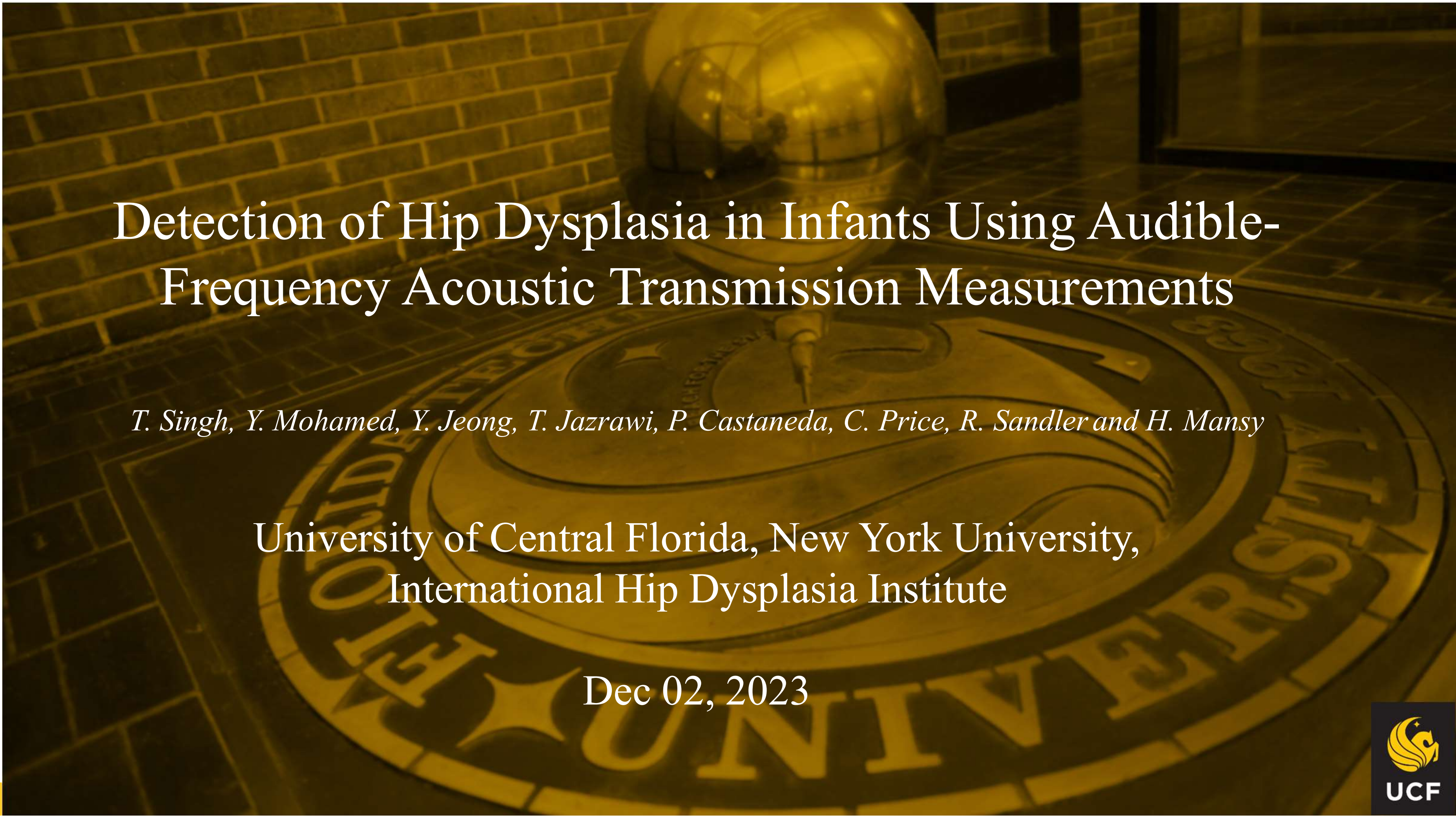

Detection of Hip Dysplasia in Infants Using Audible-Frequency Acoustic Transmission Measurements

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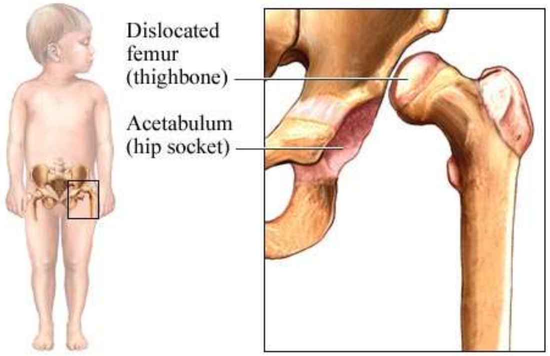
Outline

- Background and Motivation
- Research hypothesis and objectives
- Methods
- Results
- Conclusions and future work

BACKGROUND AND MOTIVATION

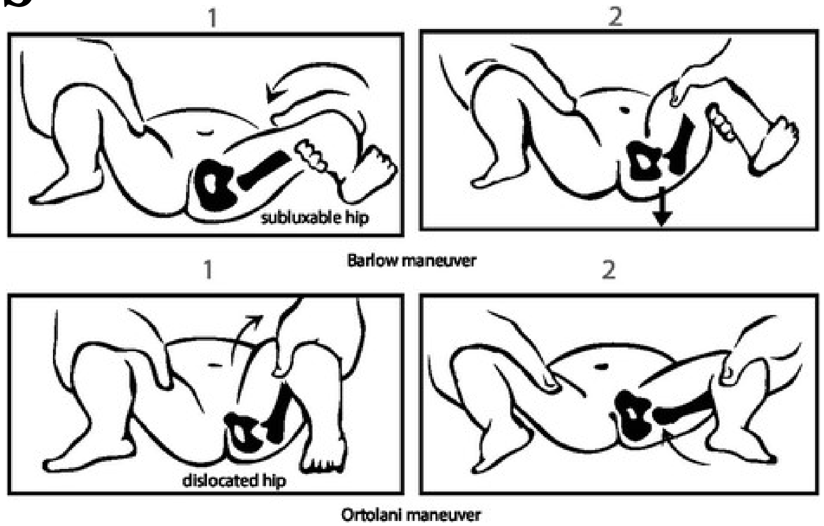
- **Definition:** Developmental dysplasia of the hip (DDH) is a problem with the way a baby's hip joint forms before, during, or after birth — causing an unstable hip and walking problems.
- **Incidence:** 2-3 neonates out of 1000 are suffering from DDH.
- **Treatment:** DDH is effectively treated if detected early; while delayed detection leads to less effective intervention and may lead to chronic disability.

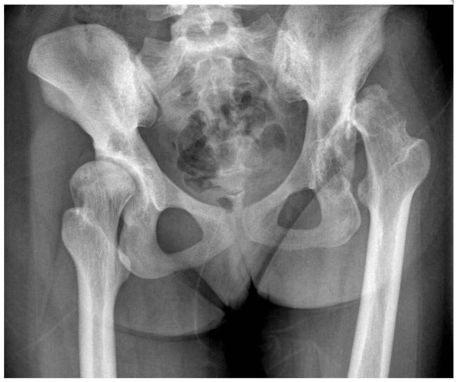


Pavlik Harness

Current diagnostic methods

- **Physical Exam:** Barlow and Ortolani maneuvers. (36% sensitivity).
- **Imaging:** The methods available include CT, Ultrasound, and X-ray.
- Imaging methods are accurate (>95%) but expensive, require significant skill and training, not the standard of care.
- A low-cost, easy to use and sensitive DDH screening method would be helpful to assist with early detection.




Developmental dysplasia of hips

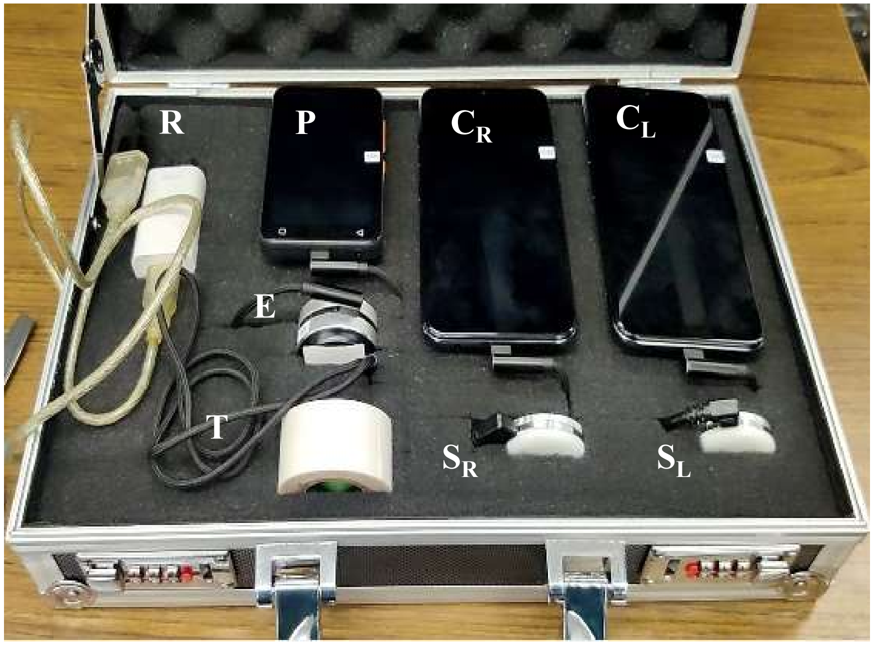
Hypothesis and Objective

- **Hypothesis:** The primary hypothesis is that audible sound transmission through the hip joint is affected by DDH and that these transmission changes are detectable.
- **Objectives**
  - Build an acoustic system that can reliably measure sound transmission across the hip joint.
  - Quantify the system accuracy in infants

The sound transmission measurement system

Requirements:

Easy to use in a clinical setting. Portable, wireless, compact, simple, self contained, high patient comfort. (Consult with physicians)



Components: The system consists of a Bluetooth digital player [P], a Bluetooth bone conduction exciter [E], two wireless stethoscopes [S_R, S_L, for the right and left patient sides], two cell phones to record transmitted sounds [C_R and C_L, for the right and left sides], a power charger [R], and a medical-grade double-sided tape [T].

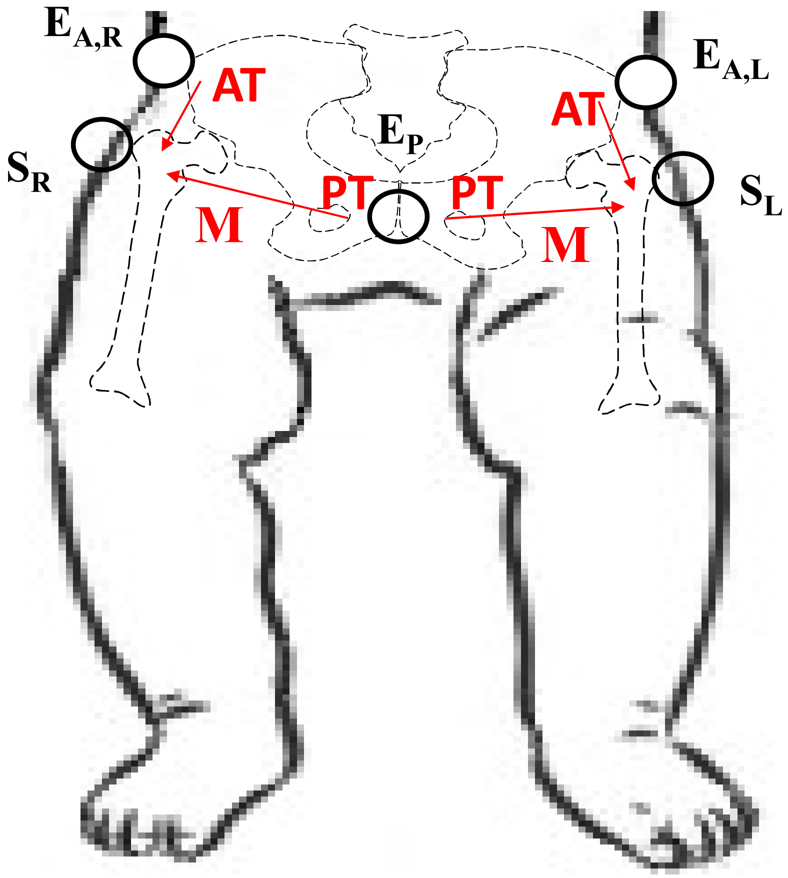
Experimental setup (showing two configurations)

- The stethoscopes stayed at the right and left trochanter [S_R and S_L].
- Two locations for the Exciter [E].

(1) At the pubis symphysis [Ep]. **PT**

(2) At either the right ASIS [$E_{A,R}$] or left ASIS [$E_{A,L}$]. **AT**

- There are muscles and soft tissue [M], that may have played a “bridging” role in sound transmission.
- Gold standard: Ultrasound imaging



Methods: Sound transmission analysis

- A MATLAB code was written to calculate the power spectral density, transfer function, phase and coherence between the excitation and transmitted signals.
- Time alignment of the excitation and transmitted signals was done using cross correlation calculations.

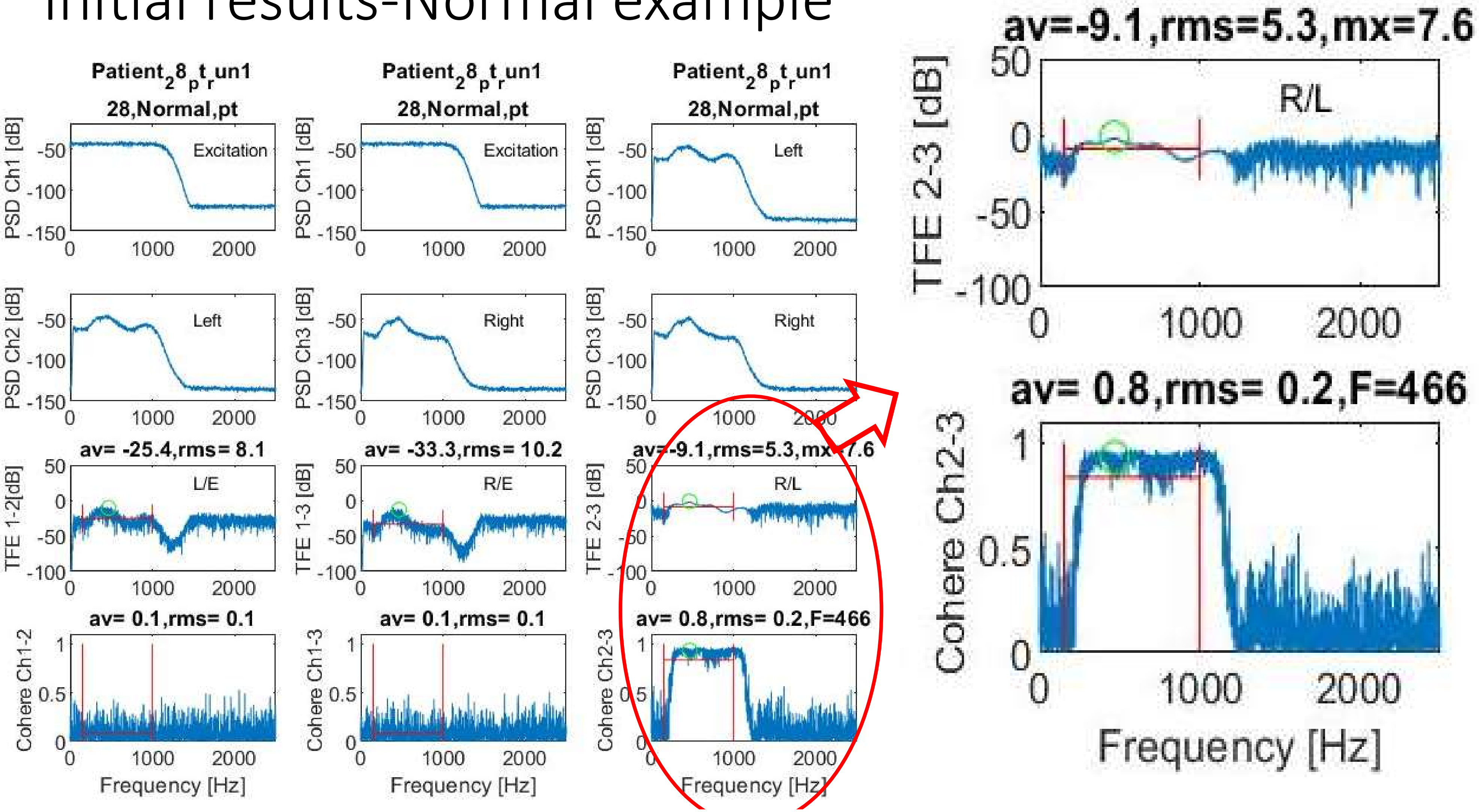
Transfer Function: Relates transmitted and stimulus signals. Measured in decibels(dB).

$$TF_{xy}\ (f) = \frac{P_{xy}(f)}{P_{xx}(f)}$$

Coherence: Measures the strength of the relation between two signals.

$$\gamma_{12}(f) = \frac{(Magnitude\ of\ the\ average\ P_{xy}(f))^2}{\left(Average\ P_{xx}(f)\right)(Average\ P_{yy}(f))}$$

Initial results-Normal example



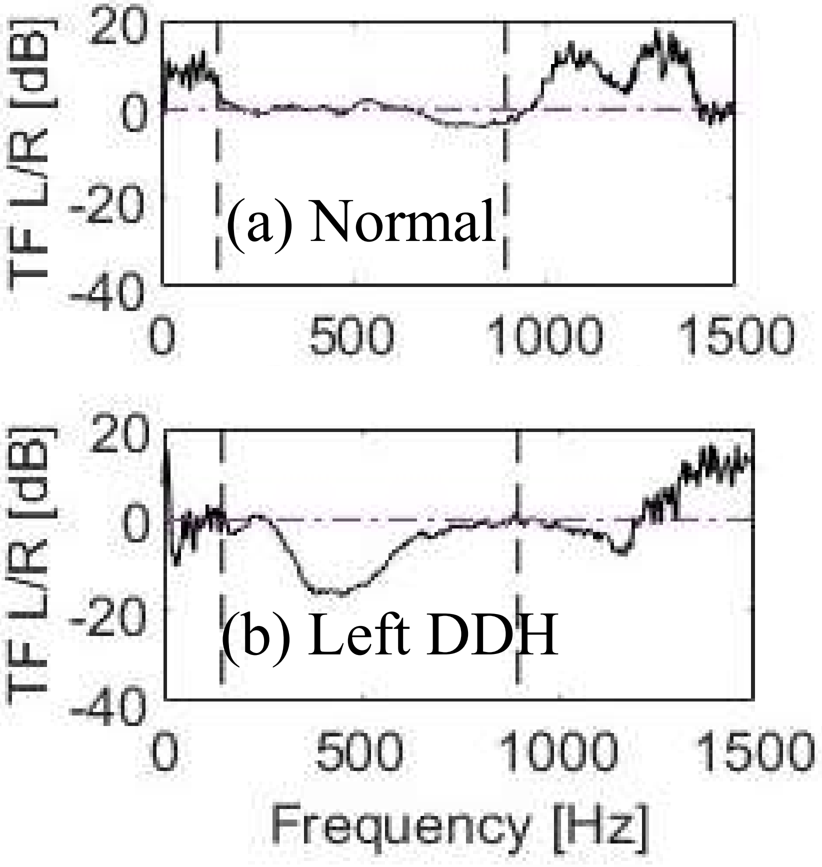
Results: Left/Right transfer function

Transfer function between the left and right stethoscopes (examples):

(a) Normal subject and

(b) Left DDH subject.

There was a drop of energy transmitted to the left stethoscope (compared to the right) in the left DDH subject. The vertical dashed lines mark the range of analysis (150-900 Hz), where the signal-to-noise ratio was high.



Results

Total: 66 subjects, 46 (70%) females

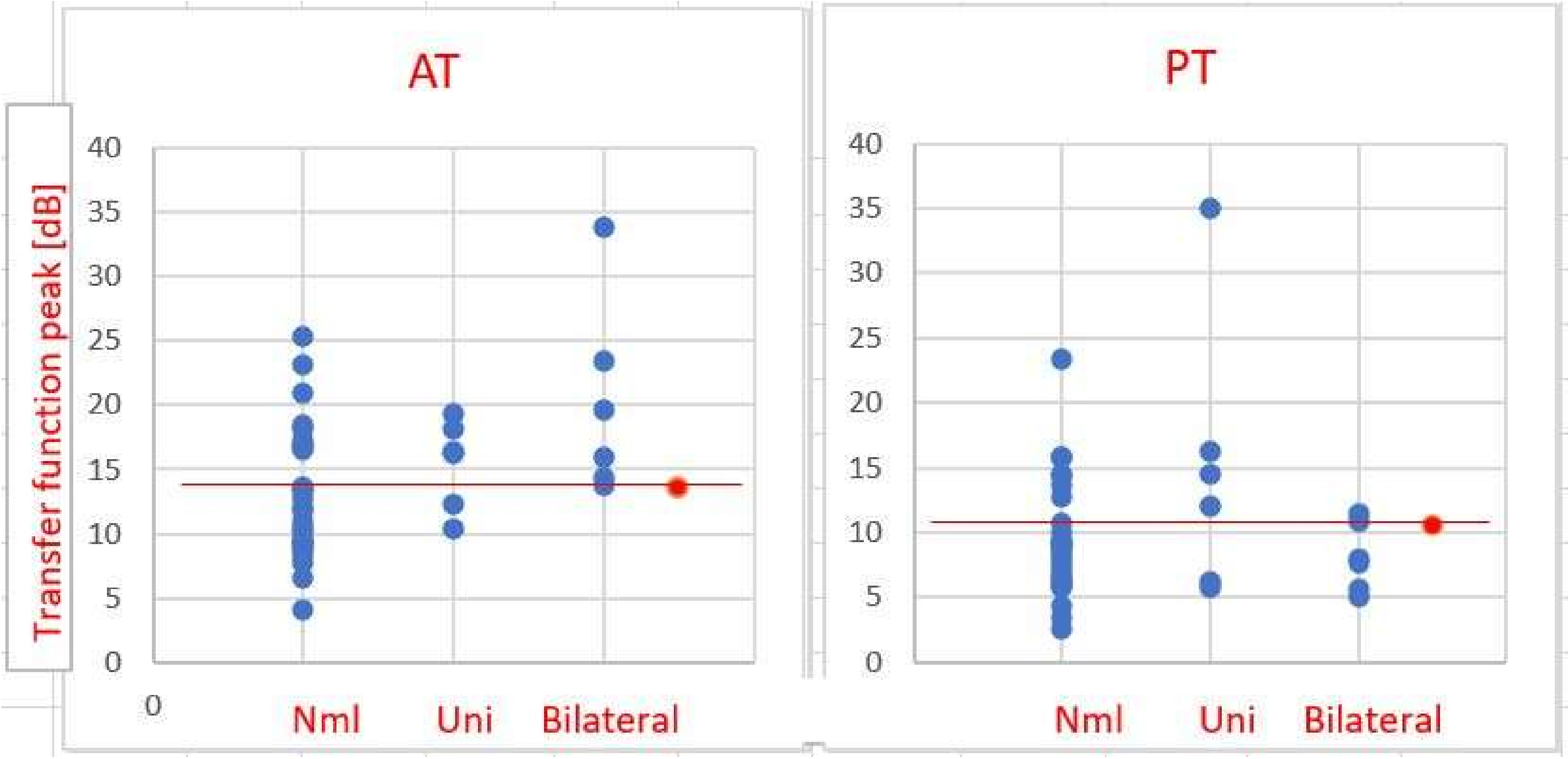
12 Subjects with DDH (positive)

- 5 unilateral (4 on the left, 1 on the right)
- 7 bilateral (worse on the left)

27 Normal (negative) subjects

27 subjects with high noise (low SNR), Excluded from analysis
Crying and movements (detected by listening to audio)

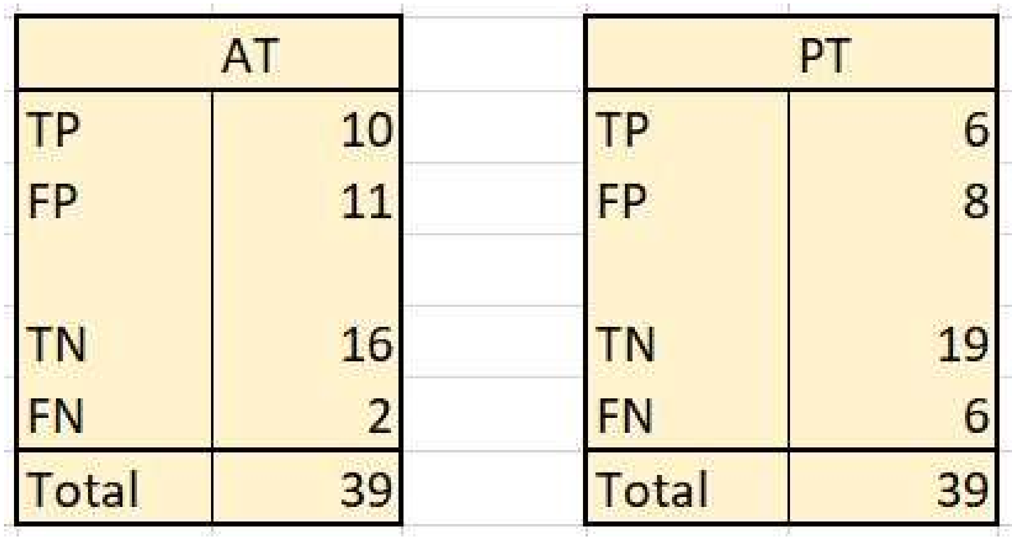
Results – Bilateral transfer function peak amplitude ($TF_{P\text{-amp}}$)



More symmetric transmission

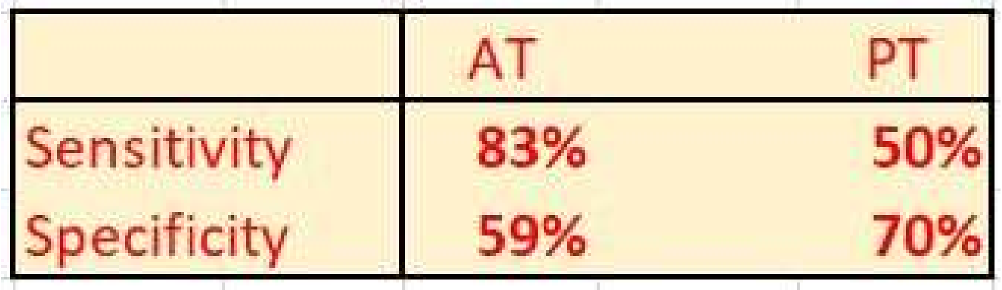
red dot=threshold level

Results



AT	
TP	10
FP	11
TN	16
FN	2
Total	39

PT	
TP	6
FP	8
TN	19
FN	6
Total	39



	AT	PT
Sensitivity	83%	50%
Specificity	59%	70%

Limitations (and potential solutions)

- Small number of subjects (more subjects)
- Enhance detection of unilateral and bilateral DDH (Hip maneuvers, extension/flexion)
- High signal noise: initially ~ 50% dropped to ~ 10% (calming baby, warming sensors, no speech during recording, noise removal methods)
  - Speech
  - Baby Crying and movement
- Time mis-alignment of different signals (optimizing time shift, add a timing mark to the future excitation signal)

Conclusions

- Sensitivity > 80% is possible
- Excitation at the ASIS and detection at the trochanter (AT configuration) provided higher sensitivity
- Calming baby significantly improved data quality

Future plans

- Collect more human data
- Add hip maneuvers, e.g., extension/flexion to the protocol (to increase asymmetry of abnormal hips)
- Add a synchronization "mark" to the excitation signal
- Perform finite element analysis of the system to help optimization