**The Utility of the Modified Fels Knee Skeletal Maturity System in Limb Length Prediction**

*Ryan J Furdock, MD*; Elizabeth Cho; Alexander J Benedick, MD; Jiao Yu, MA; Abdus Sattar, PhD; Raymond W Liu, MD
ryan.furdock@uhhospitals.org

**What was the question?**
Predicting ultimate lower extremity length is important in the treatment of lower limb discrepancy (LLD). Utilizing skeletal age over chronological age has been shown to significantly improve the prediction of ultimate lower extremity length. The most widely used skeletal maturity systems utilize left hand and wrist radiographs, necessitating additional imaging in most cases. The recently described Modified Fels knee skeletal maturity system relies on AP knee radiographs to estimate skeletal age reliably and accurately via imaging that is always available in LLD patients. We sought to evaluate the utility of the Modified Fels knee skeletal maturity system in ultimate limb length prediction when applied to standing hips to ankles radiographs in a modern adolescent clinical population.

**How did you answer the question?**
The medical records of all patients treated at our institution over a 20–year period with unilateral lower extremity pathology and hips to ankles radiographs available both before and after reaching skeletal maturity were reviewed. Skeletal maturity was defined by closed distal femoral, proximal tibial, and proximal fibular physes. The femoral, tibial, and lower extremity length was measured in all radiographs. Measurements obtained after reaching skeletal maturity were used to define the ultimate femoral, tibial, and lower extremity lengths of each subject. The Modified Fels knee skeletal maturity system was applied to all radiographs taken prior to maturity to estimate skeletal age. The accuracy of three widely utilized lower extremity length prediction systems was compared when utilizing estimated skeletal age versus chronological age inputs. Cross sectional and longitudinal statistical analyses were performed. Statistical significance was set at p&0.05.

**What are the results?**
247 radiographs (109 prior to maturity) from 47 patients were eligible for inclusion. Patient demographics and measured ultimate femoral, tibial, and lower extremity length are summarized in Table 1. On cross–sectional analysis, linear mixed effects modeling using skeletal ages was uniformly associated with higher (improved) R2 values than chronological age–based models (Table 2). On longitudinal analysis, skeletal age models had lower Akaike information criterion (AIC) values than chronological age models in all cases, similarly indicating superior performance.

**What are your conclusions?**
In treatment of LLD, the Modified Fels knee skeletal maturity system can be readily applied to available imaging to improve the prediction of ultimate femoral, tibial, and lower extremity length. This skeletal maturity system may have significant utility in estimation of ultimate limb length discrepancy and determination of appropriate timing of epiphysiodesis.

Table 1: Summary Statistics of True (Measured) Leg Length

| Variable | n | Mean | SD | Median | CV[a] |
|---|---|---|---|---|---|
| Skeletal age (years) | 43 | 11.28 | 2.1 | 11.3 | 0.19 |
| Chronological age (years) | 43 | 11.56 | 2.0 | 11.4 | 0.17 |
| Ultimate Femoral Length (mm) | 43 | 489 | 43 | 491 | 0.09 |
| Ultimate Tibial Length (mm) | 43 | 386 | 38 | 385 | 0.10 |
| Ultimate Lower Extremity Length (mm) | 42 | 874 | 80 | 877 | 0.09 |

[a]Coefficient of Variation

Table 2: Comparison of Predicted Lengths Using Coefficient of Determination ($R^2$) Obtained from Linear Mixed Effects Models

| | Ultimate Femoral Length | | Ultimate Tibial Length | | Ultimate Lower Extremity Length | |
|---|---|---|---|---|---|---|
| | Skeletal Age Prediction | Chorological Age Prediction | Skeletal Age Prediction | Chorological Age Prediction | Skeletal Age Prediction | Chorological Age Prediction |
| | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ |
| Multiplier Method | 0.843 | 0.787 | 0.883 | 0.798 | 0.869 | 0.820 |
| White-Menelaus | 0.847 | 0.822 | 0.891 | 0.856 | 0.860 | 0.836 |
| Growth Remaining | 0.828 | 0.793 | 0.877 | 0.790 | 0.870 | 0.813 |

*Higher $R^2$ means better fit.*