Assessment of the mechanical axis is routine during the examination of patients with lower extremity pain. Long-leg radiographic examination is the gold standard for exact measurement, but it is associated with a significant radiation dose. An alternative method to examine the mechanical axis has been warranted. This article validates a newly developed computerized photographic method to calculate the mechanical axis using a digital photograph. The location of the center of the femoral head was calculated using ink marks on both superior iliac spines.

Twenty-five patients (10 women and 15 men) had both legs examined using the photographic method and long-leg radiography examination. The digital photograph method was found to be highly reliable. The interobserver absolute mean difference was 0.99° ± 0.85°, and the intraobserver absolute mean difference (day-to-day variation) was 1.04° ± 0.81°. The mechanical axis determined by the 2 methods was highly correlated ($R$ = 0.943). The long-leg radiography method was within an average of ±1.88° of the photographic method, with a 95% probability.

The photographic method appears to be an effective alternative to conventional long-leg radiography. The photographic method seems convenient in the routine examination of patients with leg pain and children with suspected axial deformity and for follow-up after treatment for malalignment. Calculation coefficients for children and a possible racial difference remain to be studied.
Assessment of the mechanical axis is routine during the clinical examination of patients with pain in their lower extremity because muscular imbalance is known to be a major cause of conditions with pain (eg, tendinitis, muscle pain, bursitis) and is associated with increased risk of osteoarthritis. Realignment surgery is indicated in children and adolescents with severe malalignment and in adults with knee osteoarthritis isolated to 1 side of the joint to decrease the load to the affected side. Also, the diagnosis of less severe malalignment may be important in the prophylaxis and treatment of the abovementioned pain conditions.

Long-leg radiographic examination is the gold standard for the exact measurement of the mechanical axis of the lower limb—the axis through the center of the hip, knee, and ankle joints—but it is associated with a significant radiation dose. Therefore, an alternative method for accurately examining the mechanical axis would be useful.

In 2008, Schmitt et al introduced a digital photographic method used to measure the axis through the midpoint of the contours of the leg at the level of the ankle joint, the knee joint, and the groin. However, the method is not generally applicable because it is highly sensitive to abnormalities in the thigh geometry, especially as seen in patients who are obese and who have high levels of fat tissue located to the lateral side of the hip.

In the current study, the authors demonstrate that it is possible to accurately detect the center of the femoral head using the location of the iliac spines on a digital photograph and, consequently, to measure the mechanical axis of the lower limb.

**Materials and Methods**

All patients were referred from their general practitioner and treated at 1 of 2 regional orthopedic centers for hip and knee osteoarthritis in the North Denmark Region. Between February 1 and June 15, 2012, twenty-five consecutive patients (10 women and 15 men with a mean age 65 years [range, 43-78 years]) were included. Demographics are provided in Figures 1-3.

All patients were treated nonoperatively for unicompartamental knee osteoarthritis with realignment physiotherapy and insoles. Long-leg radiographic examination was routinely performed. Simultaneously, the deformity was examined using the digital photographic method, called the spina method. Seventeen patients were reexamined while wearing insoles, resulting in a total of 42 comparable examinations. The right and left legs were examined on the same radiography and digital photographs, and the mechanical axis was measured independently.

A multiple linear regression model with the long-leg radiographic method as the response variable and the patient, leg, shoes, and spina method measurement as the main effects was applied as a basis for model selection. Using the Bayesian Information Criterion, the authors found that the long-leg radiographic method was optimally described by using only the spina method measurement.

**Digital Photographic Method**

Before photographing the patients’ legs, the location of the 2 superior anterior iliac spines, the inferior pole of the patella, and the ankle joint line were marked with a 1-cm dot of ink.

A computer program was developed to calculate the mechanical axis from the photograph using the following procedure in an automated way (instead of doing it manually with a ruler and a protractor). The spina marks (Figure 4) were clicked using the computer mouse. The computer then calculated the length (A1) of the straight line between these marks. The location of the center of the femoral head was calculated using the horizontal (A2) and vertical distances (A3) from the ipsilateral iliac spine to the center of the femoral head. The coefficients used to calculate A2 and A3 from A1 were derived from measurements on 80 randomly selected pelvic radiography examinations (Table; Figure 5).

At the levels of the inferior pole of the patella and the ankle joint line, the
midpoints between the soft tissue outlines were marked as the center of the knee and ankle. The mechanical axis was calculated as the angle determined by the 3 points (center of the femoral head, center of the knee, and center of the ankle), and the mechanical axis deviation was 180° minus the mechanical axis. (The computer program can be obtained by contacting the corresponding author.)

**Reliability**

The inter- and intraobserver reliability of the spina method were examined using 14 volunteers (radiologists and nurses [H.T.] from the department). Photographs were taken and calculations were performed by 2 independent nurses (H.T.) on the same day and while patients were in the same position used for the radiography examination. The same procedure was repeated 2 days later. The reliability was then assessed by calculating the mean absolute difference and the SD of the absolute differences of the measurements taken of the same patient by different nurses (interobserver) and on different days (intraobserver).

**Long-leg Radiographic Examination**

The radiographic examination was performed while the patient was in a standing position with the femoral epicondylar line angular to the beam direction and the medial malleoli 10 cm apart. Mechanical axis deviation was derived by the method described by Paley. Reliability was examined by comparing the mechanical axis deviation of the radiographic examinations by 2 experienced radiologists independently.

**RESULTS**

**Reliability**

The digital photographic method was found to be highly reliable, with a mean interobserver absolute difference of 0.99° ± 0.85° and a mean intraobserver absolute difference (day-to-day variation) of 1.04° ± 0.81°. In addition, the mechanical axis determined by radiographic examination was found to be highly reliable, with a mean interobserver absolute difference of 0.26° ± 0.44°.

**Mechanical Axis Measurements**

All patients had the mechanical axis of both legs determined using both methods. The mechanical axis deviation ranged from 0° to 11°. Mean mechanical axis deviation was 4.92° ± 2.71° using the long-leg radiography method and 4.89° ± 2.83° using the spina method. Bilateral deformity was observed in 22 patients (16 varus, 3 valgus, and 3 mixed varus/valgus), and unilateral deformity was observed in 3 patients (1 varus and 2 valgus).

**Validity of the Spina Method**

The mean absolute difference between the mechanical axis calculated by the long-leg radiography method and the spina method was 0.67° ± 0.66°. The mechanical axis deviation determined by the 2 methods was highly correlated (R = 0.943).

The 95% prediction intervals for spina method values between 0° and 11° had widths ranging from 2° ± 1.86° to 2° ± 1.91° (average, 2° ± 1.88°), meaning that the long-leg radiographic method value was within an average of ± 1.88° of the spina method value, with a 95% probability.

**DISCUSSION**

For knee alignment examination, long-leg radiographic examination is superior
to conventional knee joint radiographic examination. Showing only the distal femur and the proximal tibia, the latter has a tendency to underestimate knee joint malalignment.5 Because malalignment is generally defined as the deviation from 180°, the mechanical axis in the standing position, determined using long-leg radiographic examination, is considered the gold standard for determining knee joint alignment.

Currently, radiography is the only available method to accurately demonstrate the centers of the hip, knee, and ankle joints simultaneously while patients are in the standing position. In a study of patients who underwent total knee replacement, the standing long-leg radiograph was found to have less variability than the radiograph with the patient in a prone position (SD using long-leg radiograph, 1.8°; SD in prone position, 3.6°; \( P<.05 \)).5 In the future, magnetic resonance imaging or ultrasound techniques may become available for determining the mechanical axis. For screening purposes in primary health care, conventional photographic techniques would seem to be more practical, if they have acceptable precision.

Because bowlegs and knock-knees are the most common pediatric orthopedic problems that cause concern, the standard for physical examination is careful assessment of limb length and coronal and sagittal alignment. Because measurements such as intermalleolar and intercondylar distances used to assess coronal plane alignment have not been found clinically useful, the preferred objective measure has hitherto been long-leg radiographic assessment of the deformity.6 For pediatric examination, as well as for routine examination for malalignment in other patients with lower extremity pain, a reliable photographic method seems to be a convenient method.

In addition, follow-up after treatment is expected. Because knee adduction moment is intimately linked with the development and progression of knee osteoarthritis, an increasing interest is placed on conservative biomechanical intervention strategies,7 as well as for operative correction. Gentle and effective surgical methods, called guided growth, are becoming increasingly popular.8

The computerized photographic method presented in the current study is the first to detect the center of the hip joint and, hence, to estimate the mechanical axis conventionally. The photographic method introduced by Schmitt et al5 uses the midpoint between the femoral contours at the groin level as a substitute for the center of the hip joint. In 10 volunteers who were not obese, Schmitt et al5 found that the mechanical axis determined by the photographic method reflected the mechanical axis determined using radiography with only slight deviation (range, 0.12°-1.9°). However, the method seems inconvenient for patients who are obese due to high levels of fat tissue, especially to the lateral side of the femur. Also, equal weight bearing on both legs seems most important because a 1.6° mean deviation in the mechanical axis has been reported between measurements taken with bilateral and unilateral weight bearing.9

Similarly, even standardized radiography with well-defined positioning of the foot and leg rotation has displayed inaccuracy in the evaluation of radiographs ranging from 1.1° to 1.6°.10-13

However, the introduction of digitalization of radiographic examination, as well as computerized reading programs, has increased the reliability of the mechanical axis determination considerably, as found in the current study. In addition, a computerized reading program was able to increase the reliability of photographic measurement of the mechanical axis to an acceptable level (SD, 1.3°), as demonstrated in the current study.

The high validity of the current photographic method is based on a reliably constant relationship between the position of the iliac spine and the center of the hip joint in the frontal plane, as demonstrated by the authors’ examination of 80 adult pelvic radiographs. Among the age groups examined, no influence of age, weight, or height was found. However, the significant sex-dependent difference in the pelvic shape must be taken into account when the location of the hip joint from the location of the iliac spine is calculated.
However, the presented coefficients cannot be generally applied because possible racial and younger age influences remain to be studied.

Another limitation of the photographic method is the principal methodologic difference in measuring the mechanical axis by the method suggested by Paley\(^3\) (the gold standard of long-leg radiography method) and the methods that can be used by photographic location of the centers of the hip, knee, and ankle. In Paley’s\(^3\) method, the mechanical axis is defined as the angle between the femoral mechanical axis (center of the hip to the distal femoral groove) and the tibial mechanical axis (center line of the tibia). In the normal knee, the effect of this methodological difference is minimal, but in the severely malaligned knee with possible subluxation, the difference may be significant.

**Conclusion**

The computerized photographic method, as validated in the current sample, appears to be an attractive alternative to long-leg radiographic examination and is expected to be a convenient supplement to routine clinical examination of patients with lower extremity pain and control after treatment of malalignment. It remains to be validated in broader age ranges, ethnic groups, and degrees of axial malalignment.

**References**


