GLOBAL PEDIATRIC HEARING HEALTH
IN SEARCH OF NOVEL SOLUTIONS TO CURRENT CHALLENGES

A Sound Foundation Through Early Amplification 2013

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OUTLINE

• Global Childhood Hearing Health – Challenges
  – Prevalence
  – Access to care

• Exploring Novel Solutions
  – Remote diagnosis of ear disease in primary health care
  – Mobile hearing screening solution
PREVALENCE OF CHILDHOOD HL

• Disabling HL (>40dB for adults >30dB for children in better ear) prevalence:
  – 120 mil in 1995
  – 278 mil in 2005
  – 360 mil in 2013*

* 5.3% of world population

• 32 million of which are children

• Mild and greater – 160 million children

(WHO, 2006; WHO, 2013; Olusanya & Newton, 2007)
# PREVALENCE OF CHILDHOOD HL

<table>
<thead>
<tr>
<th>Regions</th>
<th>DHL in children (&lt;15 yoa)</th>
<th>Prevalence %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Millions</td>
<td></td>
</tr>
<tr>
<td>High-income</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>6.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Middle East &amp; North Africa</td>
<td>1.2</td>
<td>0.9</td>
</tr>
<tr>
<td>South Asia</td>
<td>12.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Asia Pacific</td>
<td>3.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Latin America &amp; Caribbean</td>
<td>2.6</td>
<td>1.6</td>
</tr>
<tr>
<td>East Asia</td>
<td>3.6</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>World</strong></td>
<td><strong>31.9</strong></td>
<td><strong>1.7</strong></td>
</tr>
</tbody>
</table>

(WHO, 2013)
Prevalence decreases exponentially as GNI increases.

(Prevalence of Disabling Hearing Loss for children until 14 years old)

WHO, 2013
PREVALENCE OF CHILDHOOD HL

- **120 million** annual births in developing world

- **798 000** - permanent bilateral HL (25% from SSA)
  - *Higher prevalence of ANSD* – *(10.3 to 21.4% of permanent HL’s)*

- **53 150** - permanent bilateral HL in all developed countries *(Ratio 1:14)*

Global Situation

- Everyday 1,753 born with significant permanent SNHL:
  - 1,643 born in developing world (5/1000)
  - 110 born in developed countries (3/1000)
- >90% born in developing world

(UNICEF, 2008; Olusanya & Newton, 2007; Olusanya et al. 2008; Smith et al. 2005)
HEARING HEALTH CARE ACCESS

Goulios & Patuzzi, 2008
HEARING HEALTH CARE ACCESS

Survey of hearing health care services in SSA (Fagan & Jacobs, 2009):

![Bar chart showing audiologists per 100,000 people across different countries. The UK has significantly more audiologists than other countries.](Fagan & Jacobs, 2009)
ENT distribution across SSA countries:

1: 250,000 – 7.1 mil
HEARING HEALTH CARE ACCESS

Projected demand for audiology services over next 30 years (US)

Windmill & Freeman, 2013
HEARING HEALTH CARE ACCESS

Status of NHS screening globally

• At least 7 countries screen >90% of births
  – Austria, Netherlands, Oman, Poland, Slovakia, UK, USA

• At least 9 countries screen 30 – 89% of births
  – Australia, Belgium, Canada, Germany, Ireland, Philippines, Russia, Singapore, Taiwan

• At least 46 countries evidence programs (pilot, limited)

(White, 2010; Olusanya, Swanepoel et al. 2007)
HEARING HEALTH CARE ACCESS

• Good coverage in some developed countries
• Pilot programs starting in many developing countries
• **BUT**: Globally >90% of babies born with HL have no prospect of early detection
• Detection primarily passive:
  – Complications of OM
  – Speech & language delays
  – Unusual behavior
• Exacerbate impact of HL - consigns to seclusion, limited access & quality of life
EXPLORING NOVEL SOLUTIONS

Access to Care

Detection

Diagnosis

Intervention

1. Remote ear diagnosis

2. Mobile phone technology and connectivity for hearing screening
The number of mobile subscriptions will soon overtake the world’s population.

2002
There are over 1 billion mobile subscriptions, passing fixed-line users.

1978
First commercial cellular mobile services established.

1961
85 years later, fixed-line subscriptions reach 100 million.

1876
Alexander Graham Bell holds the first two-way telephone conversation.
The pace at which mobile phones spread globally is unmatched in the history of technology.

Percent of the world's population with mobile cell signal:

- 2003: 61%
- 2010: 90%

Over 6 billion mobile subscriptions worldwide. Over 75% of the world now has access to a mobile phone.

World Bank, 2012
THE DEVELOPING WORLD IS NOW MORE MOBILE THAN THE DEVELOPED WORLD.

Most phones are owned by people living in low-income regions.

ACCESS TO A RANGE OF MOBILE APPLICATIONS HAS INCREASED DRAMATICALLY THROUGHOUT THE LAST DECADE.

World Bank, 2012
REMOTE DIAGNOSIS OF EAR DISEASE

Background

• Global burden from chronic OM affect 65 – 330 million
• Prevalence of COM can be as high as 46%
• India & sub-Saharan Africa account for most deaths from OM
• COM – 1) risk of hearing loss and 2) life-threatening complications (e.g. meningitis, brain abscesses)
• Largely preventable and effective medical management
• Early detection and treatment at primary health care can reduce long-term morbidity and mortality

BUT - Poor access to specialist personnel limit diagnosis and appropriate treatment

(WHO, 2013; Acuin, 2004)
REMOTE DIAGNOSIS OF EAR DISEASE

• **Aim:** To evaluate the *effectiveness* and *accuracy* of *video-otoscopy* recordings by a trained *non-professional* for remote *diagnosis* of *ear disease* in children

• **Design:** Within-subject comparative design

• **Subjects:** *140* unselected children (*2 – 15* yoa; mean *6.4 ±3.5* yoa; *44.3%* female) attending a PHC

• **Context:**
REMOTE DIAGNOSIS OF EAR DISEASE
REMOTE DIAGNOSIS OF EAR DISEASE
REMOTE DIAGNOSIS OF EAR DISEASE

Equipment and procedures:
REMOTE DIAGNOSIS OF EAR DISEASE

Concordance of otomicroscopy and remote video-otoscopy

<table>
<thead>
<tr>
<th></th>
<th>Onsite diagnosis n = 272 ears</th>
<th>Remote diagnosis n = 269 ears</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Otologist (%)</td>
<td>Otologist (%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Review 1</td>
</tr>
<tr>
<td>Normal</td>
<td>75.8</td>
<td>58.4</td>
</tr>
<tr>
<td>Otitis media:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AOM</td>
<td>16.5</td>
<td>16.7</td>
</tr>
<tr>
<td>CSOM</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>SOM</td>
<td>4.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Undetermined</td>
<td>11.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

R1 Kappa = 0.702
R2 Kappa = 0.740
Substantial agreement

Sens / Spec = 78% / 95%
Intra-rater diagnosis Kappa – 0.773
CONCLUSIONS

• A non-professional, with no health care training, can be trained to acquire adequate video otoscopic recordings for remote otologic diagnosis

• Remote diagnosis accuracy is similar to inter- and intra-rater agreement previously reported

• Accompanied with audiometric data it can be a valuable diagnostic tool to underserved populations

• Video recordings improved diagnostic utility above images

• More experience may improve quality of recordings
School-based screening

First opportunity for screening in sub-Saharan Africa

Screen for barriers to learning – educationally significant HL

South Africa - 2012 policy requiring screening of 1.2 mil children entering school annually
CHALLENGES WITH SCREENING?

6. Data capturing; 7. Data surveillance
MOBILE HEARING SCREENING SOLUTION

- **Aim**: To determine if an Android-based smartphone can be used as a calibrated screening audiometer with real-time noise monitoring for school-based screening using semi-automated test sequences

- **Design**: 3 phase study
  1. **Calibration accuracy** of pure tones across smartphones using commercial headphones
  2. Accuracy of smartphone microphone calibration for noise monitoring
  3. **Screening outcomes** of smartphone based semi-automated compared to conventional hearing screening
MOBILE HEARING SCREENING SOLUTION

Android application developed:

• **Transforming** smartphone to screening device using commercial headsets

• **Calibration functionality** for pure tone signals

• **Pre-programmed** screening protocols & **automated** test sequences

• **Microphone SLM calibration functionality** to monitor environment

• **Data capturing** and **sharing** features integrated
MOBILE HEARING SCREENING SOLUTION
PHASE 1 – PURE TONE CALIBRATION

Evaluate calibration of four Samsung S5301 smartphones (Android v4.0.4)

Commercial Sennheiser (HD202) headsets

Standard artificial ear B&K Type 4152 coupler

Rion NA-28, Intergrating Sound Level Meter and 1/3 Octave Band Analyser
# PHASE 1 – PURE TONE CALIBRATION

Pure tone calibration difference from specified standards across 4 phones and headsets (ANSI 3.6)

<table>
<thead>
<tr>
<th>Calibration levels</th>
<th>20 dB HL</th>
<th>30 dB HL</th>
<th>40 dB HL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 kHz</td>
<td>2 kHz</td>
<td>4 kHz</td>
</tr>
<tr>
<td>Average Difference</td>
<td>0.9</td>
<td>0.5</td>
<td>-0.6</td>
</tr>
<tr>
<td>SD</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Max diff (abs)</td>
<td>1.0</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

≤ 1 dB calibration error
**PHASE 2 – NOISE MONITORING**

**Phase 2a:** Attenuation of headphones to assess MPANL’s 15 normal hearing subjects

Free-field thresholds testing with and without transducers
Phase 2 – Noise Monitoring

**Phase 2b**: 5 microphones to determine reference levels corresponding to Type 1 SLM NBN intensity presented from 30 to 70 dB SPL in 5 dB increments (0° azimuth, 1m from speaker, 87.5cm above floor).

Corresponding smartphone amplitude readings recorded.

Average calibration map determined and variability between microphones investigated.
PHASE 2 – NOISE MONITORING

![Graph showing FFT average value vs. SLM (dB) for different frequencies (1 kHz, 2 kHz, 4 kHz).](image-url)
PHASE 2 – NOISE MONITORING

Maximum deviation across 5 smartphone microphones compared to reference sound intensity

![Graph showing maximum deviation across different dB SPL levels for 1 kHz, 2 kHz, and 4 kHz frequencies.](image-url)
DEVICE FEATURES
DEVICE FEATURES

1kHz Left Ear

1kHz at 35dB (L)

Present

1kHz at 20dB (L)

1kHz at 30dB (L)

Did you hear the sound?

No

Yes

University of Pretoria Patent
DEVICE FEATURES

TEST RESULTS

Test Duration: 38s
Left Ear: Fail
  30dB 1kHz: Pass
  20dB 1kHz: Fail
  20dB 2kHz: Pass
  20dB 4kHz: Pass
Right Ear: Fail
  30dB 1kHz: Pass
  20dB 1kHz: Pass
  20dB 2kHz: Fail
  20dB 4kHz: Pass
Final Result: Refer

Filter Database

Select Database Filters

- Facility Filter
  - Select Facilities

- Date Filter
  - From: To:

yyyy/mm/dd

Share Via

University of Pretoria Patent
PHASE 3 – CLINICAL VALIDATION

- Screening audiometry – 1, 2 and 4 kHz at 25 dB
- Conventional and smartphone-based screening
- Same-day counterbalanced
- 136 children (5 – 9 yoa; Ave 6.7 +/- 0.7)
PHASE 3 – CLINICAL VALIDATION
# PHASE 3 – CLINICAL VALIDATION

<table>
<thead>
<tr>
<th>Mobile phone screening</th>
<th>Conventional screening</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
<td>Refer</td>
</tr>
<tr>
<td><strong>Pass</strong></td>
<td>92.6% (252)</td>
<td>3.7% (10)</td>
</tr>
<tr>
<td><strong>Refer</strong></td>
<td>2.6% (7)</td>
<td>1.1% (3)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>95.2% (259)</td>
<td>4.8% (13)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mobile phone screening</th>
<th>Conventional screening</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
<td>Refer</td>
</tr>
<tr>
<td><strong>Pass</strong></td>
<td>93.4% (121)</td>
<td>4.4% (6)</td>
</tr>
<tr>
<td><strong>Refer</strong></td>
<td>4.4% (6)</td>
<td>2.2% (3)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>97.8% (127)</td>
<td>6.6% (9)</td>
</tr>
</tbody>
</table>

Smartphone screen: **26.3 seconds (6.4 SD; Range 19 – 49)**
PHASE 3 – CLINICAL VALIDATION

2014 Clinical Trials

School-based
- School screening of 2000 - 3000 children with conventional and smartphone based screening
- Diagnostic follow-up to establish sensitivity / specificity

Community Health Care Worker project
- Roll-out to 500 CHW
CONCLUSIONS

• Rapidly changing world
• **Hearing loss** prevalent with inadequate human resources to meet **demands**
• Continued **growth** in **technology** and **connectivity** will change the way in which we deliver services. E.g.
  – Remote ear diagnosis
  – Cost-effective solutions for reliable hearing screening
• Promise of **reaching** more patients, and especially those in **underserved** areas, **more effectively** (time and cost)

*Because “children [with hearing loss] are equally entitled to an exciting and brilliant future”*
QUESTIONS?