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Case Series

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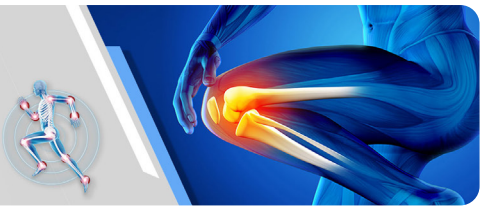

Accuracy of Ultrasound in Determining Proximal Humeral Epiphyseal Widening in Youth Athletes: A Case Series

Scott C Everett[1*], Andrew L Alejo[1], Blake Boggess[2], Emily Reinke[2], Cindy Green[2], Emily Poehlein[2], Benjamin Boswell[3,4]

Abstract

Exposing children to numerous radiographs in order to diagnose various musculoskeletal injuries is not ideal due to the deleterious side effects of ionizing radiation on growth plates. In particular, Little Leaguer's Shoulder is a common pediatric and adolescent injury that relies mainly on radiographs in order to recognize and treat. Thus, if other imaging modalities without ionizing radiation, such as ultrasound, can be shown to be reliable and accurate in measuring humeral physeal width, it may serve as a better means of identifying these injuries. The purpose of this study was to assess the consistency of two separate physician measures of proximal humeral epiphysis widening in children ages 12-16. Inter-rater and intra-rater reliability of ultrasound measurements of the proximal humeral epiphysis was calculated among twelve patients with open physes. Longitudinal measurements of the epiphyseal plate were obtained in three locations: just distal to the most lateral aspect of the acromion, 2 cm anterior to that line, and 2 cm posterior to that line with the same measurements repeated on the opposite arm. Measurements were then averaged for an overall width. Overall, no statistically significant variation was found when comparing epiphyseal plate width on dominant versus non-dominant arms. Ultrasonographic measurement of proximal humeral epiphyseal width shows narrow variability when used and interpreted by a sports medicine physician.

Keywords: Ultrasound, Shoulder, Humeral epiphysis, Epiphyseal widening

Abbreviations: BA: Bland-Altman; CI: Confidence Interval; LOA: Limits of Agreement; SD: Standard Deviation; US: Ultrasound

Introduction

Every year, millions of children play Little League baseball in the United States. Little Leaguer's Shoulder is a common injury that occurs most frequently in male overhead pitchers; however, it has also been observed in female overhead pitchers, youth catchers and tennis players. Little Leaguer's Shoulder is a common overuse injury occurring in young baseball pitchers resulting in epiphysiolysis of the proximal humerus. This injury typically appears between the ages of 11-16 years old and is increasing as rising numbers of youth athletes are developing sport specialization at a younger age. Currently, the diagnosis of Little Leaguer's Shoulder is made by comparing proximal humeral epiphyseal plate widening of the affected arm versus the unaffected arm by using ionizing plain film radiography [1-3].

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Various studies that compared ultrasound (US) to x-ray in pediatric forearm fractures found that ultrasound was cheaper, faster, and less painful for patients in addition to avoiding the use of ionizing radiation [4]. Sensitivity for ultrasound, compared to an x-ray gold standard, was 85% for metaphyseal humeral fractures in pediatric patients with a 75% negative predictive value [5]. MRI on the other hand, has also been shown to be helpful in diagnosing injuries to the growth plate that was not found on radiographs and allows the physician to follow the patient's progress during their recovery without the use of ionizing radiation, however it is often costly to the patient [6].

The most common ultrasound finding in juvenile males diagnosed with Little Leaguer's Shoulder was epiphyseal widening [7]. Other findings on sonography of the dominant shoulder displayed were physeal irregularities (45%), physeal fragmentation (21%), periosteal thickening (36%), and physeal widening (83%) [8]. Given the advantages of ultrasonography and the likelihood of success, we aimed to test the ability to consistently measure proximal humeral epiphyseal width in children ages 12-16 by using point of care US to see if it might be possible to use US in place of radiographs.

Methods

The enrollment phase of the study occurred during a 2-month period at an outpatient sports medicine clinic. During that time, subjects were screened during their evaluations for specific inclusion criteria. These criteria include subjects between ages of 12-16, radiographs within three weeks demonstrating an open physis in any extremity, and the availability of a parent or guardian to give legally effective consent. Exclusion criteria were findings of a proximal humerus fracture on radiographs, closed physeal plates, history of genetic abnormality, history of abnormal development, or inability to provide legally effective consent.

Once patients were enrolled, two primary care sports medicine providers performed US measurements of bilateral arms. Within a 10-week period, subjects returned to obtain another round of measurements by both physicians. Each physician was blinded from all previous measurements to prevent bias, and each measurement round was performed by the same physician separated by at least five days.

Measurements were obtained by placing the US probe on the lateral aspect of the acromion and scanning directly inferior until a long axis view of the humeral epiphyseal growth plate was obtained. Measurements were obtained in the same fashion: 2 cm anterior and posterior to the initial location, obtaining 3 measurements for an average measurement of the humeral epiphyseal plate. These measurements were then repeated on the opposite arm. All measurements were obtained using the linear probe on the same ultrasound machine (Sonosite X-Porte). This method was used to limit potential measurement differences among various machines.

Descriptive statistics were calculated to describe baseline demographic and clinical characteristics of patients undergoing ultrasound of bilateral arms. A paired t-test was used to compare the average dominant and non-dominant arm measurements from the first round of testing. Continuous variables were presented using the mean and standard deviation (SD) or median with 25th and 75th percentiles (Q1-Q3) as appropriate based on variable distribution. Categorical variables were summarized with frequency counts and percentages. Width measurements of the growth plates taken from ultrasound were measured in triplicate on both the right and left side with the average value used for analysis. A linear mixed-effects regression model was used to analyze the average width using both the patient undergoing ultrasound and physician reading ultrasound as the fixed effects and random effects dependent on the model (inter- or intra-rater) to account for the correlation between measurements conducted on the same patient and by the same physician.

Limits of agreement (LOA) and their associated 95% confidence interval (CI) were estimated in order to provide an interval within which 95% of the differences between measurements were expected to be found using the Bland-Altman (BA) method. This method was used for both inter-rater (Physician 1 vs. Physician 2) and intra-rater (Physician 1 vs. Physician 1 and Physician 2 vs. Physician 2) agreement. A BA plot was constructed to visualize both the inter- and intra-rater agreement. The acceptability of these limits of agreement was assessed based on clinician expertise. Analyses were performed using R (Hmisc, BlandAltmanLeh, and Blandr) and SAS version 9.4 (SAS Institute, Inc., Cary, NC).

Results

Twelve patients were enrolled in our study after parental consent and patient assent were obtained. Nine patients completed all four rounds of measurements. Two males and one female did not complete more than the first round of measurements. Patient ages ranged from 12 to 15 years, with an average age of 14 +/- 1 year. Seven patients (58.3%) were male and 11 (91.7%) were right arm dominant. Of the patients enrolled, five played baseball, three were gymnasts, one each were a soccer player, cheerleader, swimmer, or non-athlete. There were four patients enrolled who played multiple sports.

Measurements were taken using a static image. Locations used for measurements included the most lateral aspect of the epiphyseal plate extending from the proximal edge (marked by white crosses) to the distal edge (Figure 1). Overall, there was no statistically significant variation when comparing average epiphyseal plate width measured in the first round

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on dominant versus non-dominant arms (p=0.600) (Figure 2A). We observed what is likely to be the expected negative relationship between physeal width and subject age, but due to small sample size, this could not be statistically described with any significance (Figure 2B).

Average physeal width measurement in cm in the dominant vs nondominant arm in baseball (dark circles) and non-baseball players (light circles) at the first testing round (A). Dominant arm average physeal width in cm vs age in boys (black x) and girls (grey +) (B). The diagonal line represents x=y.

Raw comparisons between the two physicians for trial one and comparing between trial one and two for each physician was calculated (Figure 3). These comparisons across the identity line, demonstrate similar tight clustering for intra-rater measurements and looser cluster for inter-rater comparisons. To mathematically describe these comparisons, a Bland-Altman analysis was used (Figure 4). The mean inter-rater difference (bias) between Physician 1 and Physician 2 (Figure 4A) was 0.023 ± 0.045 cm, with a lower LOA of -0.066 cm (95% CI: -0.105 to -0.026) and an upper LOA of 0.112 cm (95% CI: 0.073 to 0.151). The difference between the mean bias and upper- and lower-most 95% CI of the LOA was +/- 0.089 cm. The mean intra-rater difference for Physician 1 (Figure 4B) was 0.018 ± 0.032 cm, with a lower LOA of -0.044 cm (95% CI: -0.072 to 0.017) and an upper LOA of 0.080 cm (95% CI: 0.052 to 0.107). The difference between the mean bias and upper- and lower-most 95% CI of the LOA was +/- 0.062 cm. The mean intrarater difference for Physician 2 (Fig 4C) was 0.010 ± 0.032 cm, with a lower LOA of -0.053 cm (95% CI: -0.082 to -0.025) and an upper LOA of 0.074 cm (95% CI: 0.046 to 0.102). The difference between the mean bias and upper- and lower-most 95% CI of the LOA was +/- 0.064 cm.

Average physeal width in cm comparisons for Physician 1 vs. Physician 2 on their first trial (A) and Physician 1 trial 1 vs. trial 2 (dark triangles) and Physician 2 trial 1 vs. trial 2 (grey squares) (B). The diagonal line in both graphs represents x=y.

Inter-rater agreement comparing Physician 1 to Physician 2 (data points for trial 1 only shown) (A), intra-rater agreement for Physician 1 during two trials (B), and intra-rater agreement for Physician 2 during two trials (C) is displayed using a Bland-Altman graph. The value in the boxes in the lower right of each graph represents the distance between the mean difference (bias) and the upper- and lower-most 95% confidence interval for the limits of agreement.

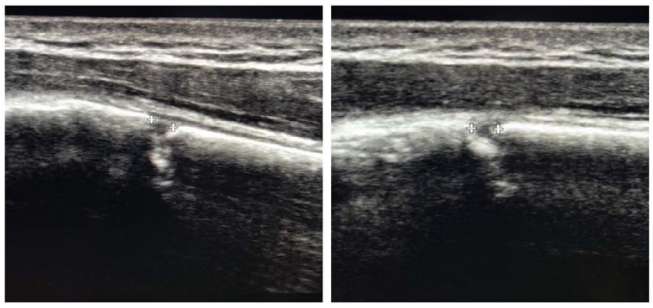

Figure 1: Ultrasonographic measurements obtained in long axis using a linear probe.

Discussion

Our study concluded that the ultrasound measurement of proximal humeral epiphyseal width is promising when used and interpreted by a physician, showing good intra-rater reliability. However, there is a larger variation when two separate physicians are measuring the humeral epiphyseal width, which limits inter-rater reliability. This is similar

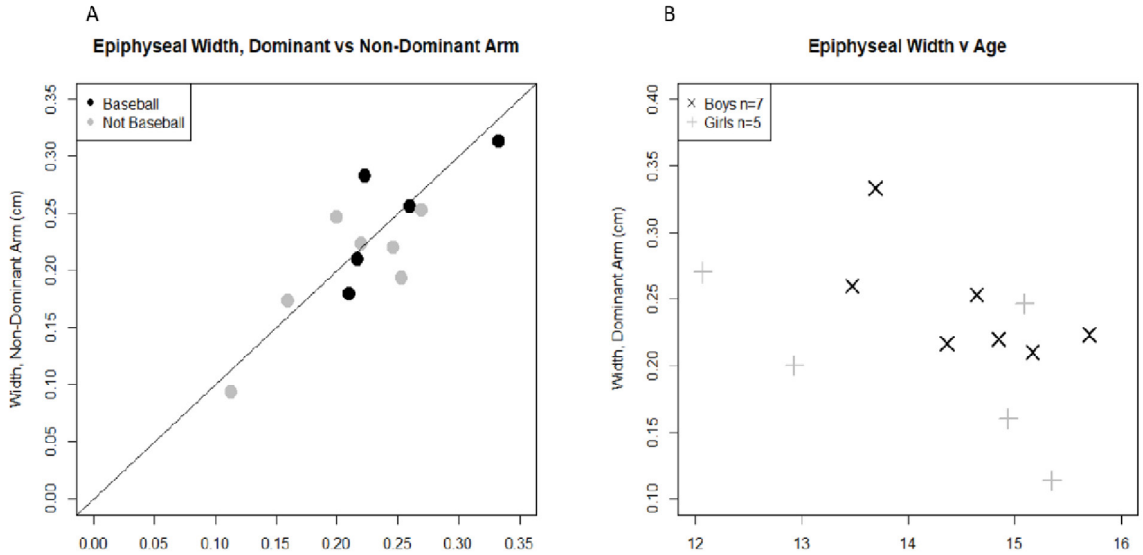

Figure 2: Graphical analysis of average physeal width.

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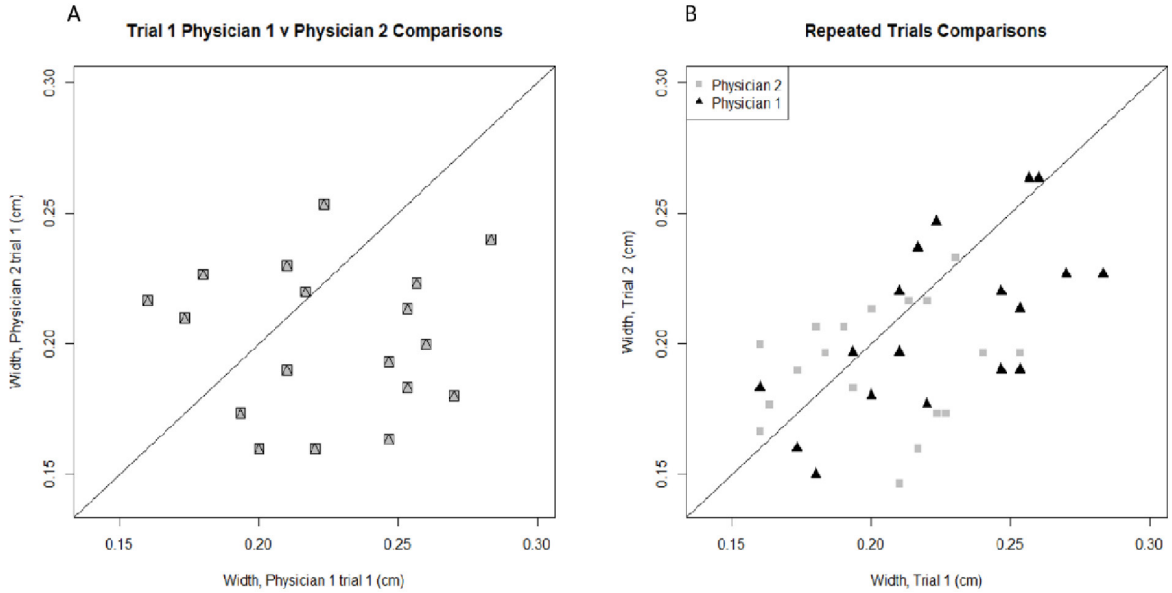

Figure 3: Graphical analysis of physeal width between physicians.

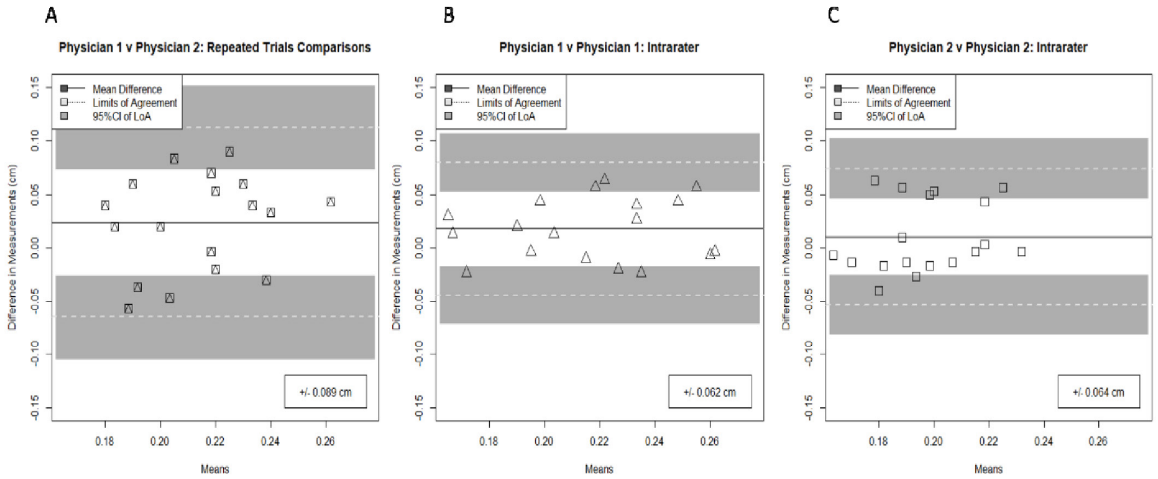

Figure 4: Graphical analysis of inter-rater agreement among physicians.

to what was found in a systematic review of ultrasound measurement of acromiohumeral distance done by McCreesh et al. [9]. A statistically significant difference was not found in epiphyseal width on dominant versus nondominant arms in asymptomatic patients, including both overhead and non-overhead athletes. This is in contrast to a report which found two of ten healthy juvenile males to have proximal humeral widening on radiograph despite the absence of any symptoms [10].

A systematic review by Douma-den Hamer D et al. [11] examined the diagnostic efficacy of using US in metaphyseal forearm fractures in children. They concluded that US carries high sensitivity and specificity. Sensitivity of ultrasound in forearm fracture diagnosis in the study was 97%, while the specificity was 95% [11]. This study also concluded that utilization of ultrasound can be faster, less painful, and more cost-effective, which was in line with our findings. Chen et al. [12] reviewed diagnosing and guiding reduction of forearm fractures in children using bedside ultrasound and found it was a reliable and convenient method to diagnose and reduce these fractures in the emergency room. Their initial success rate of ultrasound-guided reduction was 92%. Ultrasound application has been growing in the emergency department and its use has been advancing to assist physicians throughout various procedures. Decreasing ionizing radiation exposure to pediatric patients by using ultrasound in the previously mentioned studies has been shown to be a good substitute for radiographs. Our study adds onto the available data on using US in order to diagnose Little Leaguer's Shoulder.

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Limitations to this study included a small sample size, selection bias, patients lost to follow-up, and potential for user bias. Additionally, ultrasound in this setting has a potential for user error, absence of radiology comparison, no standard measuring system when crossing imaging modalities, variation in measurements, and potential to miss alternative pathology.

Conclusion

Overall, this study demonstrated the potential use of diagnostic ultrasonography for adolescents suffering from Little Leaguer's Shoulder and/or those who have other epiphyseal stress injuries. Currently, radiographs are the most commonly used imaging modality for the diagnosis of epiphyseal widening, and there is no protocol for the use of US as an alternative imaging technique currently. However, the results of this study demonstrate that ultrasound should be considered as a reliable alternative to imaging as a way of moving away from ionizing radiation in pediatrics and adolescents.

Conflicts of Interest:

The authors have no conflicts of interest to declare.

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