of radiological and clinical measurement of genu valgum in children

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## ABSTRACT

**INTRODUCTION:** Genu valgus is a condition characterised by a lateral shift of the knee's mechanical axis. The deformity can be characterised using clinical examinations and long hip-knee-ankle (HKA) angles, but it is unclear how these investigations correlate with each other. Our aim was to examine the correlation between clinical and radiographic measurements of the lower extremities in children.
**METHODS:** A total of 49 children between 5.9 and 16.7 years of age who had been referred with genu valgum deformity were included. They all had their intermalleolar (IM) distance measured and a standardised anterior-posterior radiograph of the lower extremities taken. IM distance was adjusted for the mean tibial and femoral length to adjust for differences in leg length. We calculated the Spearman's rank correlation coefficient to study the reliability between radiographs and clinical examinations.
**RESULTS:** We found no correlation between clinical IM distance and the HKA angles. Spearman's rho for comparison between adjusted clinical IM distance measurements and HKA angles on radiographs was found to be 0.36
**CONCLUSIONS:** We found a poor correlation between clinical examinations and HKA angles as data were corrected for leg length. More studies are needed to provide clear recommendations for following children with malalignment.
**FUNDING:** none.
**TRIAL REGISTRATION:** The study was registered with the Danish Data Protection Agency.


Genu valgum is a condition characterised by valgus beyond what is physiologically normal and can be corrected in the growing child if excessive and symptomatic [1, 2]. The deformity is typically treated with reversible hemiepihyseodesis before skeletal maturity. The use of this method requires regular follow-ups to avoid overcorrection. One method for evaluating bony malalignment is long-standing X-rays; this investigation may, however, expose the child to unnecessary radiation. Of particular interest would therefore be if monitoring could be done by clinical examination alone. Clinical measurement of the distance between the medial malleoli in the standing or prone child has been used to quantify the degree of genu valgus, assuming that neutral alignment genu varus has an intermalleolar (IM) distance of zero. However, the intra-and inter reliability has never been estimated to validate how best to perform this clinical assessment. Furthermore, clinical measurements might be inaccurate as the IM may not only depend on the bony alignment but also on laxity and obesity. To the best of our knowledge, no prior clinical studies have examined the correlation between the clinical IM distance and the hip-knee-angle (HKA). Our aim was to examine the correlation between clinical and radiographic measurements of the lower extremities in children through retrospective review of patient files. We hypothesised that IM distances may be used as a surrogate measure for radiographic measurement of lower limb alignment, which would reduce the need for repetitive and costly long leg standing radiographic and reduce the radiation hazard for the patient.

## METHODS

For this study, we selected children referred with valgus malalignment of the lower extremities seen at the Department of Children's Orthopaedics, Aarhus University Hospital (AUH) or in Hospital Unit West, Denmark from 1 January 2005 to 31 December 2011, who also had a standardised anterior-posterior (AP) radiograph taken. A total of 54 children satisfied these criteria. Moreover, the children had to be younger than 18 years of age and have had their standing IM distance measured clinically at their referral for radiological examination.

The population was identified through a retrospective review of patient files using diagnosis codes, and all relevant data were arranged in an Excel spreadsheet. The average age of the children was 11.1 year. The youngest child was 5.9 years and the oldest 16.7 years. Five patients were excluded (**Figure 1**).

### Intermalleolar distance

IM measurements were done with the child standing, the legs placed together so that the knees were touching. The IM distance was measured with measuring tape between the medial malleolus on the right and the left foot [1, 3], and each child was measured once. The measurements were done by three different doctors at AUH and three others at Hospital Unit West.

### Adjusted intermalleolar distance

To account for differences in length among the included

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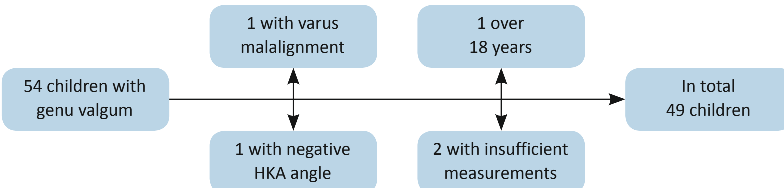
FIGURE 1

Exclusion flow chart.




HKA = hip-knee-ankle.

children, we adjusted IM distances for individual length by combining the mean femoral and tibial length measured on each child's radiographs. The median value for all these children were then used to create an adjusted factor for each child:

median length/actual length × measured IM distance = adjusted IM distance.

**Full-length standing anteroposterior radiographs**
Initially, an exact lateral image was obtained using fluoroscopy with the posterior part of each femoral condyle being used as reference. A footprint was drawn on the floor to be able to reproduce the position of the limb for the final radiograph. One standing AP recording was made with both lower extremities exposed at the same time and with the child standing in a weight-bearing position. Blocks were placed under the foot in case of leg length discrepancy. All knee joints were fully extended, and the knees were touching. To minimise parallel axis error, a distance of 3.5 m was chosen [4-8]. The beam was centred at level with the knees. Images were saved in the picture archiving and communication system.

The HKA angle is the angle between the mechanical axis of the femur and the tibia [4, 6]. It is obtained by connecting the centre of the femoral head to the midpoint of the tibial eminential spine in a line tangential to the femoral condyles, and another line from here to the centre of the trochlea tali (**Figure 2**). The HKA angle can also be expressed as x degrees of deviation from a neutrally aligned lower extremity (180°) [9]. We measured the length of the tibia and the femur along the anatomical axis. The radiographs were primarily obtained in a standardised fashion, and all HKA angles, tibia and femur lengths, were measured using Impax 6.3.1 (AGFA HealthCare, Denmark). All measurements were made by the same radiologist (MBH). For data analysis, the right and the left HKA angles were added to allow data to be correlated with the measured IM distances.

FIGURE 2

Hip-knee-ankle angle measurements.


**Statistics**
All statistical calculations were performed in Stats/IC version 12.1. Normal distribution tables and scatter plots with linear regressions were done in Excel. Spearman's correlation was used for non-parametric data.

*Trial registration:* The study was registered with the Danish Data Protection Agency.

**RESULTS**
There was no evident linear regression between the clinically measured IM distance and the HKA angle (**Figure 3**). We suspected that this could be due to lacking adjustment of the IM distance for leg length. However, leg length was not stated in the patient files and was therefore measured on HKA radiographs. The relationship between the adjusted IM distance and the HKA angle is given in **Figure 4**.

We found no correlation between the clinically measured IM distance and the HKA angle. When IM distances were corrected for leg length, Spearman's rho increased to 0.36.

**DISCUSSION**
We examined the correlation between clinical and radiographic measurements of the lower extremities in 49

FIGURE 3

Scatter plot with no evident linear regression for clinical intermalleolar distance and hip-knee-ankle angle.

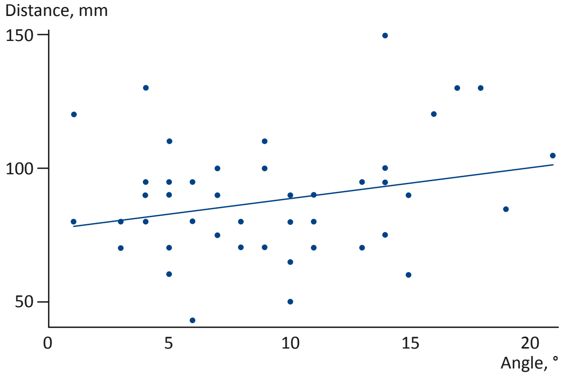
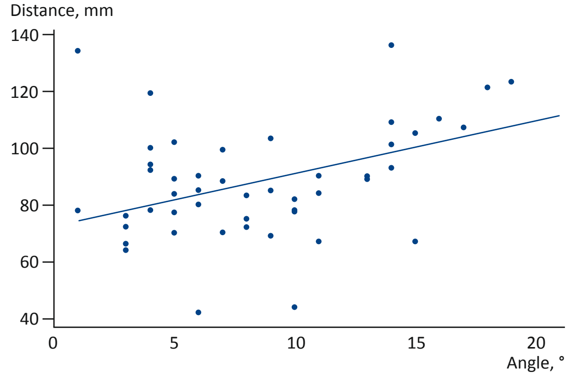



FIGURE 4

Scatter plot with no evident linear regression for adjusted intermalleolar distance and hip-knee-ankle angle.




children with genu valgum by retrospective review of patient files. We found a poor correlation between clinical examinations and radiographic angles, even after correlating the clinical examinations with the child's overall leg length measured radiographically. This was contrary to our expectations, because both measurements are used in diagnosing malalignment in children and used for monitoring treatment effect of reversible hemi-epiphyseodesis. Data were adjusted for radiographic leg length. To our knowledge, this has not been done before. However, in 1957, Morley [10] described the relationship between IM distance and leg length as dependent on each other, and other authors have speculated about a relation between the two [1, 9]. However, adjusting for leg length did not much improve the correlation between IM distance and leg length in our study. This might imply that apart from long bone geometry and alignment of joint surfaces, other soft tissue factors such as soft tissue thickness, laxity and hypermobility may also play a role in IM measurements. Our results questions IM distance as a valid clinical examination for lower limb alignment. Thus, our results contrast with what is found in the existing literature, where there is general consensus on the use of IM distance in diagnosing of malalignment of the lower extremities, because this method is easily applicable and reproducible [1, 4, 11, 12].

Full-length AP standing radiographs are the gold standard imaging modality for describing and characterising alignment, joint orientation angles and length discrepancy of the lower extremities [9, 13]. In addition to serving diagnostic purposes, radiographs can be used to rule out pathological causes of the deformity, to help determine the site of the deformity [14] and to identify treatment complications after surgery [15]. The literature on the reliability of performing full-length AP standing radiographs in children is sparse, and most publications focus on adult patients with degenerative knee joint conditions. When obtaining full-length standing radiographs for measurement of the HKA angle, it is important to secure correct rotation of the lower limb. In a true AP radiograph of the knee, the patella is positioned forward [16]. At our institution, it was decided to use the posterior part of the femoral condyles as anatomic landmarks instead [7], giving a 3-5° external rotation from the true AP view in the knee axis [17]. Using the posterior part of the femoral condyles, malalignment of the patella has no impact, in contrast to a true AP radiograph. Additionally, all knee joints were fully extended to minimise the risk of unwanted rotation of the knee, because differences in the mechanical axis between full extension and 20° of flexion are negligible [8]. In all, it can be challenging to standardise the technique for obtaining the full-length AP standing radiographs and precisely position a young child. To meet this challenge, every child in whom such radiographs are obtained had his or her footprint drawn on the floor.

### Limitations of the present study

The following limitations must be acknowledged. Firstly, with a population based on children with valgus malalignment who also had a standardised AP radiograph taken, the sample size of our study was limited. A radiograph is not standard for all children referred with malalignment, but is taken for example in cases considered for surgery or to rule out pathology. Secondly, the IM distance measurements were done by six different investigators, which may give rise to increased data variability. Additionally, our data were collected retrospectively from patient files. Although IM distance measurements were not done according to a standardised protocol, minor differences in the approach between clinicians may arise in everyday clinical practice; furthermore, it must be acknowledged that some difficulties may arise in relation to the positioning of the subjects during measurements. We have not been able to find studies of inter- and intraobserver reliability for the measurement of IM distance, but we used a standardised method for IM measurement that is used worldwide. Furthermore, three doctors did more than 75% of the measurements, and all doctors were experienced orthopaedic surgeons who perform the measurements routinely.

As mentioned, soft tissue thickness in overweight children may increase the IM distance [12] to a minor degree [18], and is a possible source of error. Still, we have not been able to find literature on medial and lateral ligament laxity and the effect this could have on the IM distance. The patient records contained no systematic registration of weight and height or hypermobility, so any influence of these parameters on IM distance is purely speculative. All in all, we believe that our measurements are valid.

Finally, it should also be addressed whether there is sufficient evidence for using HKA angle values in children. If HKA angles are to be used as a permanent reference parameter for diagnosing malalignment of the lower extremities, stronger evidence and larger studies supporting HKA as the best measurement are needed. Evidence for this and reference values for HKA in adults have been found in several studies [4, 9], but we have only been able to find a single study on HKA values in children [6]. This study concluded that HKA reference values for adults can be used for children who are seven years or older, because HKA angles stay more or less unchanged at higher ages. For children who are younger than seven years, age-specific values should be applied. The study concluded that HKA angles should always be obtained during a clinical examination to reduce the risk of overtreatment. HKA angles in children have also been described in orthopaedic paediatric textbooks [19] for children of all ages, further supporting the use of HKA angles in describing and diagnosing malalignment of the lower extremities in children.

## CONCLUSIONS

We found a poor correlation between HKA angles and clinical measurements in children with genu valgum, with or without adjusting data for leg length. Radiographs in the context of genu-valgum malalignment are used both diagnostically and to identify treatment complications after surgery and before removal of implants, and radiographs are, indeed, indicated in these situations. More studies are needed before clear recommendations can be made on how to follow children with malalignment.

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