



● Clinical Note

UNUSUALLY HIGH CALCANEAL SPEED OF SOUND MEASUREMENTS IN CHILDREN WITH SMALL FOOT SIZE

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Abstract—The purpose of this clinical note is to describe the performance of the Lunar Achilles Insight device in assessing bone quality at the calcaneus in 142 children between the ages of 5 and 11 y accessing healthcare in Johannesburg, South Africa. We observed an asymmetric bimodal distribution in speed of sound (SOS). The minor mode consisted of unusually high SOS values (≥ 1625 m/s), which were primarily observed among children with foot size <19 cm and height <119 cm. Cortical regions of the bone may have been inadvertently included in the region of interest for smaller feet, causing unusually high SOS values. The unusually high SOS values indicate that the validity of SOS in this device, as it is currently used for measuring bone quality in young children, is questionable. Future studies using this device in young children should develop new methodology to account for smaller foot size. (E-mail: mt4@columbia.edu) © 2016 World Federation for Ultrasound in Medicine & Biology.

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INTRODUCTION

Quantitative ultrasonography (QUS) assesses bone quality by measuring the attenuation and speed of ultrasound wave propagation through bone. Speed of sound (SOS), a measure of velocity, refers to the distance traveled by the ultrasound wave divided by its travel time, while broadband ultrasound attenuation (BUA) is the slope of the frequency-dependent attenuation associated with the transmitted ultrasound wave. In calcaneal QUS with the Lunar Achilles Insight device, SOS and BUA are combined to calculate a manufacturer-specific parameter known as “stiffness index.”

Dual-energy x-ray absorptiometry (DXA) is considered the gold standard for assessing bone health; however, QUS has some advantages over DXA—QUS does not require radiation exposure or high-level training, it is

portable, it costs less than DXA to perform and it has a short scan time making it potentially well-suited for assessing and tracking bone acquisition in resource-constrained settings.

Although the manufacturer does not recommend its use in patients less than 20 y of age, data from the Lunar Achilles Insight device have been published on patients as young as 2 y (Herrmann et al. 2014; Sawyer et al. 2001). As part of a study to investigate the utility of QUS for assessing bone health in resource-constrained settings, we evaluated the performance of the Lunar Achilles Insight device in a group of children between the ages of 5 and 11 y in Johannesburg, South Africa. After observing a bimodal distribution in SOS values but not in BUA, we investigated what factors could account for this distribution.

MATERIALS AND METHODS

Patients

The Changes Bone Study is a longitudinal study of bone health in 440 children in Johannesburg, South Africa, including 220 HIV-infected children and 220

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population-appropriate HIV-uninfected control children. The study examines DXA as a primary outcome (Arpadi et al. 2016), while calcaneal and distal radius QUS are included as secondary outcomes. A future paper will compare QUS to DXA as well as compare QUS measurements between HIV-infected and uninfected children. The purpose of the current report is to investigate reasons for the bimodal distribution of SOS we observed in calcaneal QUS data from 142 participant visits that occurred between December 2014 and December 2015. Parents or guardians provided written informed consent, and children provided assent if they were at least 7-y-old and able to understand. The study was approved by the Institutional Review Boards of Columbia University (New York, NY, USA) and the University of the Witwatersrand (Johannesburg, South Africa).

Measurements

Measurements at the calcaneus of SOS in m/s and BUA in dB/MHz were obtained by a Lunar Achilles Insight QUS device (GE Healthcare, Madison, WI, USA). The device's built-in quality assurance test was run before every use to ensure proper coupling, unit temperature and water level. Standard operating procedures were followed as specified in the operator's manual provided by the manufacturer. The size and location of the region of interest (ROI) as well as the proper positioning of the foot were determined by consulting the real-time QUS image produced by the device. The smallest ROI setting of approximately 18 mm was used. Shims were utilized for positioning participants' feet that were smaller than USA women's size 6 and UK women's size 4.5, as recommended by the manufacturer. In addition, calcaneus stiffness index was calculated by the device using the following equation adapted from Njeh et al. (1999): stiffness index = $(0.67 \cdot \text{BUA} + 0.28 \cdot \text{SOS}) - 420$.

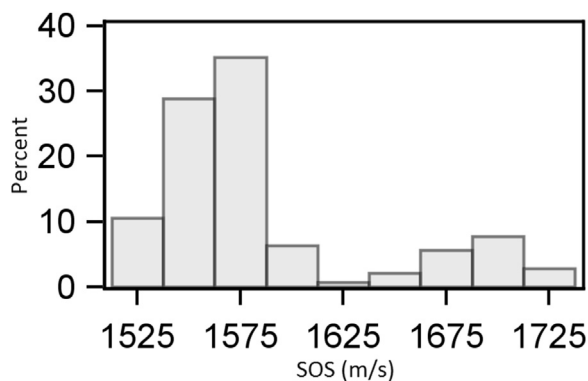


Fig. 1. The distribution of speed of sound (SOS) ultrasound measurements at the calcaneus in 142 South African children.

SOS exhibited an asymmetric bimodal distribution (see Fig. 1). As the minor mode consisted of SOS values ≥ 1625 m/s, we categorized these values as “high” SOS. The major mode of SOS < 1625 m/s was categorized as “low” SOS. In contrast, BUA had a slightly left-skewed distribution and did not appear to have any unusual measurements. Only one set of ultrasound measurements was taken for each child. However, we evaluated the agreement between ultrasound measurements in eight children taken by the two operators and found intra-class correlation coefficients of 0.91 for BUA and 0.98 for SOS.

Weight to nearest 0.1 kg was measured by a digital scale and height to nearest 0.1 cm by a stadiometer. Foot size to the nearest 0.5 cm was measured from the tip of the longest toe to the back of the heel, using a measuring mat imprinted with a ruler.

Statistical analysis

The characteristics of children with high SOS and low SOS were compared using *t*-tests or Wilcoxon tests for continuous variables and χ^2 tests or Fisher's exact tests for categorical variables.

SOS was plotted against foot size, height and age. Pearson correlation coefficients were calculated for foot size, height and age. All analyses were conducted using SAS 9.4 (SAS, Cary, NC, USA).

RESULTS

A total of 142 children (72 HIV-infected and 70 HIV-uninfected) were included in this analysis (Table 1). Approximately half (47.9%) were female and the median age was 7.4 y. The mean weight was 23.8 kg and mean height was 120.3 cm.

SOS was bimodally distributed (see Fig. 1). Of the 142 children, 26 (18%) had unusually high SOS (≥ 1625 m/s). Compared to children with low SOS, children with high SOS had a greater proportion of girls (65.4% vs 44.0%, $p = 0.048$), a significantly lower median age (6.7 y vs 7.8 y, $p < 0.01$), lower mean weight (18.8 kg vs 25.0 kg, $p < 0.01$) and lower mean height (112.1 cm vs 122.2 cm, $p < 0.01$). Children with high SOS also had lower mean BUA (65.4 m/s vs 93.9 m/s, $p < 0.01$) and higher mean stiffness index (98.0 vs 79.0, $p < 0.01$) compared to children with low SOS. HIV status, however, did not differ between children with high SOS and low SOS ($p = 0.0976$).

Figure 2a shows SOS plotted against foot size, grouped by age. The SOS data cluster into two groups corresponding to the two modes of the distribution of SOS—the low SOS group includes a wide range of foot sizes and the high SOS group includes predominantly smaller foot sizes, *i.e.*, < 19 cm. Of the 56 children with foot size < 19 cm, 24 (42.9%) had high SOS. In contrast

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