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Original article

No relationship between mild limb length discrepancy and spine, hip or knee degenerative disease in a large cadaveric collection

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ABSTRACT

Background: Although asymptomatic mild limb length discrepancy (LLD) in children is generally treated non-operatively, there is limited high quality follow up data to support this recommendation.
Hypothesis: We hypothesized that there would be no association between LLD and arthritic changes with mild limb length discrepancy.
Materials and methods: We studied 576 well-preserved cadaveric skeletons ranging from 40 to 79 years of age. Limb length discrepancy was based on combined femoral and tibial lengths measured using digital calipers. Degenerative disease was hand graded in the spine, hips and knees using a previously described classification system. Power was set at 90%.
Results: Average age was 56 ± 10 years and average LLD was 4.8 ± 4.0 mm. Multiple regression analysis did not demonstrate any correlation between LLD and degenerative disease. After screening to find 26 additional specimens with LLD 10 mm or greater, and assessing a potentially quadratic relationship, we still did not find any detrimental effects of LLD.
Discussion: Our data support the general clinical recommendation of observation for mild asymptomatic LLD. These results do not apply to larger LLD nor LLD associated with other deformities or clinical symptoms.
Level of evidence: Not applicable, anatomic basic science study.

1. Introduction

Limb length discrepancy (LLD) is a common orthopaedic finding. A study in 999 men enlisted for compulsory military training in Sweden found that 32% had a discrepancy between 0.6–1.5 cm and 4% had a discrepancy of 1.6–2.5 cm, using examination of the iliac spines in stance [1]. A separate radiographic study found a mean LLD of 5.5 ± 4.1 mm in 247 controls [2].

The criteria for treatment of asymptomatic mild limb length discrepancy (LLD) are not well supported. Although it is often stated that a child with a predicted discrepancy of under 2 cm does not require any treatment [3], the literature behind this cutoff is mixed. Multiple studies suggest increased symptoms or gait issues starting at 2 cm or higher [4–8], while many others note findings starting below 2 cm [9–14].

Studies have compared LLD to arthritic changes in the spine, hips and knees in the older literature, with only one study written in the past 20 years per our knowledge [11,15,16]. These previous studies all have bias because their LLD groups were taken from symptomatic pools of patients, and their applicability to an asymptomatic adolescent patient is difficult. In treating the pediatric population, it would be clinically useful to know whether there are associated long-term consequences. This would help guide recommendations for epiphyseodesis and provide data for physicians to counsel families concerned about mild discrepancies.

Our hypothesis was that there would not be any association between mild limb length discrepancy and degenerative arthritis of the spine, hips and knees in a large random population.

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2. Materials and methods

2.1. Specimens

Cadaveric femora from the Hamann Todd Osteological Collection were analyzed. This is a collection of approximately 3000 well-preserved and well-documented skeletons. We randomly chose 625 skeletons where the femoral lengths had been previously measured. Inclusion criteria were any specimen in an existing femoral length database and between the ages of 40 to 79 years. Exclusion criteria included any obvious fractures of the femur or tibia (15), obvious rheumatologic disease (13), slipped capital femoral epiphysis (2), suspected Blount disease (1), evidence of infection affecting the joint surfaces (2), incomplete demographic information (2), or incomplete skeletons (14). Thus, we included 576 skeletons for primary analysis. Mean age for the 576 skeletons was 56 ± 10 years. There were 78 females and 498 males. There were 176 African-Americans, 398 Caucasians and 2 other ethnicities.

In order to increase the number of high LLD specimens, an additional 871 specimens were screened and both femoral and tibial lengths measured as noted below. Using the inclusion criteria of LLD 10 mm or greater and the same exclusion criteria above, we obtained 26 additional subjects for a total of 602 in our secondary analysis.

2.2. Length measurements

All length measurements were obtained using a digital ruler using a previously published technique [17]. Each femur was measured from the superior aspect of the femoral head to the femoral condyles. Femoral lengths were previously measured and available in a public database. One hundred sets of bilateral femora were measured by one of the study authors to confirm the accuracy of the database, with 25 sets chosen from each decade of life. Intraclass correlation coefficient between these measurements and the database was 0.999.

Tibiae were measured by the study authors from the lateral tibial plateau to the lateral tibial plafond. The femoral and tibial lengths on each side were then added together and compared to the opposite side to calculate limb length discrepancy. The height of the foot was not accounted for in this study, given the disarticulated nature of the skeletons.

2.3. Arthritis grading

Arthritis grading was performed by one author using a previously published grading system [17]. The grading system is based on direct examination of each specimen, with a focus on the percentage of the joint with osteophytic changes and the magnitude of these changes. Lumbar spines were graded from 0 to 4 at each level from L1-L2 to L5-S1 and averaged. Hips were graded from 0 to 3 at the acetabulum and proximal femur and combined. Knees were graded from 0 to 3 and each end of the medial, lateral and patellofemoral compartments to form three combined scores, which were then averaged. Thus, spine arthritis was graded between 0 to 4 and hip and knee arthritis each graded between 0 and 6. Arthritis grading was previously performed for the randomly selected 576 primary skeletons, with previous reliability analysis demonstrating Kappa values all within the good to excellent range with inter-relator reliability ranging from 0.60 to 0.88 between two experienced investigators, and intra-relator reliability ranging from 0.63 to 0.93 for the single investigator who graded all the specimens in the study. Arthritis grading was performed for the additionally screened high limb length discrepancy cohort for this study, using the same grader.

2.4. Statistics

All statistics were performed using SPSS Statistics Version 23 (IBM, Armonk, New York, USA). For our multiple regression analysis, independent variables were age, sex, race and absolute limb length discrepancy. Sex and race were categorical variables, while age and limb length discrepancy were continuous.

In order to ensure adequate sample size, a series of a-priori power analyses were conducted for each dependent variable (spine, long hip, short ship, long knee, short knee) [18]. For each power analysis, a "moderate" effect size of 0.15 was used [19], power was set at 0.9, significance was set at 0.05 and four independent predictors were assumed. This resulted in a minimum required sample of 108 specimens, indicating that our study was overpowered, which was desirable due to the anticipated lack of effect.

Separate analyses were run with the dependent variable set as degenerative arthritis of the spine, long hip, short hip, long knee and short knee. When analyzing the long hip group, we analyzed the arthritic score for the hip joint of the side with a longer combined femur and tibia length for each subject. A similar process with repeated for short hip, long knee and short knee. For each dependent variable, a repeat analysis was performed using a transformation where limb length discrepancy was squared, to evaluate for a possible non-linear relationship between LLD and arthritis. This analysis was performed in the primary data set of 576 specimens and then repeated in the larger secondary data set of 602 specimens. In each multiple regression analysis, multicollinearity was assessed as negative based on VIF (variance inflation factor) < 10 and coefficient tolerance > 0.1, normal probability plots of the regression standardized residual were inspected for normality, scatterplots of the standardized residuals were inspected for homoscedasticity and the lack of any undue influence from outliers was confirmed with a Cook's distance < 1.

3. Results

In the randomly selected set of 576 skeletons, mean femoral length was 455 ± 28 mm and mean tibial length was 365 ± 27 mm. Mean limb length discrepancy was 4.8 ± 4.0 mm, ranging from 0.0 to 30.9 mm. There were 56 specimens with discrepancy 10 mm or greater.

In regard to our hypothesis, there were no statistically significant effects of limb length discrepancy with arthritis of the spine, hips or knees. There was a strong correlation between age and arthritis grading (Fig. 1, Tables 1 and 2), with standardized betas ranging from 0.481 to 0.573 ($p < 0.0005$ for all). Females were protected against spine arthritis with a standardized beta of -0.072 ($p = 0.04$) and African-Americans have more knee arthritis in both the longer and shorter lower extremities, with standardized betas of 0.135 ($p < 0.0005$) and 0.099 ($p = 0.008$), respectively. Otherwise, there were no relationships between gender nor race with arthritis scores.

The addition of 26 specimens with LLD of 1 cm or greater provided a better representation at the higher LLD values. When adding these additional 26 specimens to the original 576, we had 65 specimens with LLD between 10 and 15 mm and 17 specimens with LLD above 15 mm. Multiple regression analysis of the 602 specimens demonstrated similar values at with the original 576 specimens, with no relationship between LLD or LLD^2 with arthritis at the spine, hips or knees (Table 3).

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