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# Update on the Clinical Utility of Vestibular Evoked Myogenic Potentials

Faith W. Akin
*East Tennessee State University*, akin@etsu.edu

Owen D. Murnane
*East Tennessee State University*, murnane@etsu.edu

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Faith W. Akin, Ph.D. and Owen D. Murnane, Ph.D.
Vestibular/Balance Laboratory
VA Medical Center, Mountain Home, TN

Department of Audiology and Speech Language Pathology
East Tennessee State University



# Disclaimer

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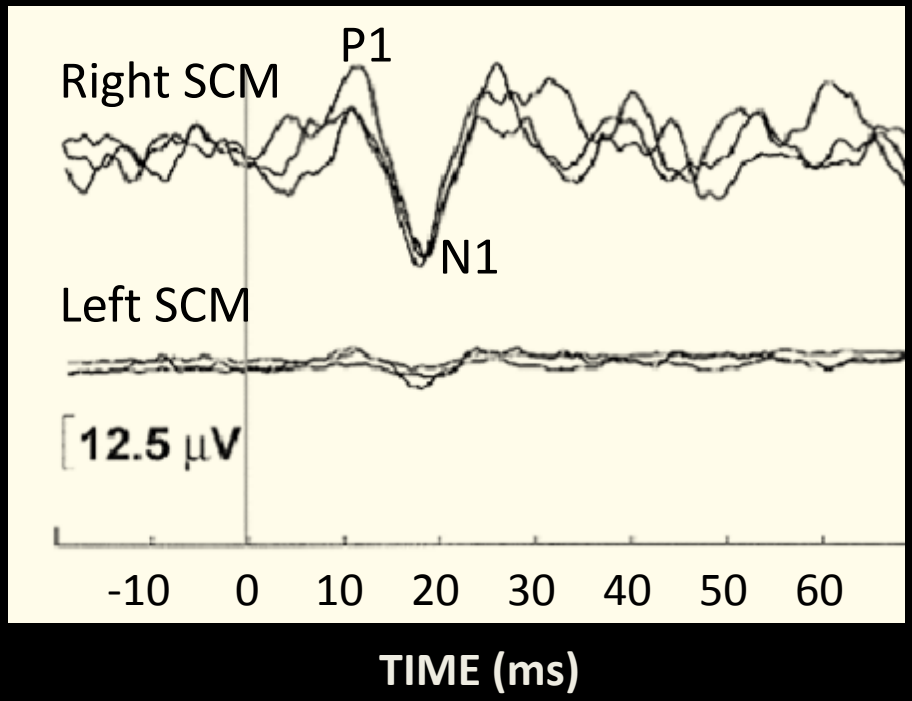
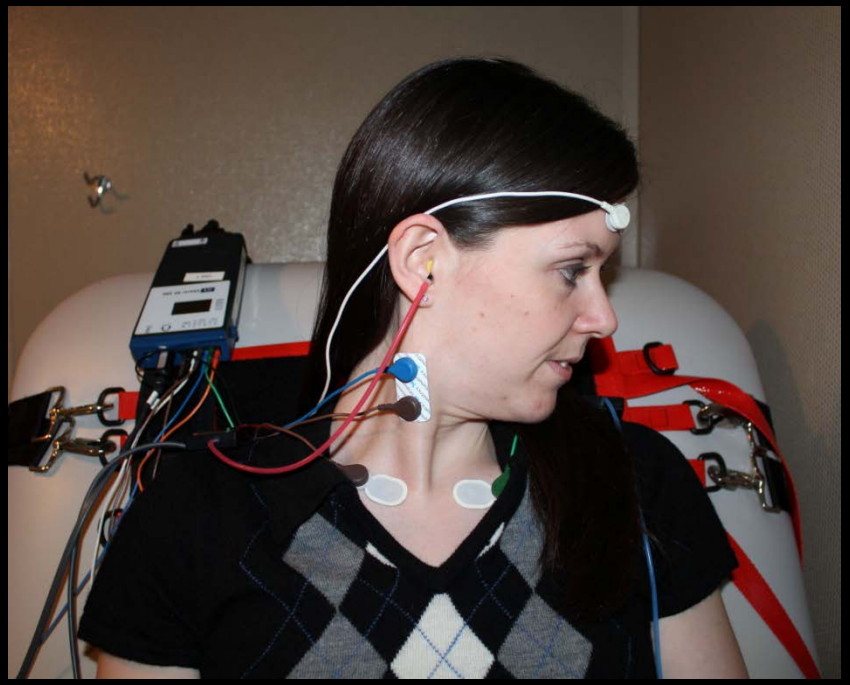
The views expressed here are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

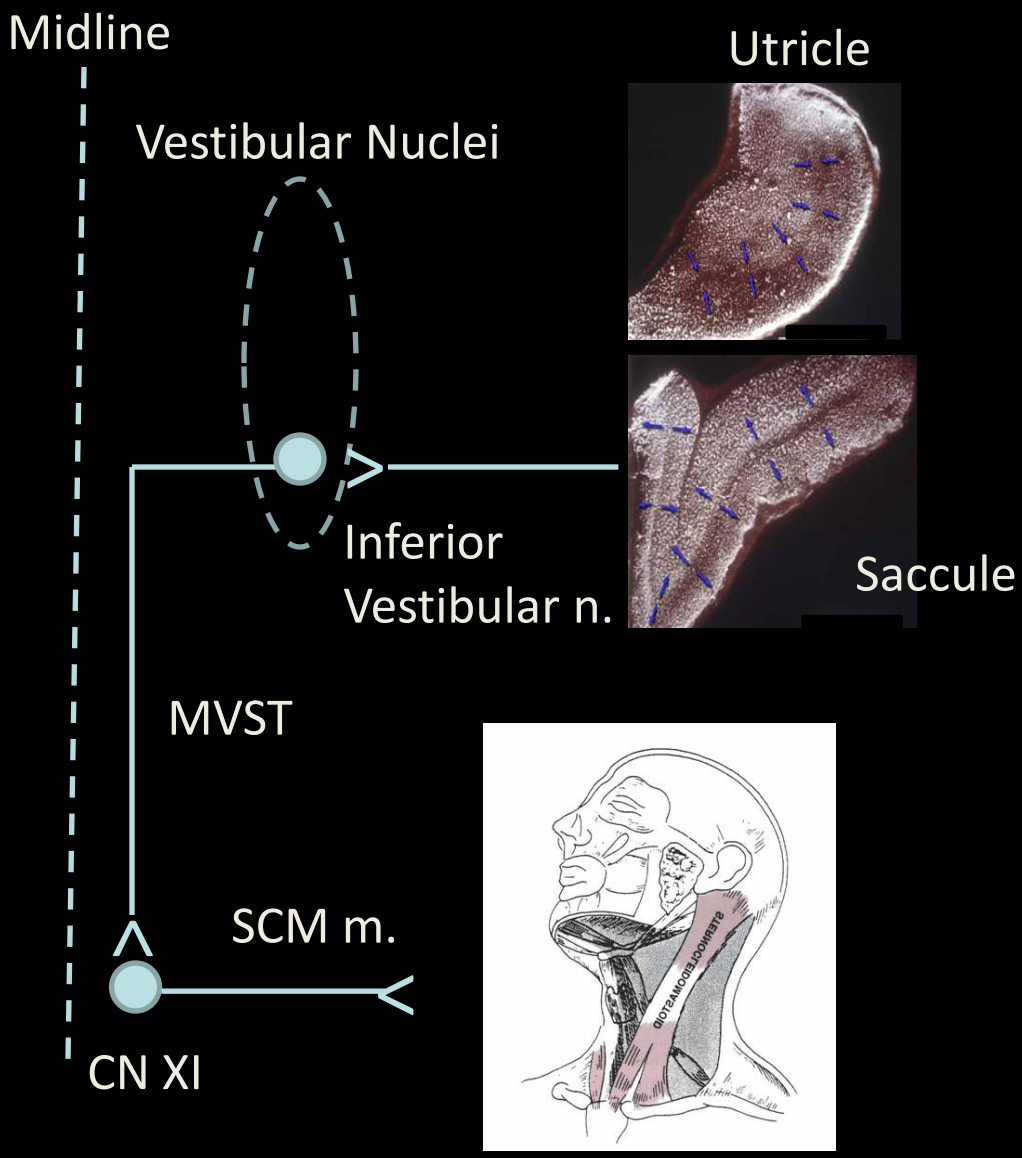
# Two-Channel Recording of cVEMP

Right SCM M. Activation/
Right Ear Stimulation



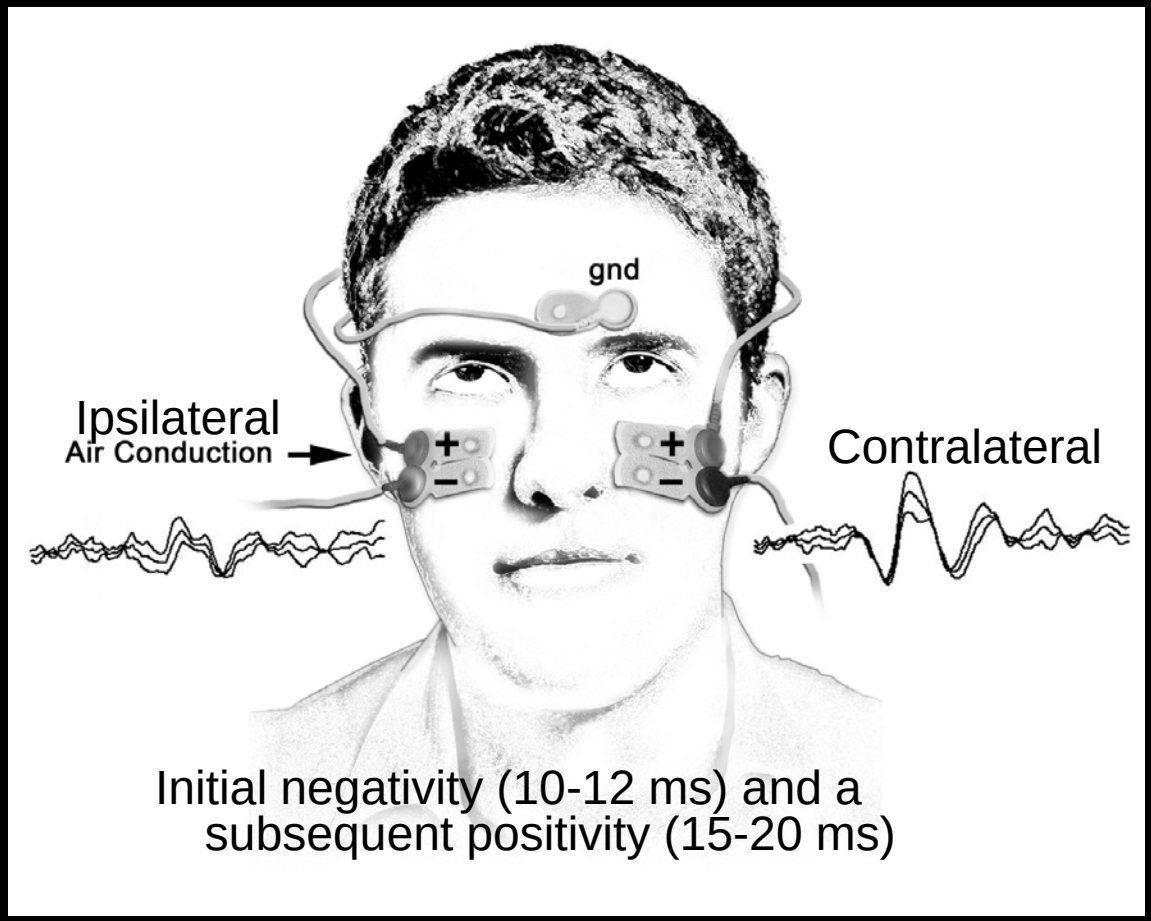



# cVEMP Pathway



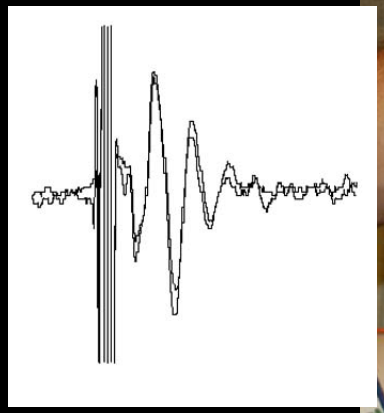
# Ocular VEMP: Air Conduction

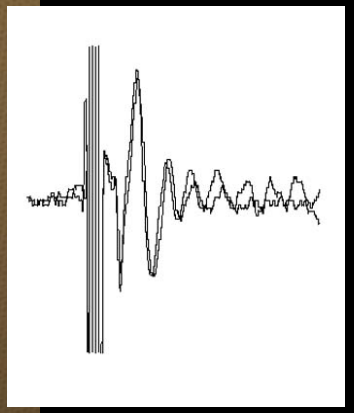
Recorded from electrodes beneath the eyes with patient looking up



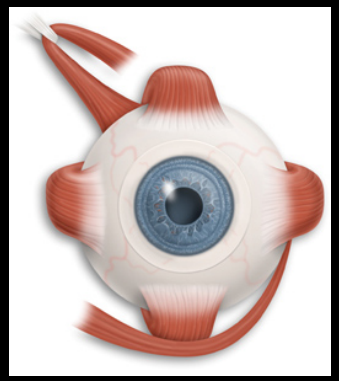

*adapted from Murnane & Akin, 2009*

# oVEMP B&K 4810 Minishaker





# oVEMP Pathway



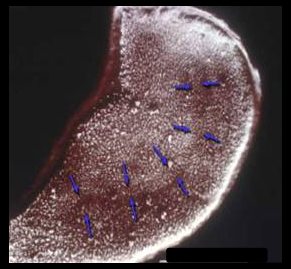
CN III

Inferior Oblique m.

MLF

Vestibular Nuclei

Utricle



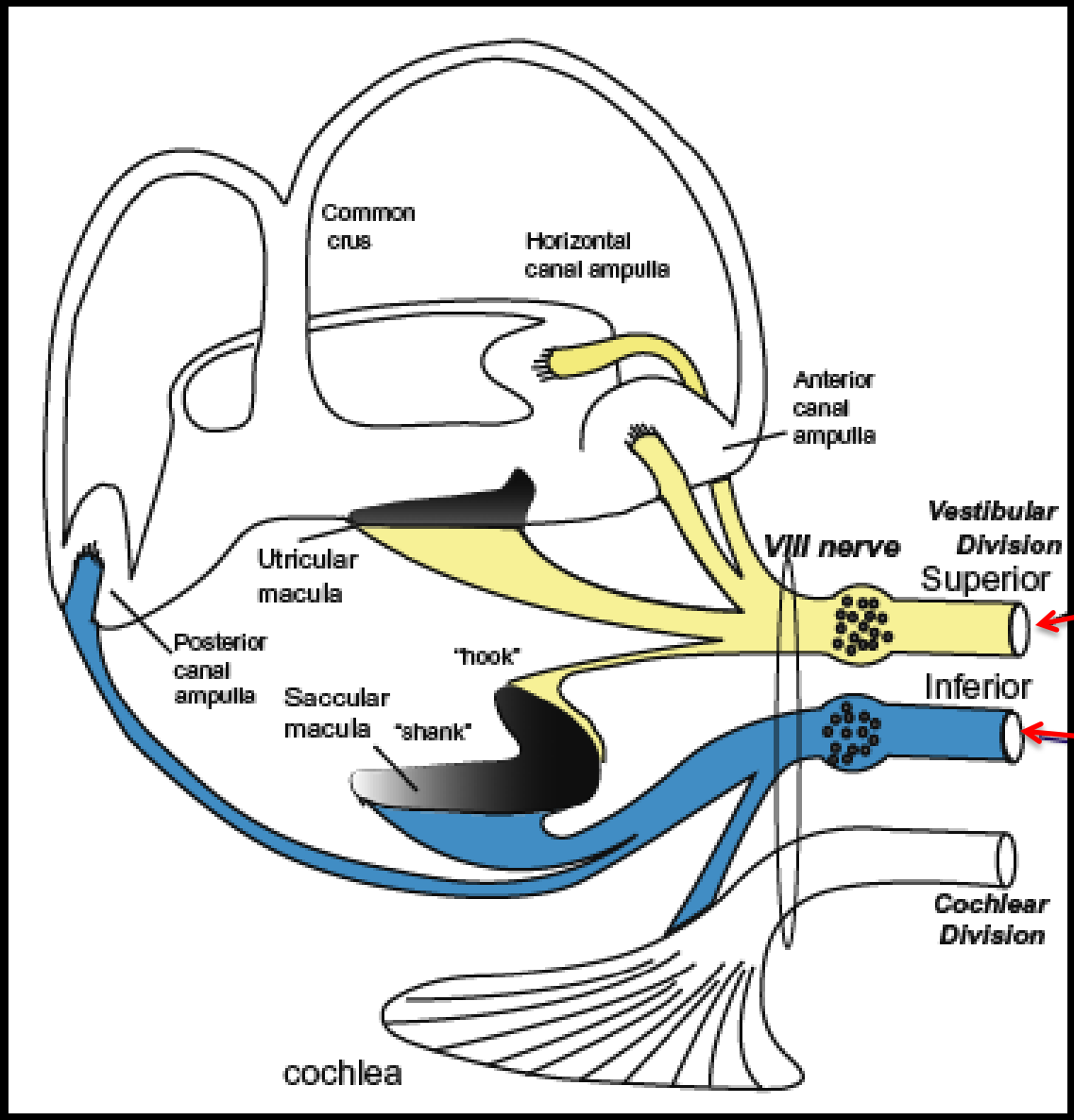
Superior Vestibular Nerve

Saccule

Midline

*Suzuki et al., 1969*
*Curthoys, 1987*
*Weber et al., 2012*

# Origin of cVEMP and oVEMP




oVEMP

cVEMP

*Adapted from Curthoys, 2009*

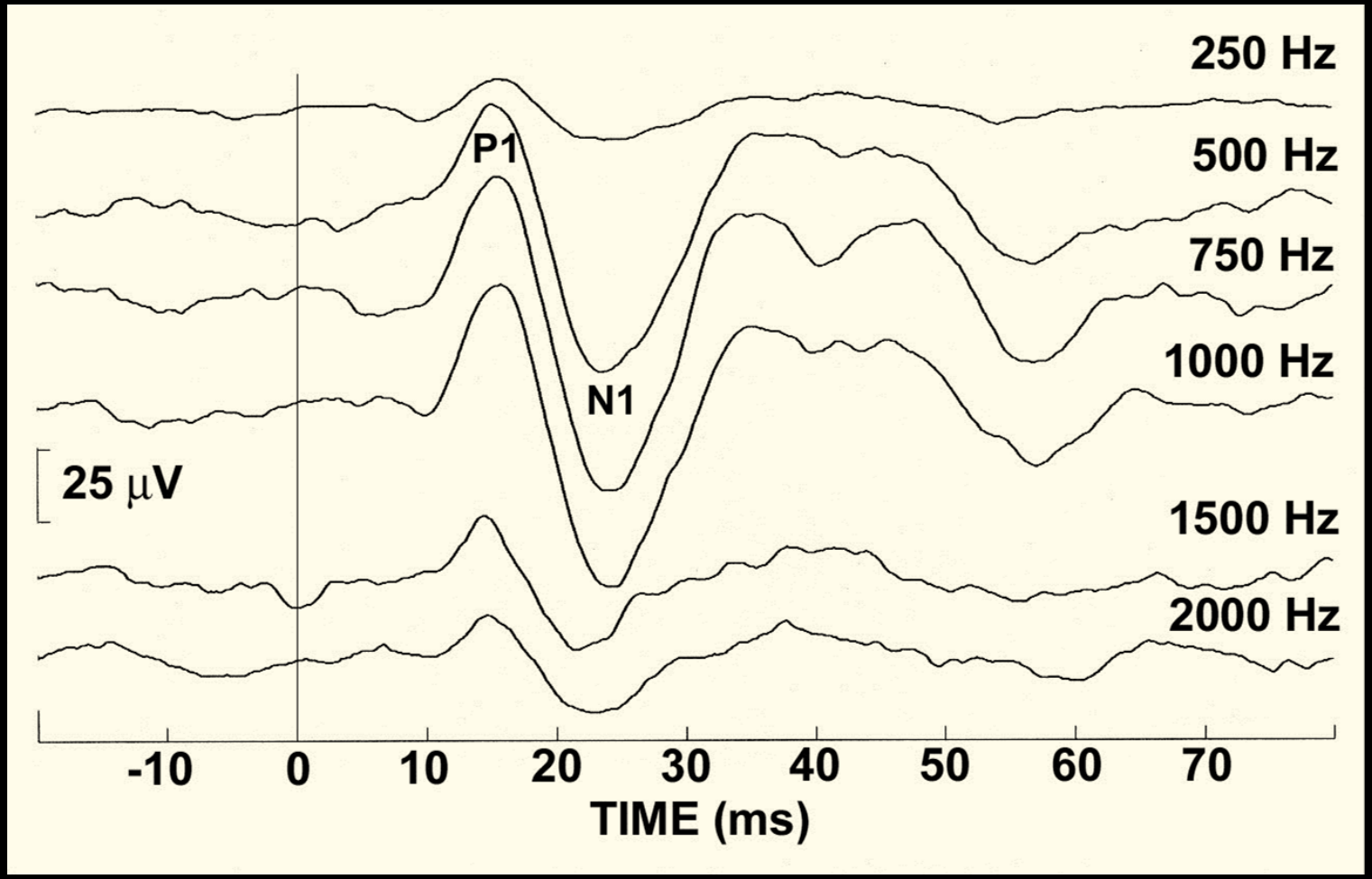
# Agenda

- Recording and stimulus parameters
- Normative data
  - Response prevalence and amplitude
  - Asymmetry ratio
- Clinical data
- Effect of aging
- Effect of noise exposure
- TBI/blast exposure

# cVEMP Recording and Stimulus Parameters

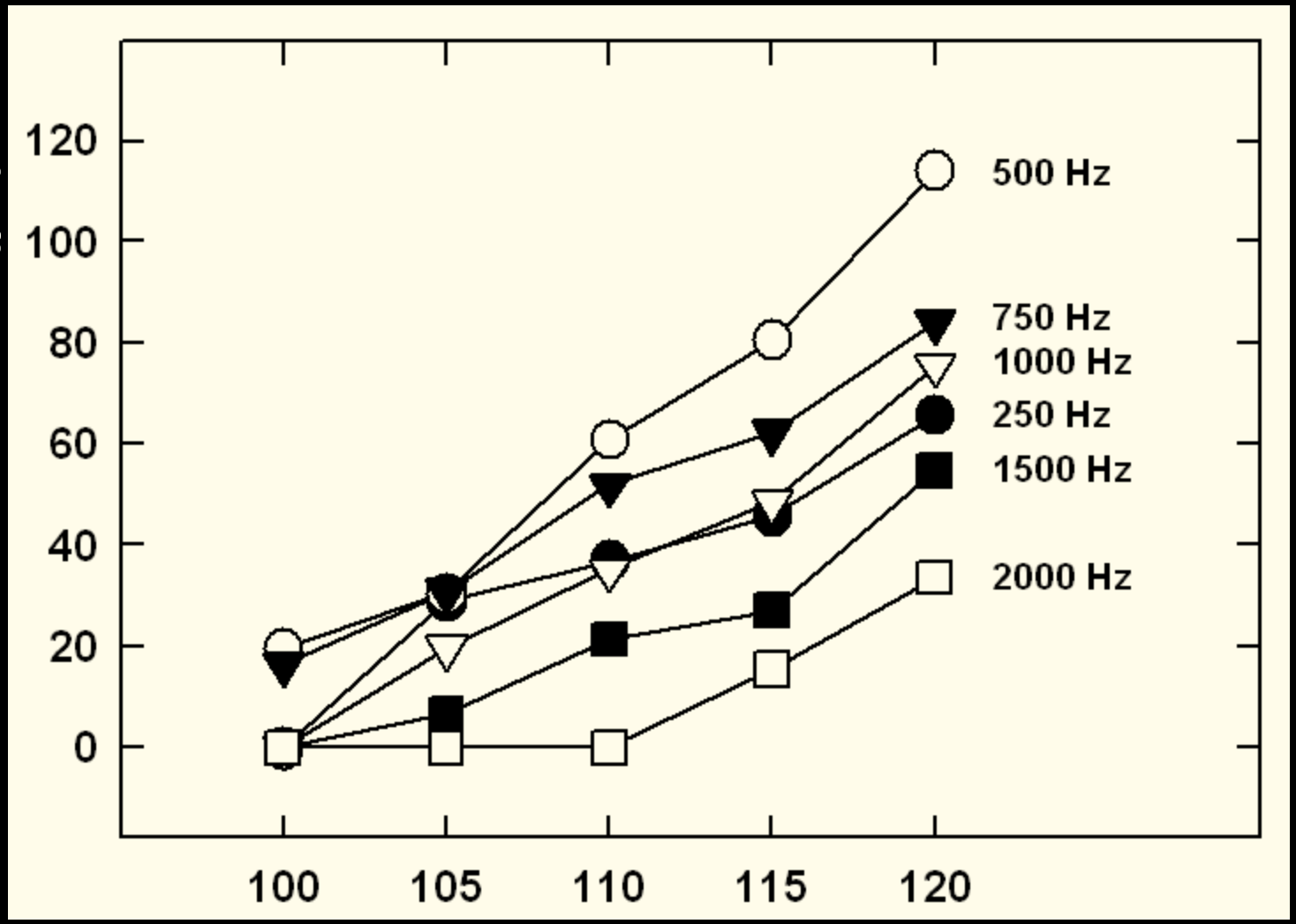
# AC cVEMP: Stimulus Frequency

120 dB $_{peak}$SPL
Rise/Fall = 4 ms




*adapted from Akin, Murnane, Proffitt (2003)*

# AC cVEMP: Stimulus Level

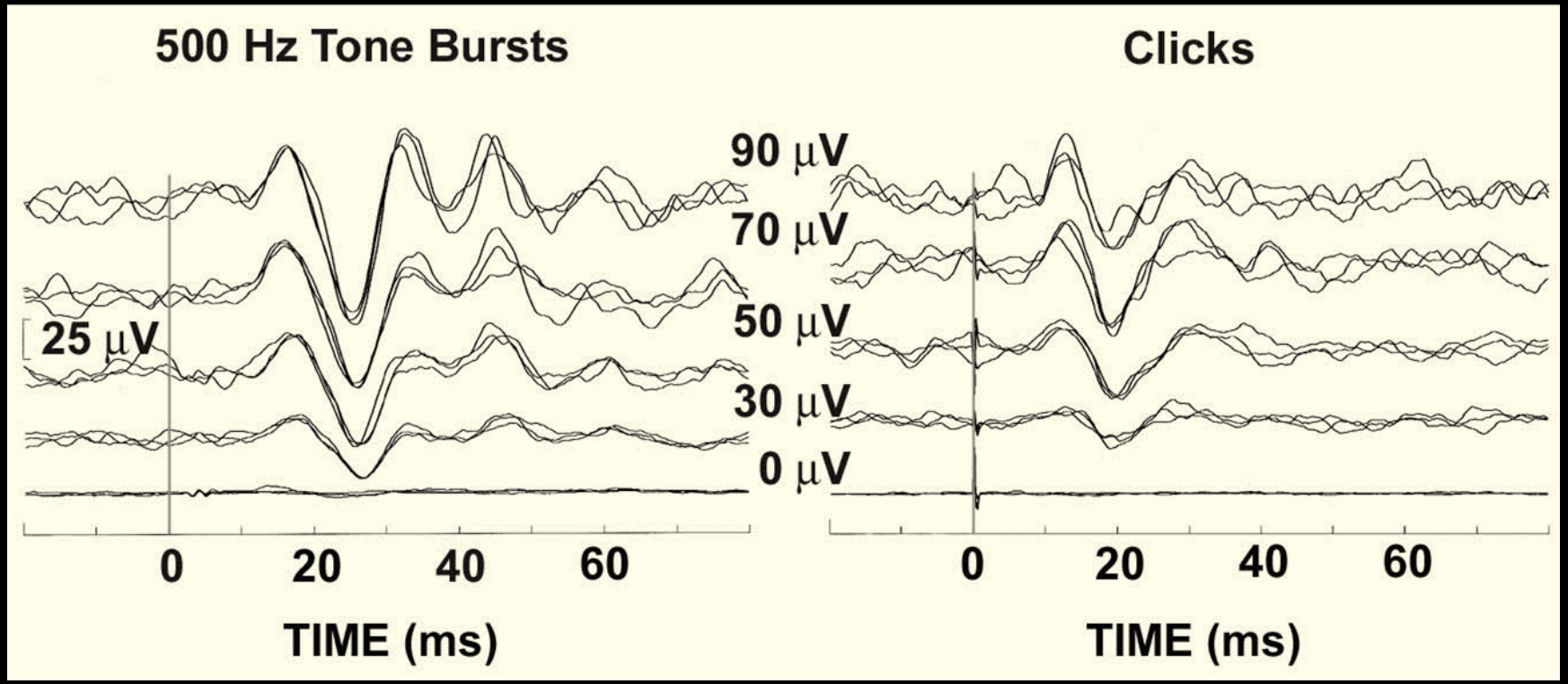



*Akin, Murnane, Proffitt (2003)*

# Stimulus Parameters: AC cVEMP

- Type: 500-Hz tone burst
- Phase: Rarefaction
- Rise/Fall: 2 cycles
- Plateau: 0 cycles
- Gating: Blackman
- Level: 120 dB pSPL (90 dB nHL)
- Rep Rate: 5/s

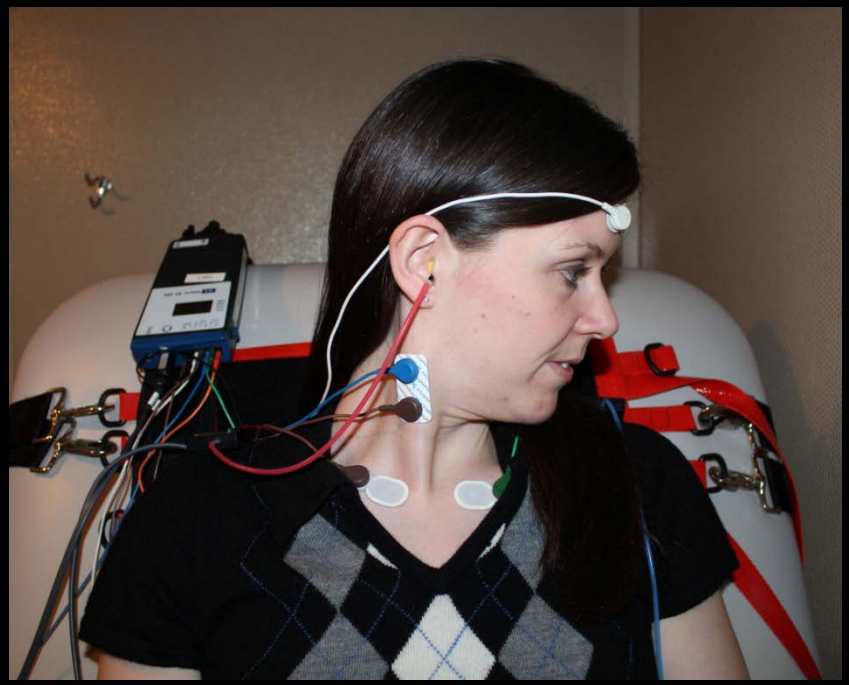
# cVEMP Amplitude is Proportional to SCM m. EMG Level




*Akin, Murnane, Panus, Caruthers, Wilkinson, Proffit, 2004*

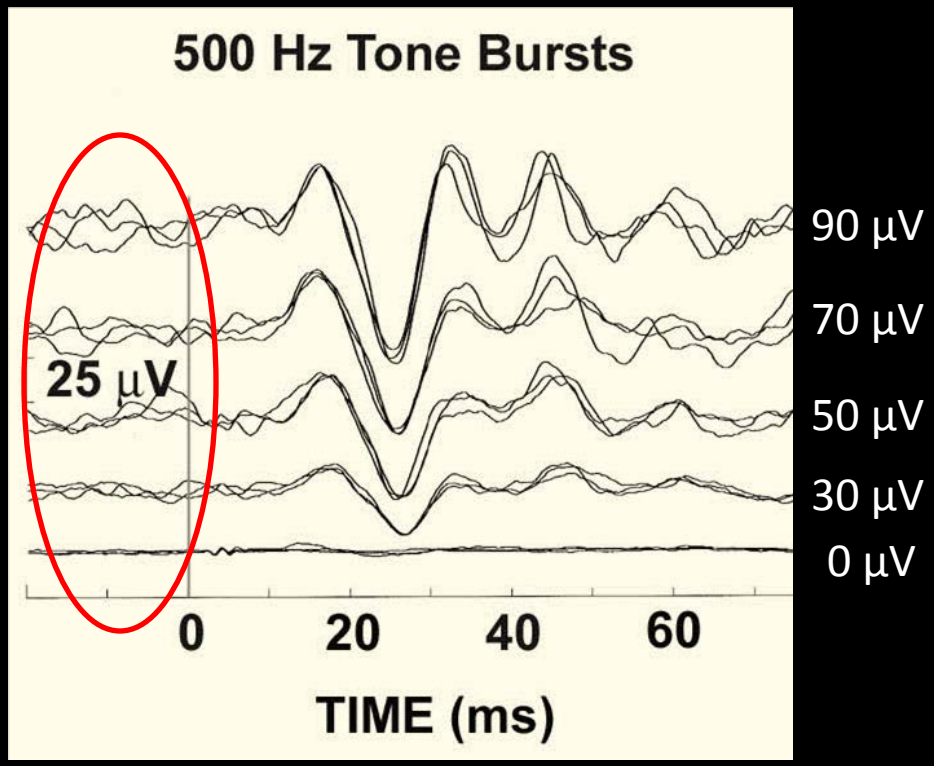
# Strategies to Account for the Effects of EMG Level on cVEMP Amplitude

# SCM Muscle EMG Feedback




Control for EMG level during cVEMP recording by providing visual feedback to the patient

# Corrected P1/N1 Amplitude

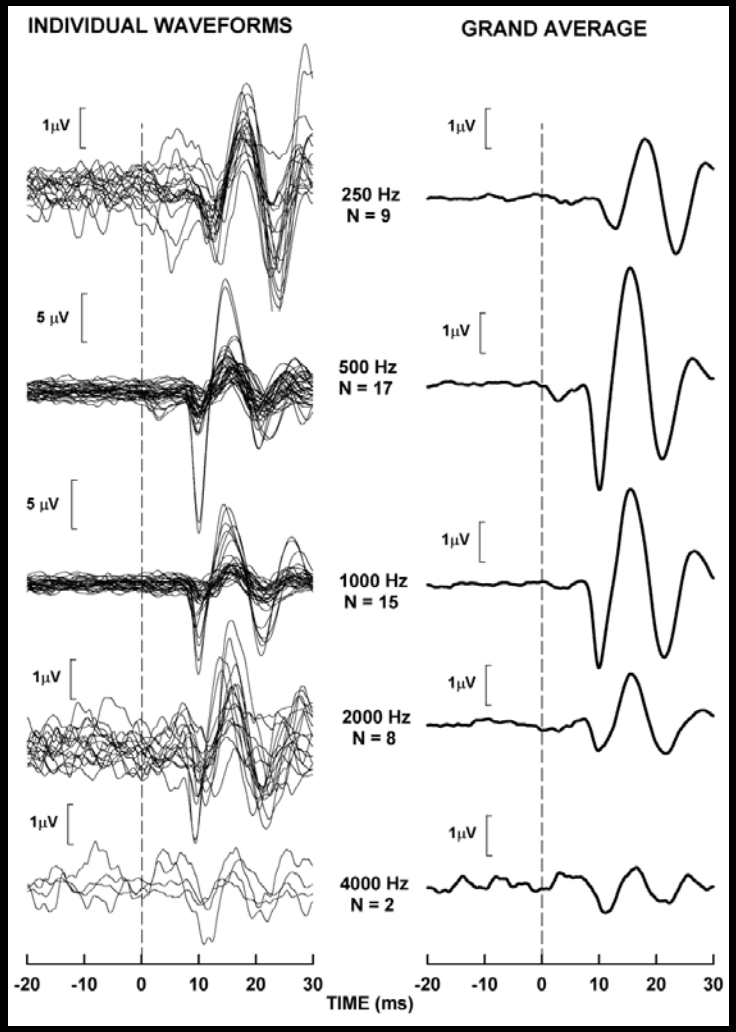


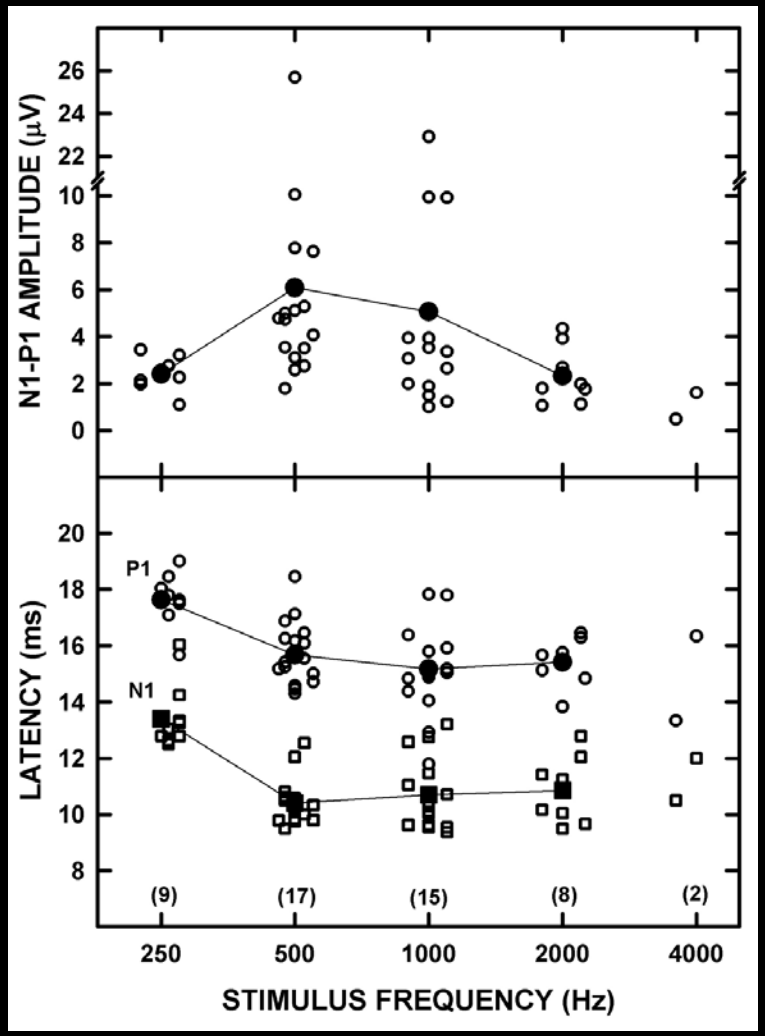

Correct P1-N1 amplitude after cVEMP recording by using pre-stimulus baseline as a gross estimate of EMG level

*Colebatch et al., 1994*

# oVEMP Recording and Stimulus Parameters

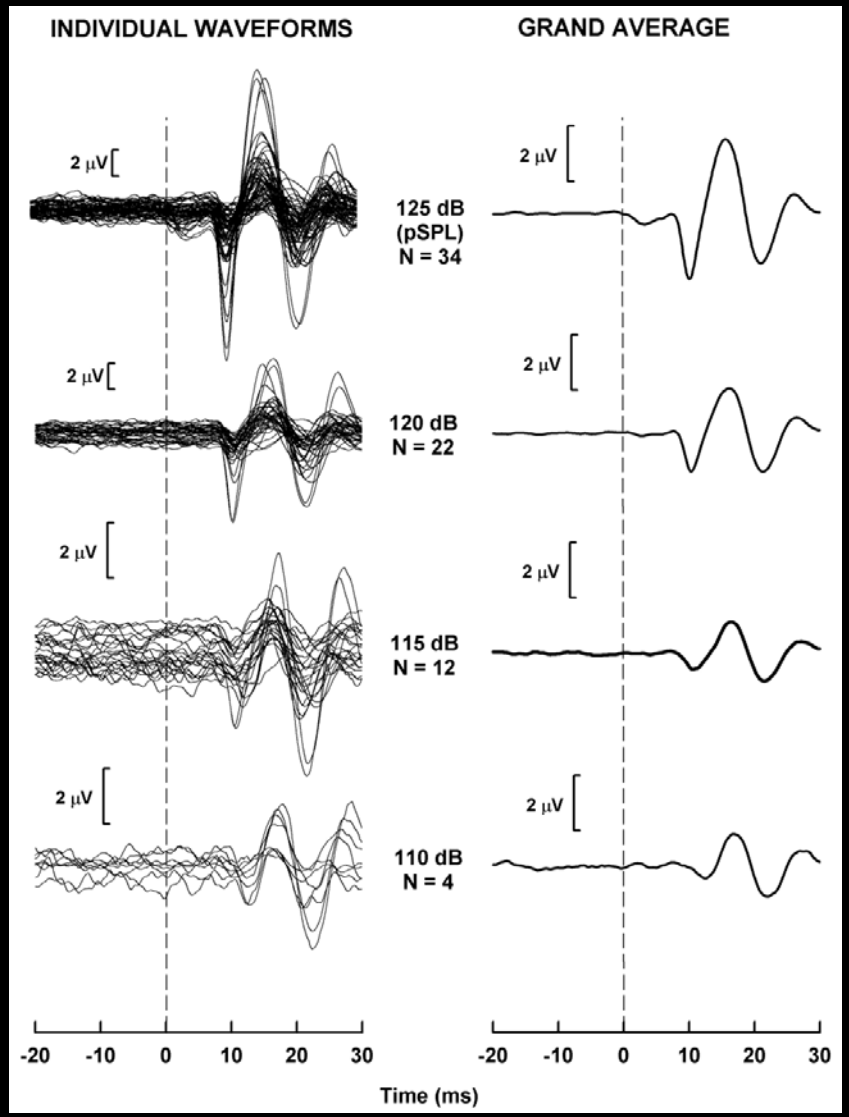
# AC oVEMP: Frequency

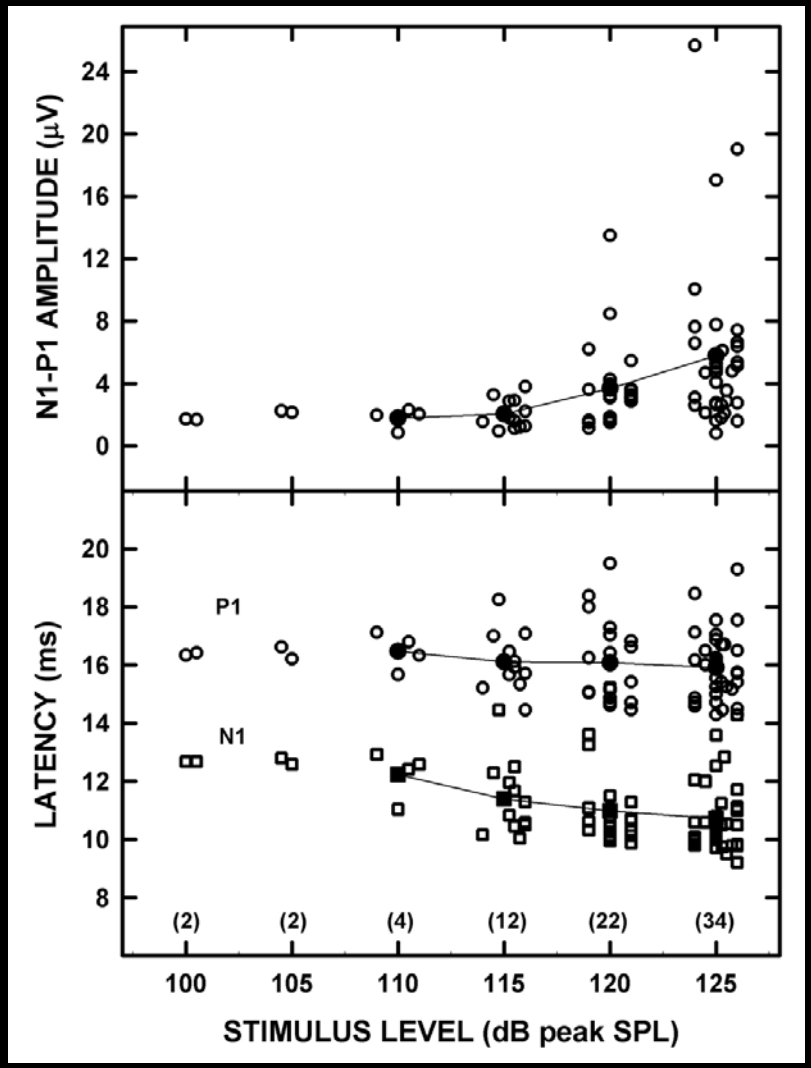



*Murnane, Akin, Kelly, Byrd, 2011*

# AC oVEMP: Stimulus Level



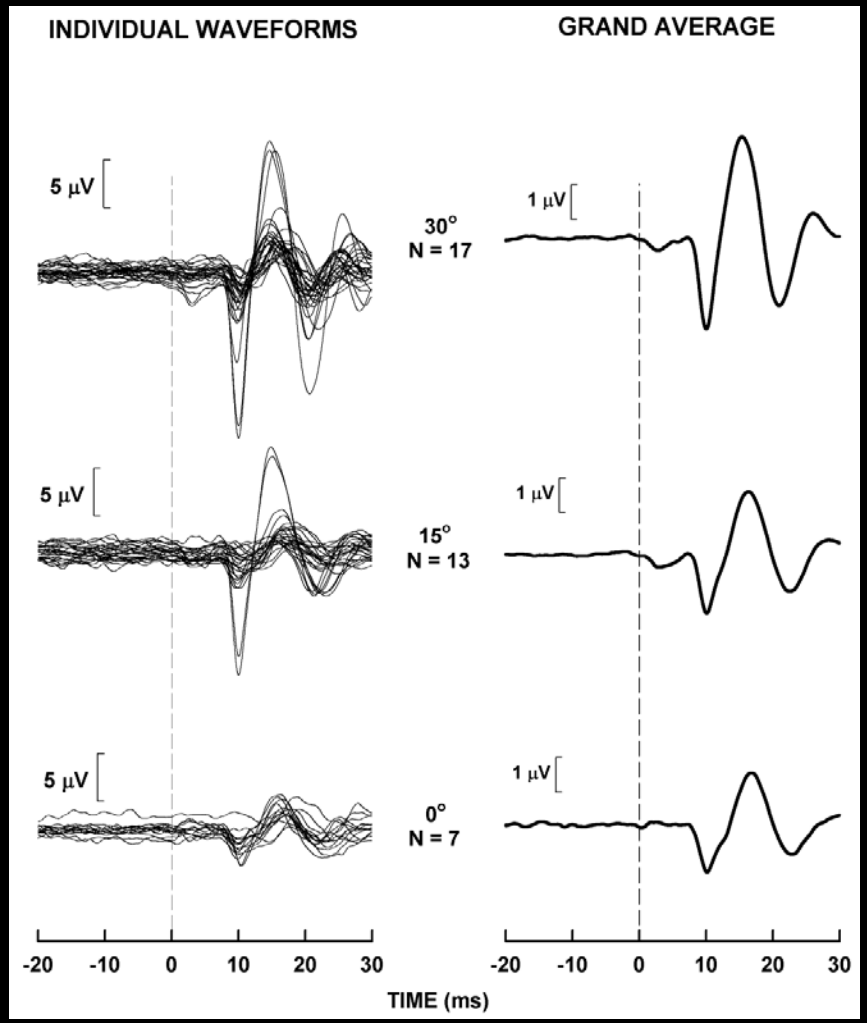



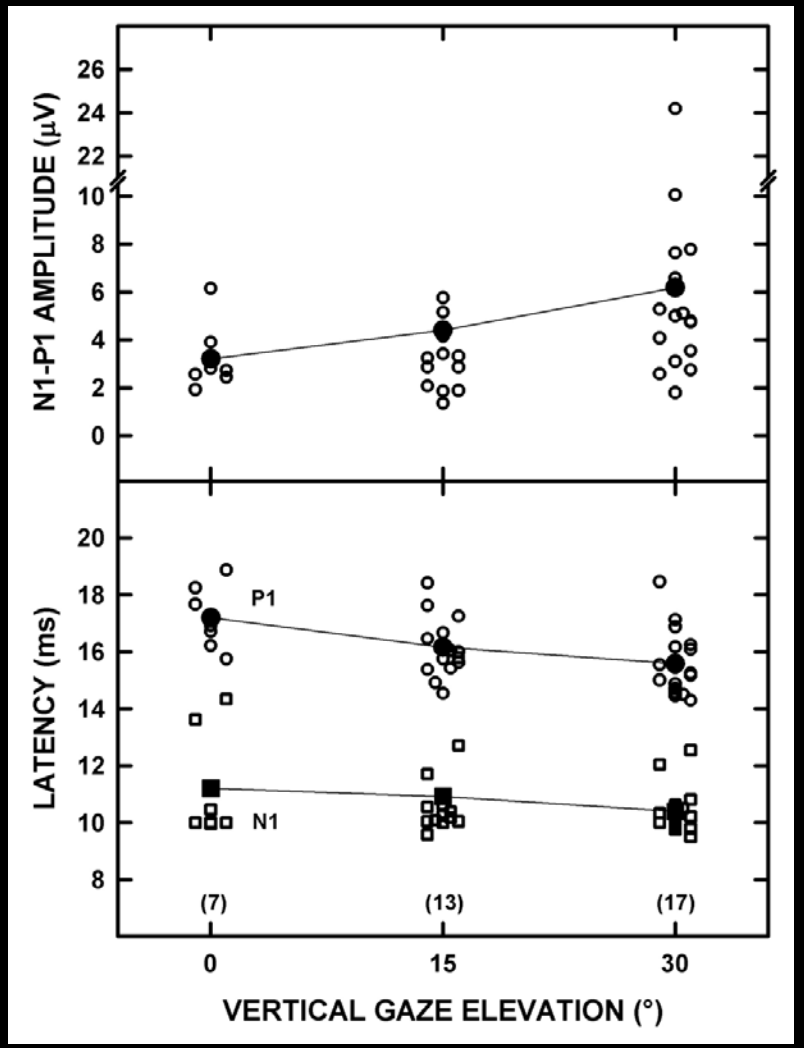

*Murnane, Akin, Kelly, Byrd, 2011*

# AC oVEMP Stimulus Parameters

- Transducer: ER-3A
- Type: 500-Hz tone burst
- Onset Phase: Alternating
- Rise/Fall: 2 ms
- Plateau: 0 ms
- Gating: Blackman
- Level: 125 dB pSPL
- Rep. Rate: 5 Hz

# AC oVEMP: Gaze Elevation



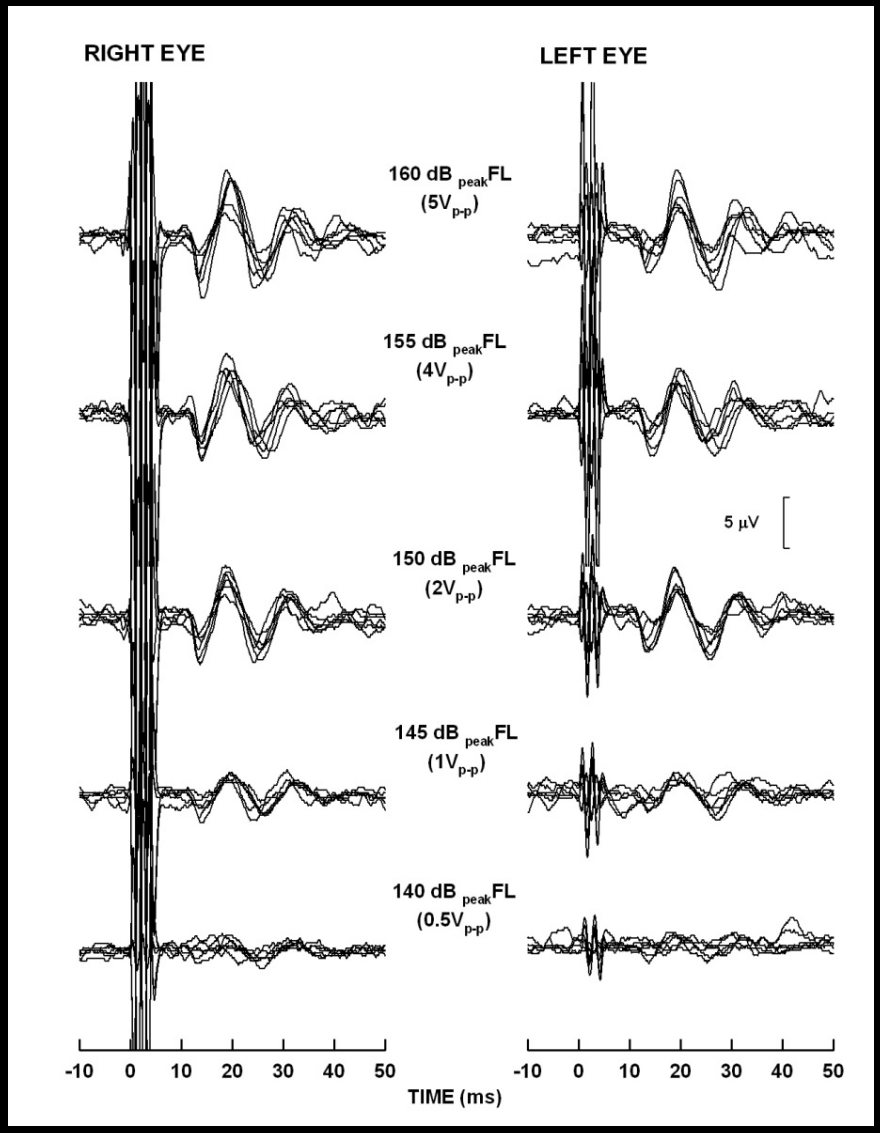




*Murnane, Akin, Kelly, Byrd, 2011*

# AC oVEMP Recording Parameters

- No. of channels: 2
- Amplifier gain: 100,000 x
- Response filter: 1 – 1000 Hz
- Sweep time: 50 ms
- No. of sweeps: 500
- Artifact rejection: 36 µV
- Vertical gaze angle: 30° (midline)

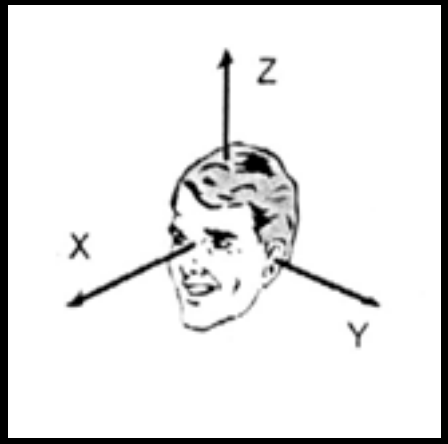
# BC oVEMP: Stimulus Level



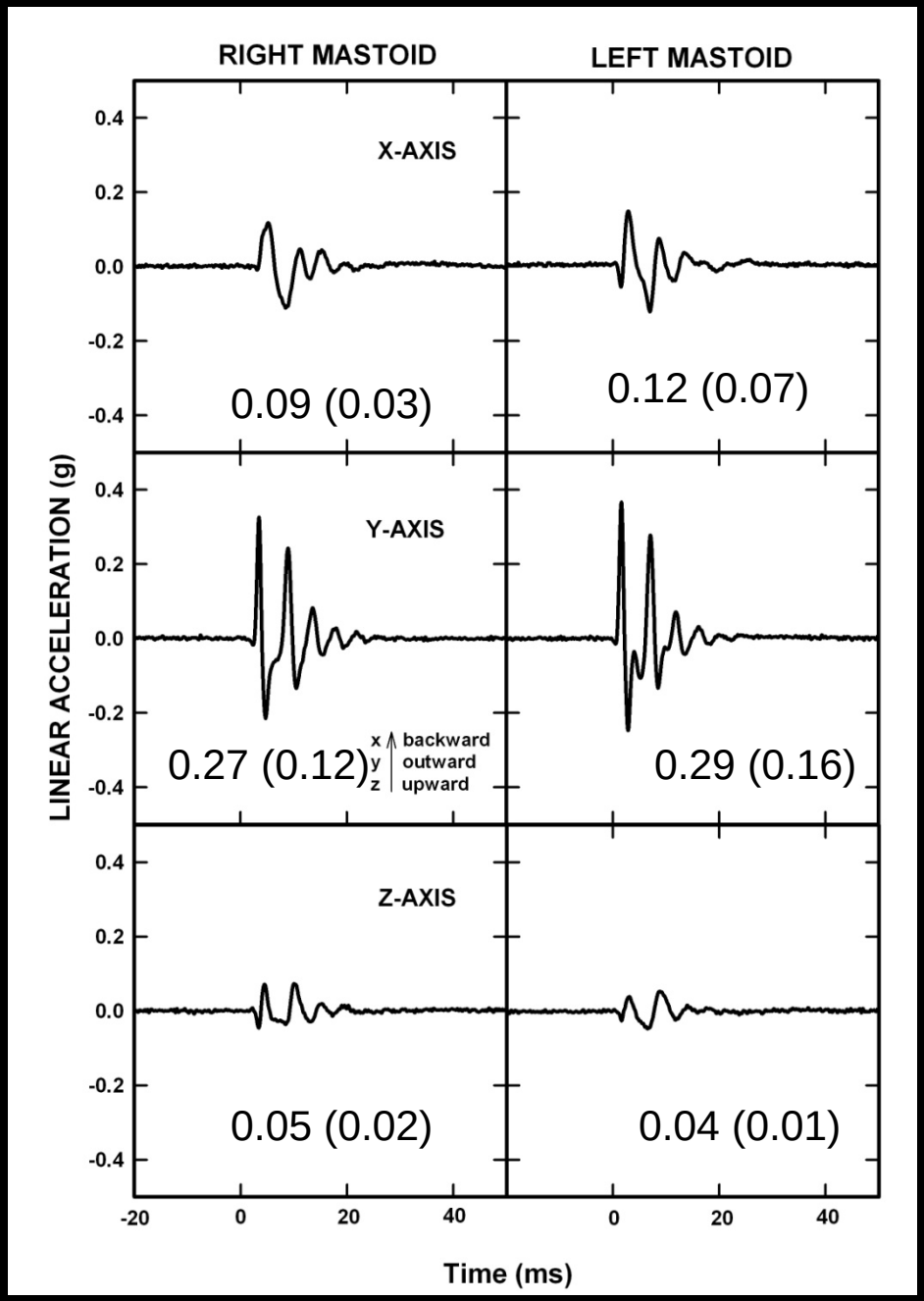
# BC oVEMP Stimulus Parameters

- Amplifier: B&K model 2718
- Transducer: B&K model 4810
- Type: 500-Hz tone burst
- Onset Phase: rarefaction
- Rise/Fall: 2 ms
- Plateau: 0 ms
- Gating: Blackman
- Level: 155 dB peak FL
- Rep. Rate: 5 Hz

# Linear Acceleration at Mastoids




Mean linear acceleration at Fz: 20.0 g (0.99)

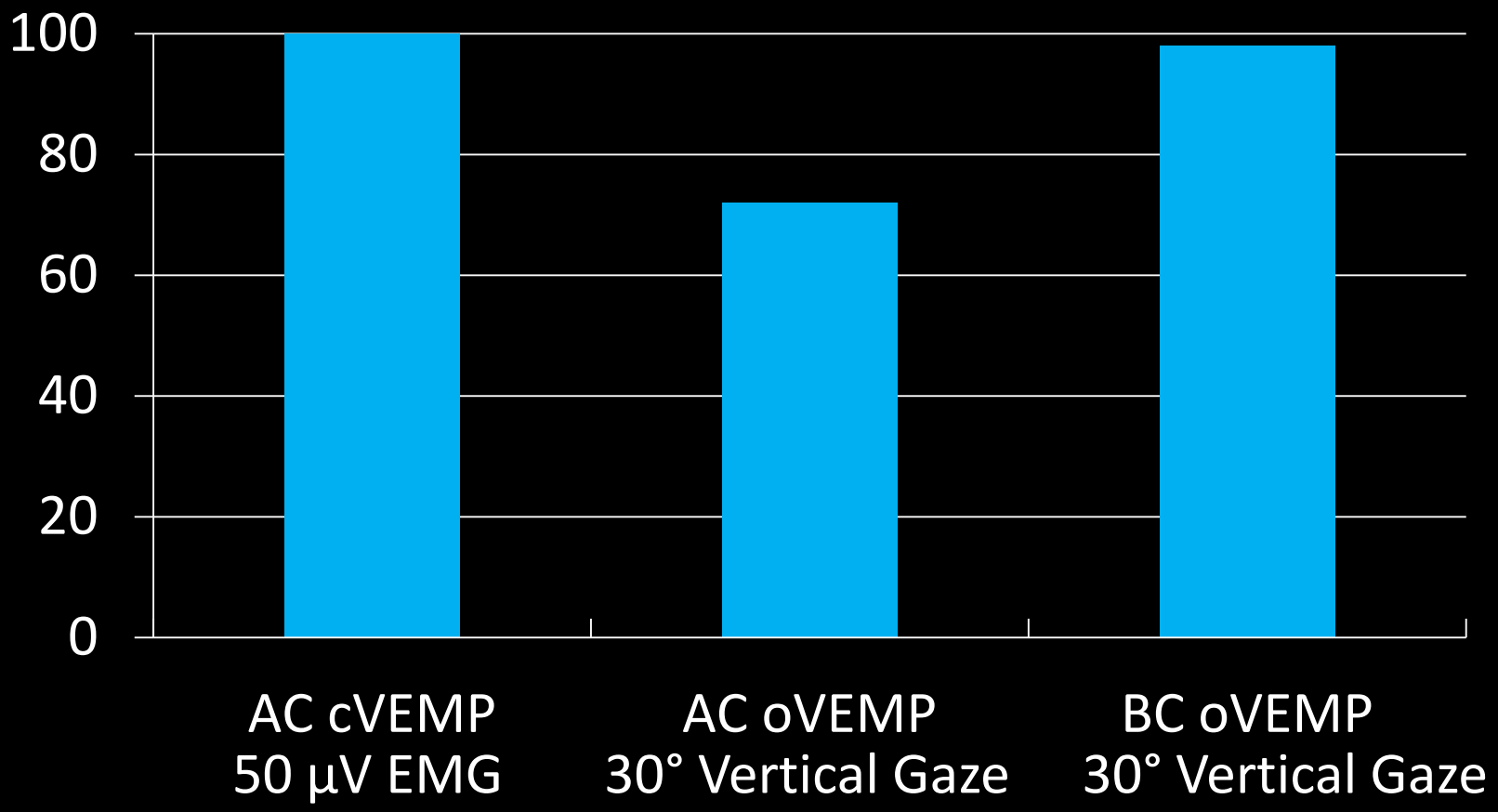


# BC oVEMP Recording Parameters

- No. of channels: 2
- Amplifier gain: 100,000 x
- Response filter: 1 – 1000 Hz
- Sweep time: 50 ms
- No. of sweeps: 75
- Artifact rejection: off
- Vertical gaze angle: 30° (midline)

# Normative Data

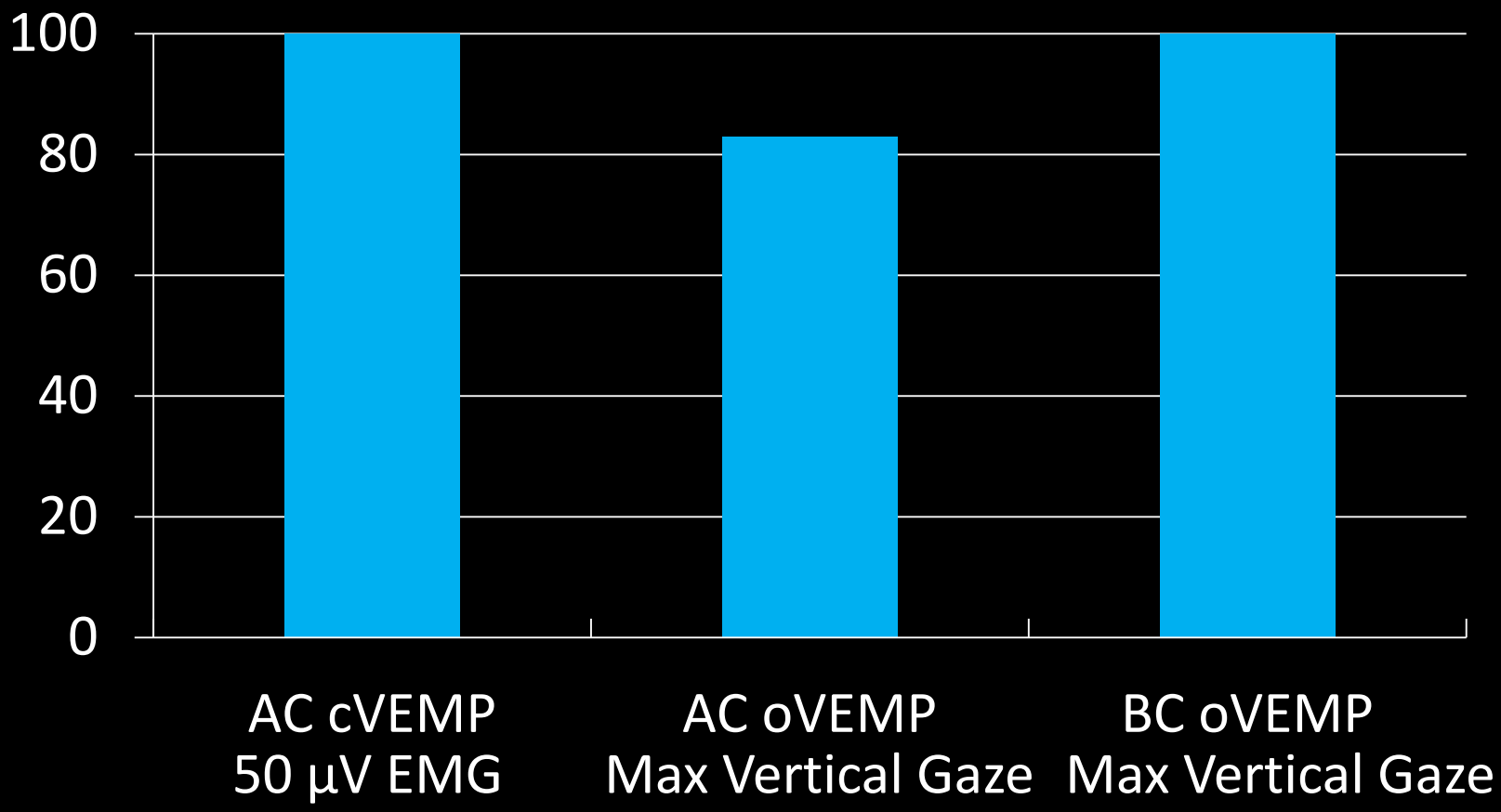
# VEMP Prevalence




N = 54 ears/eyes

Mean Age = 23 (18-35 years)

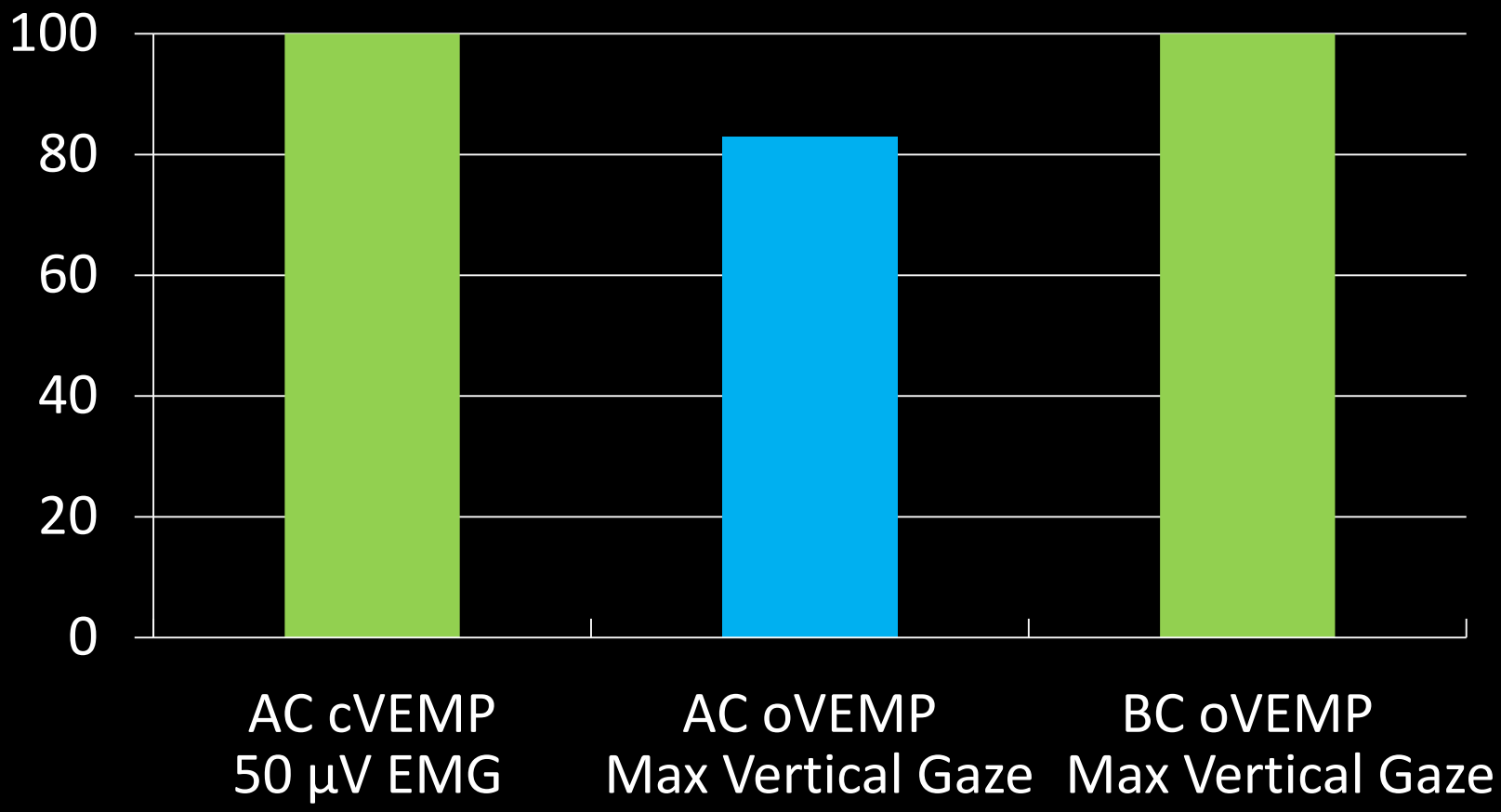
# VEMP Prevalence




N = 54 ears/eyes

Mean Age = 23 (18-35 years)

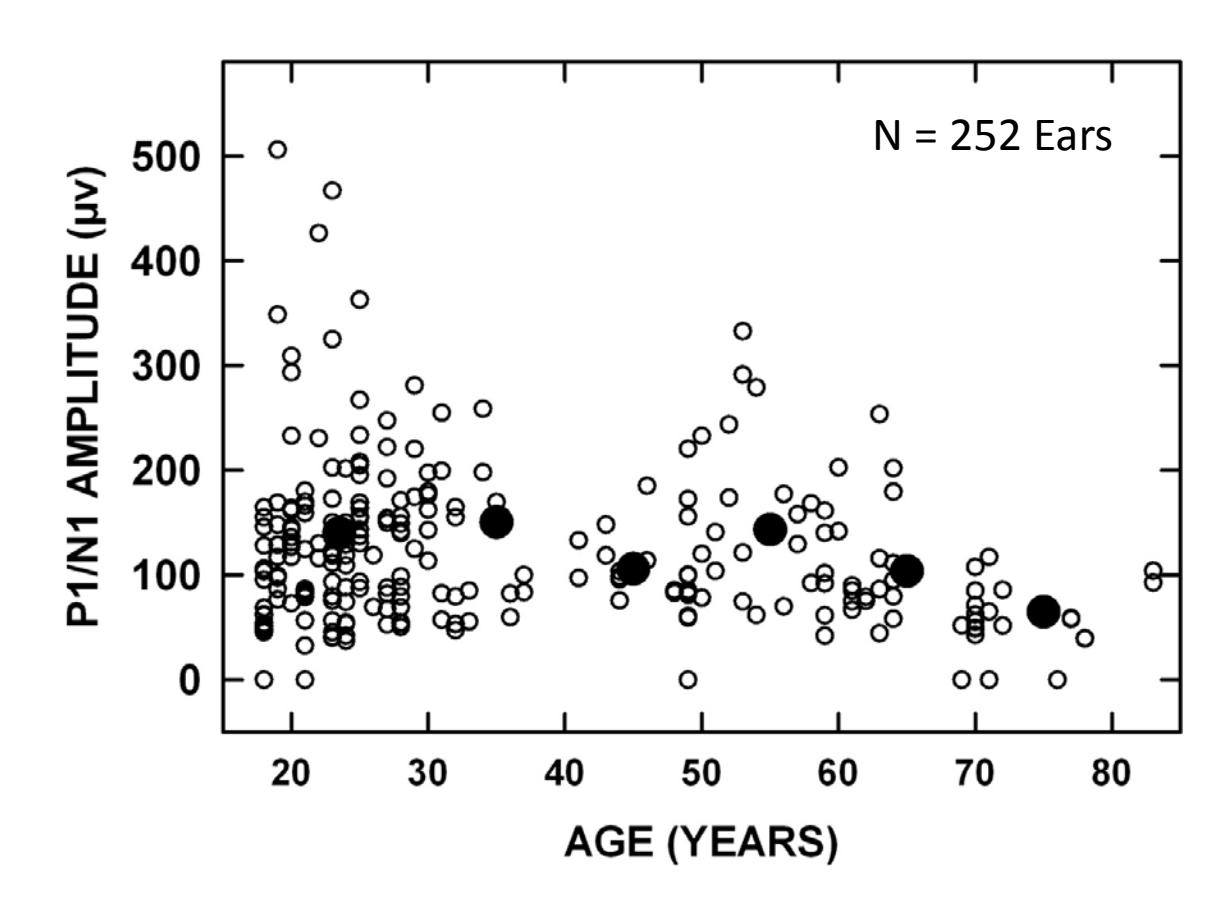
# VEMP Prevalence




N = 54 ears/eyes

Mean Age = 23 (18-35 years)

# AC cVEMP Amplitude




50 µV EMG

Mean Age = 37 years (±18)

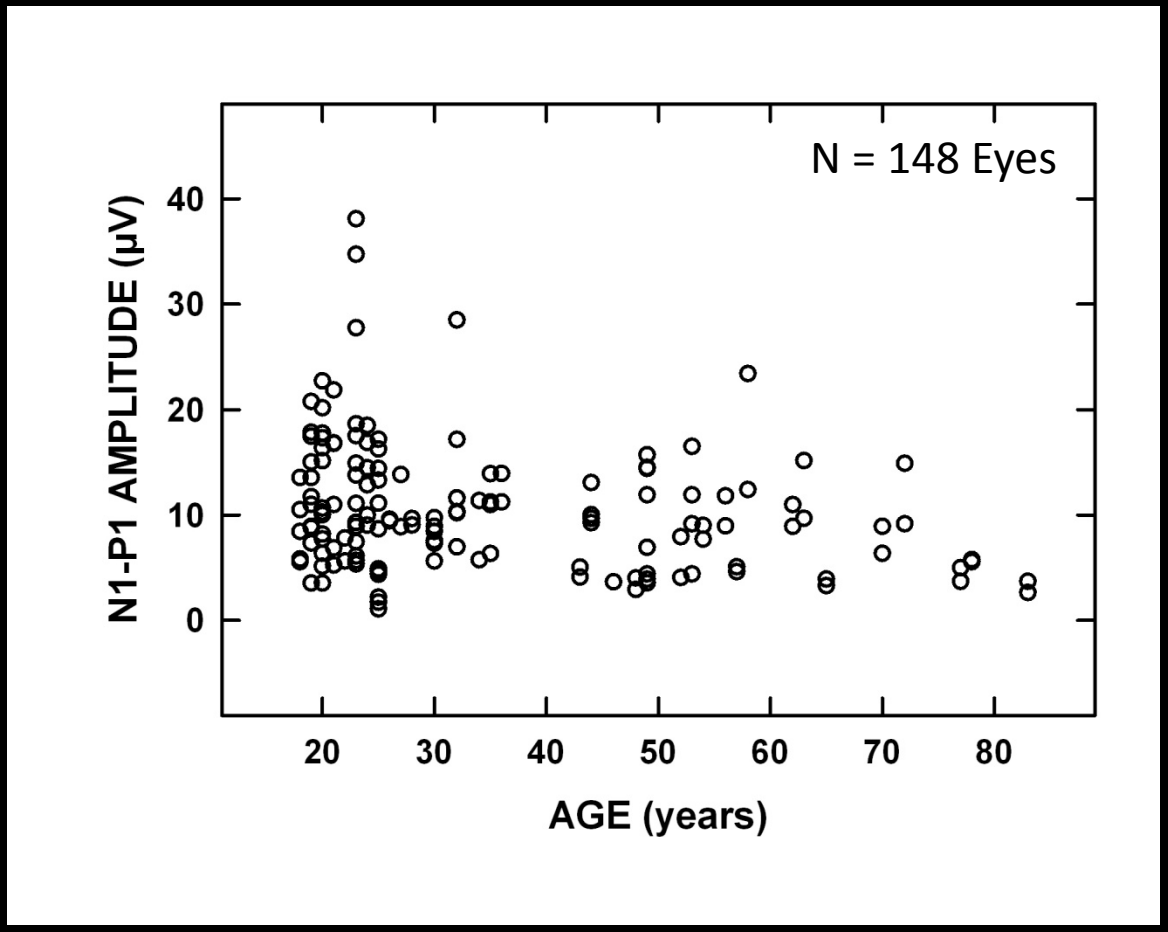
Mean P1/N1 = 124 µV (±78)

# AC cVEMP Asymmetry Ratio


N = 115 subjects

50 µV EMG

# BC oVEMP Amplitude

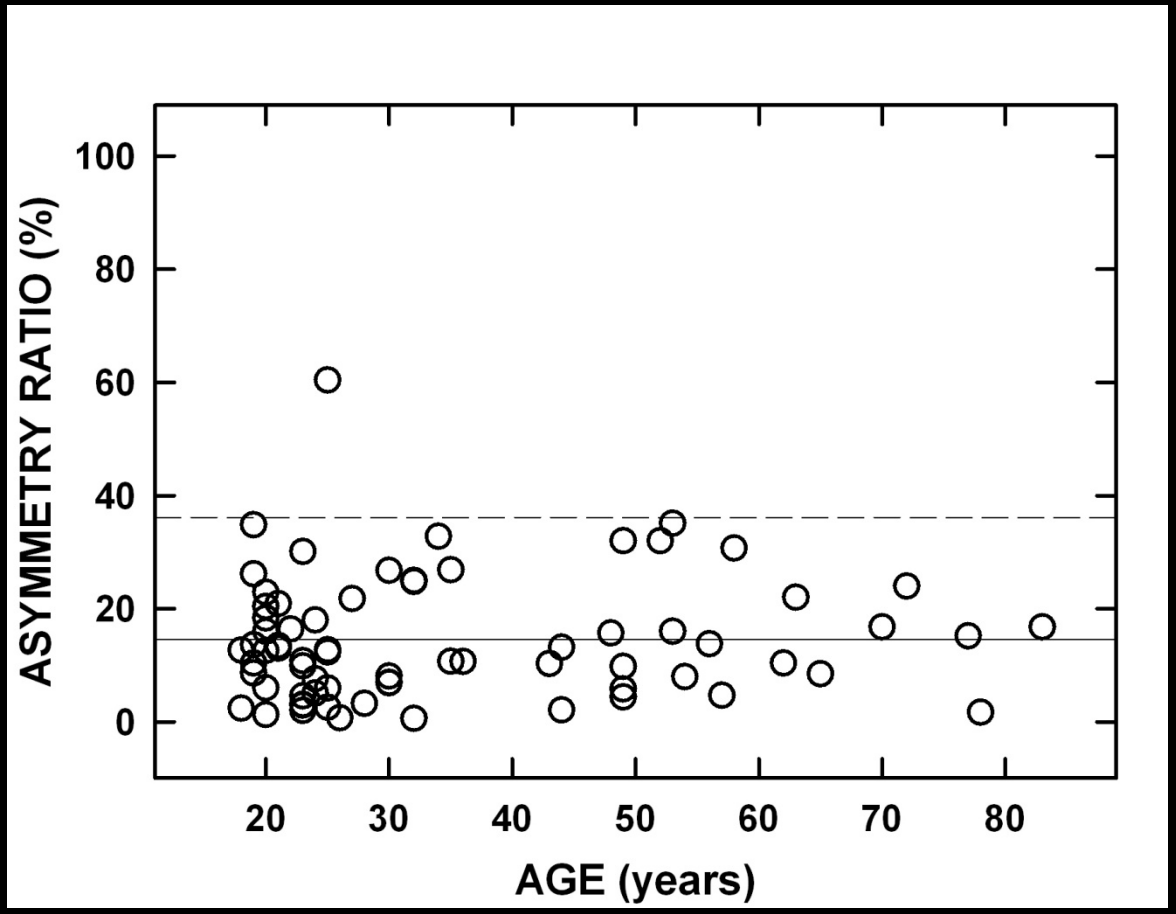



30° Vertical Gaze

Mean Age = 35 years (±17)

Mean N1/P1 = 10.5 µV (±6)

# BC oVEMP Asymmetry Ratio




N = 74 subjects

30° Vertical Gaze

# Clinical Data

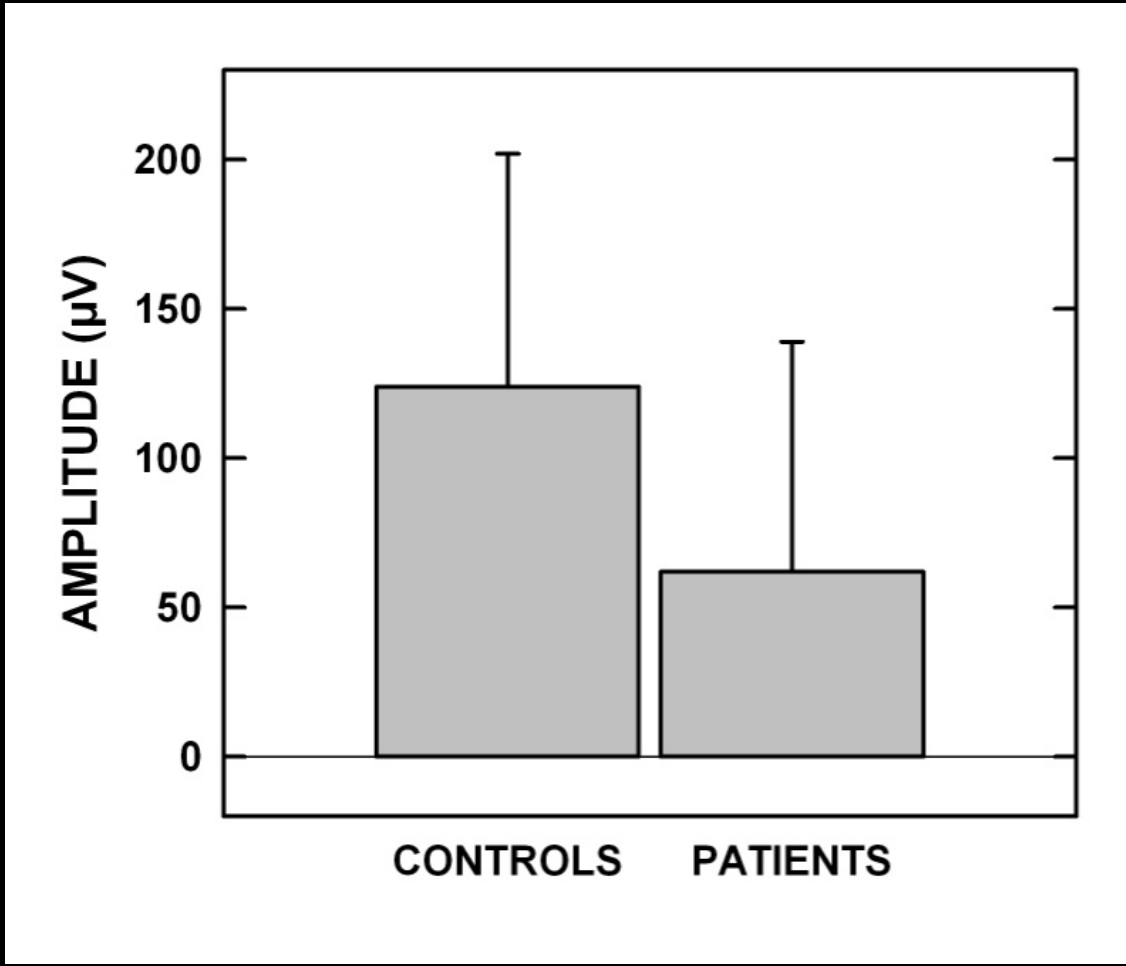
# Demographics

- 312 consecutive patients referred to Vestibular Clinic
- Age Range = 22 - 89 years (X = 60 ±15 yrs)

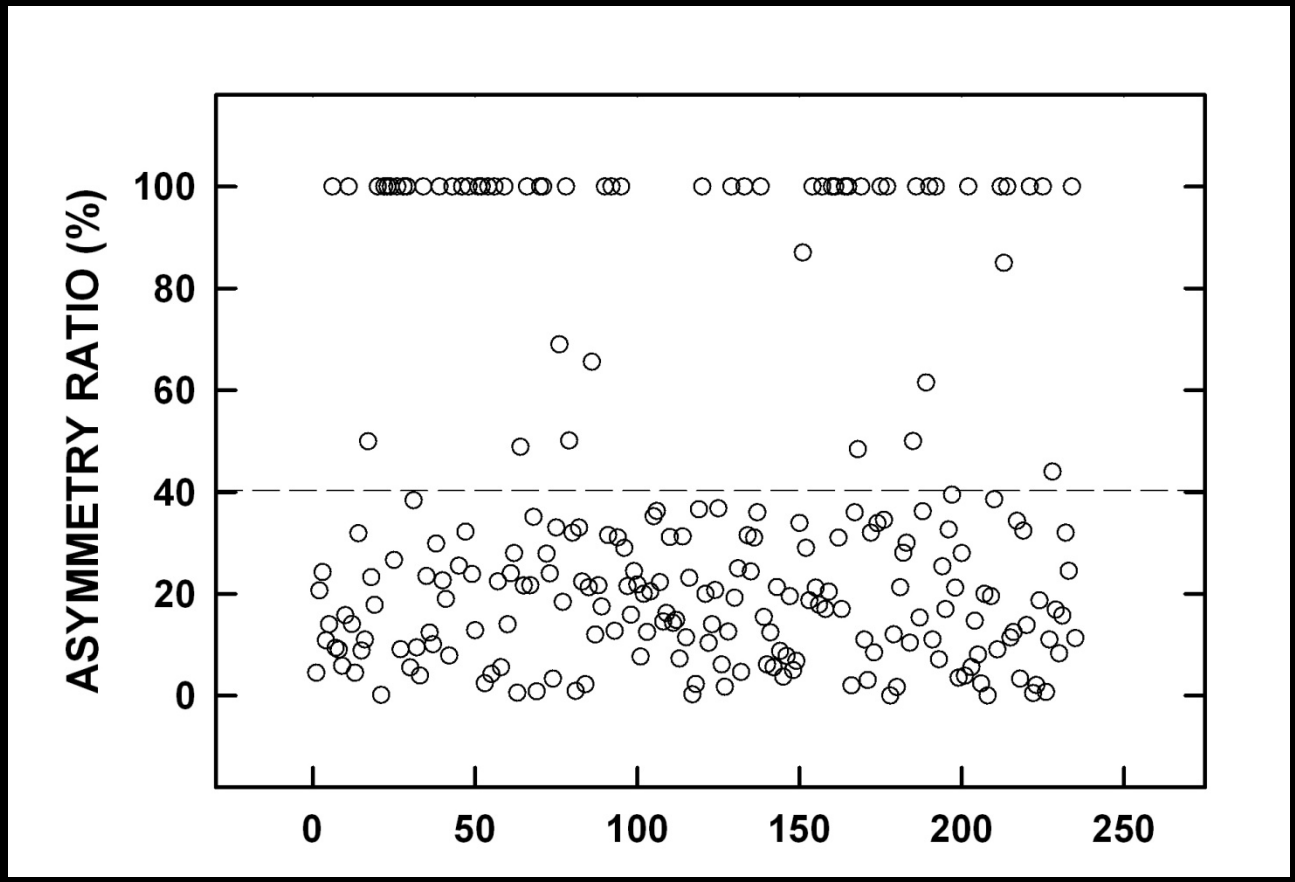
# VEMP Protocol

- AC cVEMP
  - 500-Hz tone bursts at 120 dB pSPL (90 dB nHL)
  - 50 μV EMG
    - If no response, maximum voluntary contraction (MVC)
  - SSCD Screen at 65 dB nHL
- BC oVEMP
  - 500-Hz tone bursts at 155 dB pFL
  - 30° vertical gaze angle
    - If no response, then maximum gaze angle

# AC cVEMP Amplitude: Patients vs. Healthy Individuals

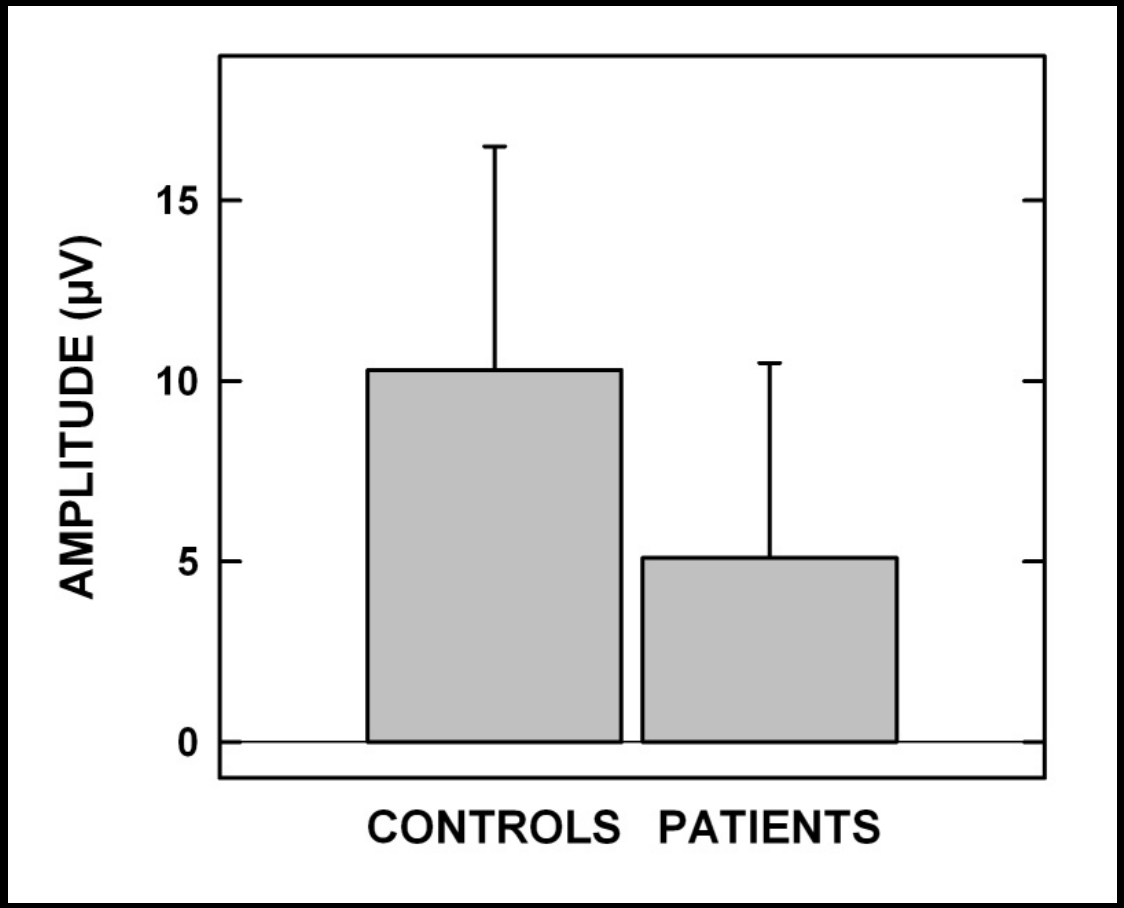


# cVEMP Asymmetry Ratios in Clinic Patients

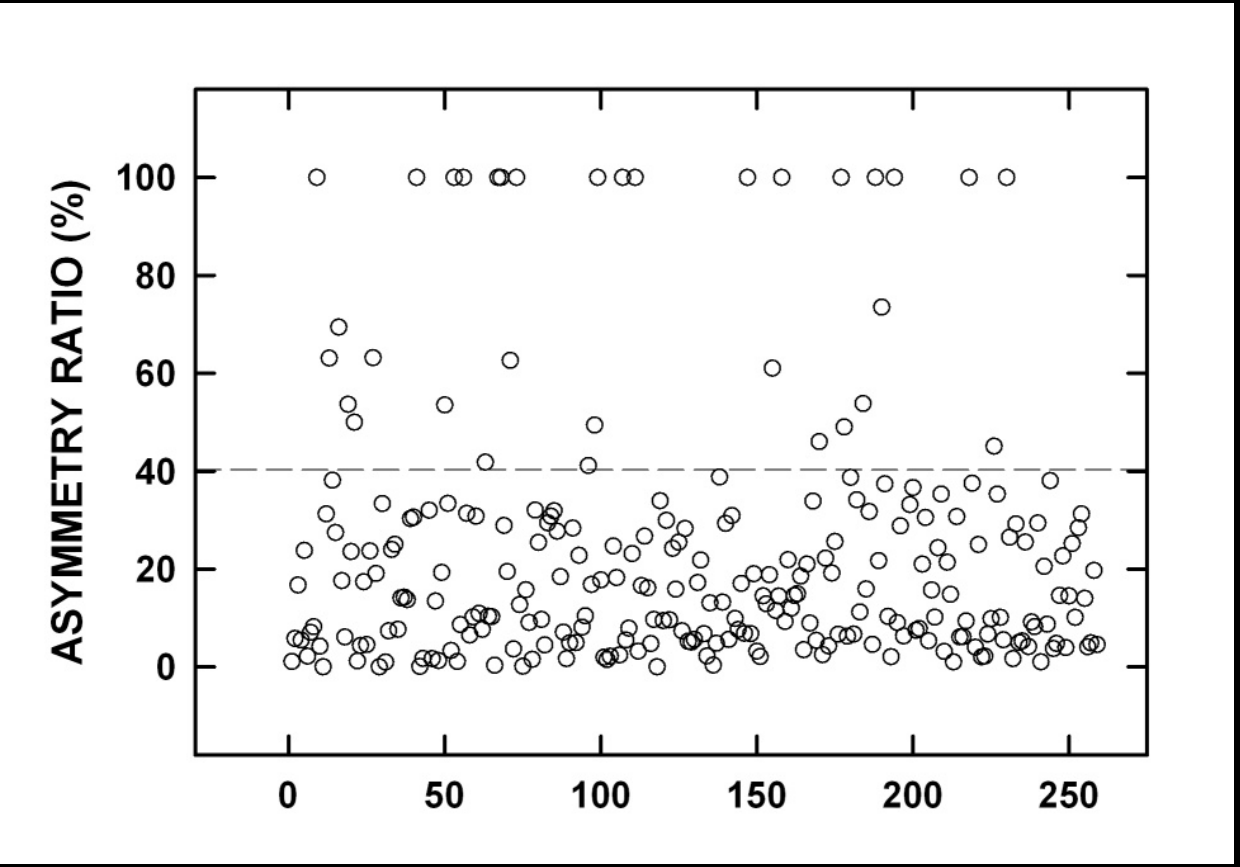



N = 235

# BC oVEMP Amplitude: Patients vs. Healthy Individuals



# oVEMP Asymmetry Ratios in Clinic Patients




N = 259

# VEMP Findings in Clinic Patients

| | AC cVEMP<br>N = 312 | BC oVEMP<br>N = 289 |
|---|---|---|
| | Normal Findings | |
| | 32%@ 50 µV EMG | 61%@ 30˚gaze |
| | 28% @ MVC | 17% @ max gaze |
| **Total** | **60%** | **78%** |
| | | |
| | Abnormal Findings | |
| AR > 40% | 19% | 11% |
| left/right | 8/11% | 5/7% |
| Bilateral absence | 12% | 10% |
| **Total** | **31%** | **22%** |
| | | |
| + SSCD screen | 2% | N/A |
| Could not test | 11% | 0.01% |

# Effect of Aging on cVEMP

# Decrease in cVEMP amplitude in individuals > 60 years

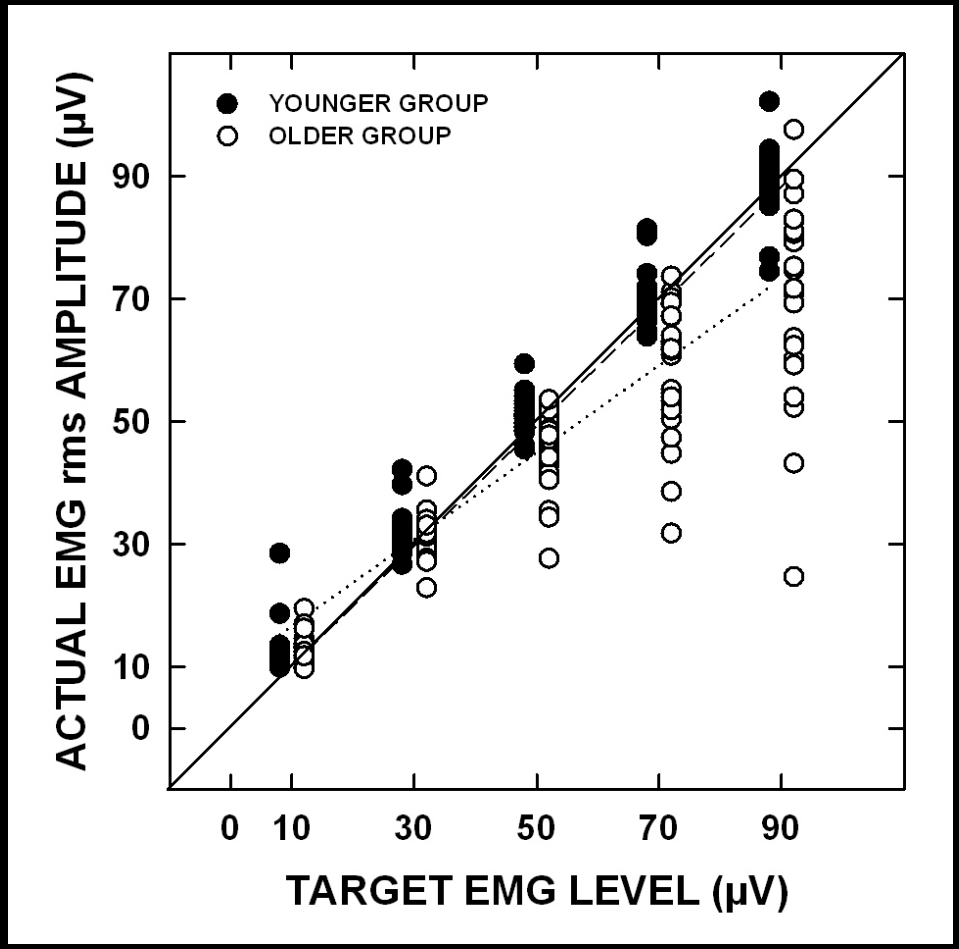
*Ochi and Ohashi 2003; Basta et al. 2005; Basta et al. 2007; Su et al. 2004; Welgampola and Colebatch 2001b; Zapala and Brey 2004; Brantberg, Granath, Schart 2007*

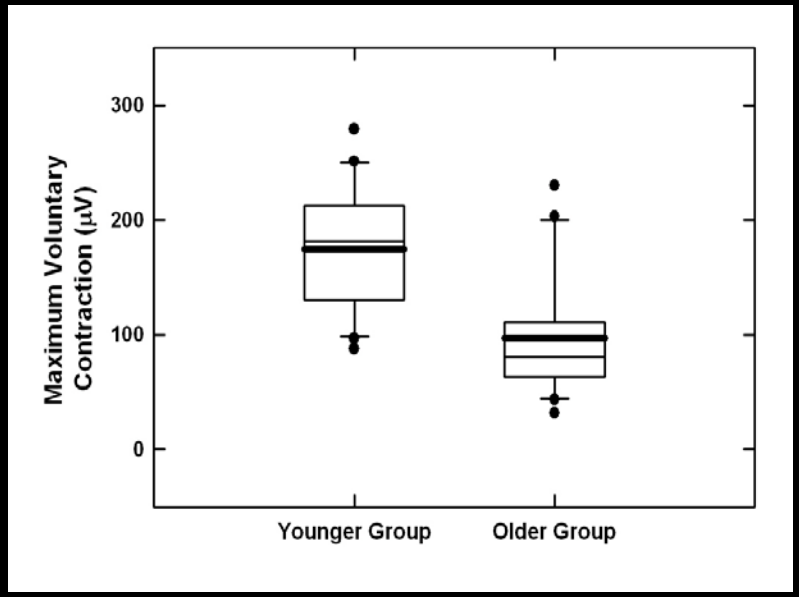
# Akin, Murnane, Tampas, Clinard (2011). The effect of age on the vestibular evoked myogenic potential and sternocleidomastoid muscle tonic EMG level, *Ear & Hearing*

- Are amplitude decrements influenced by age-related changes in the vestibular system or age related changes in SCM muscle?

- 24 young individuals (22 – 31 years; X = 24 ± 3)
- 24 older individuals (61 – 86 years; X = 70 ± 6)

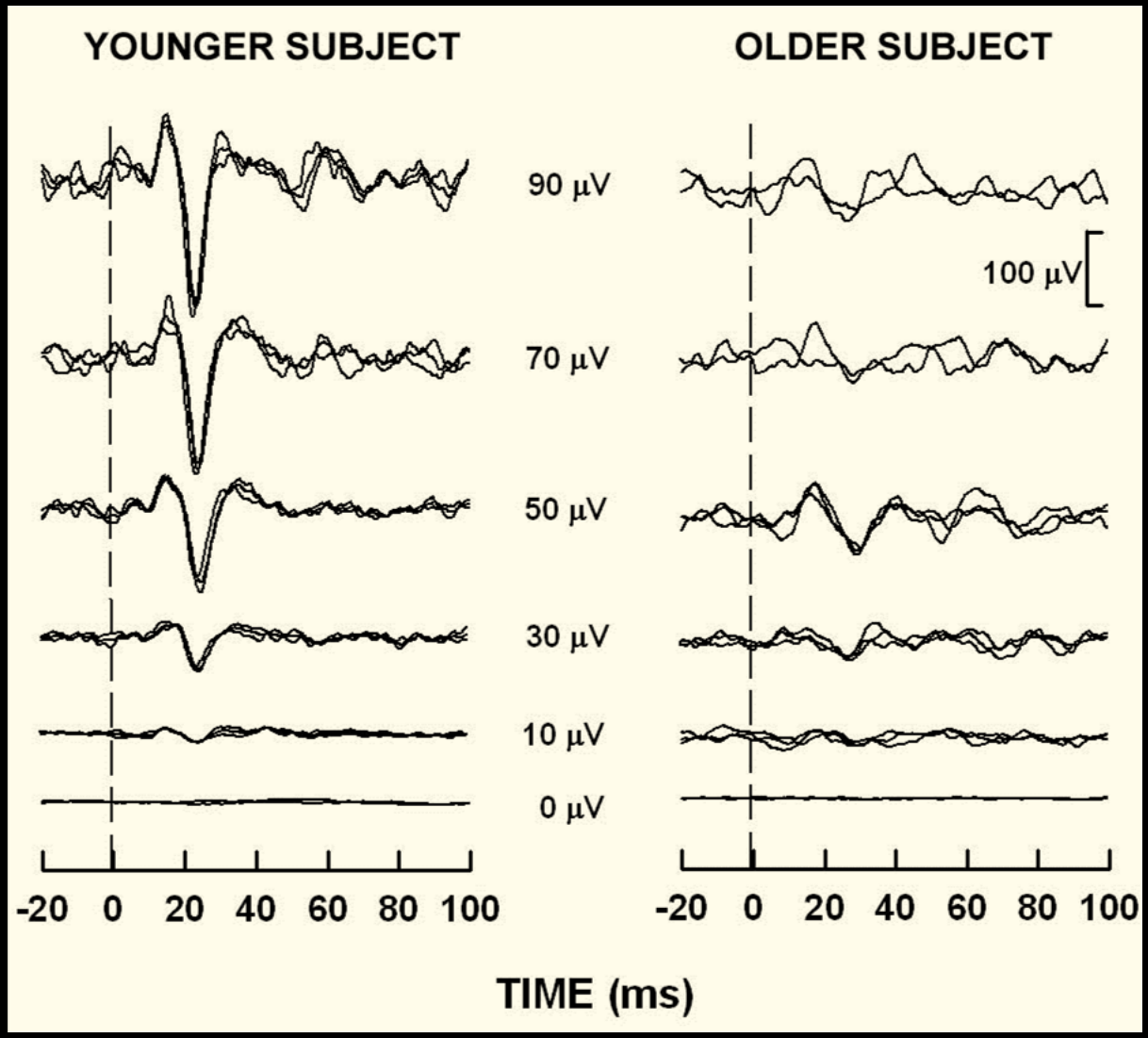
# Effect of Age on SCM m EMG Level



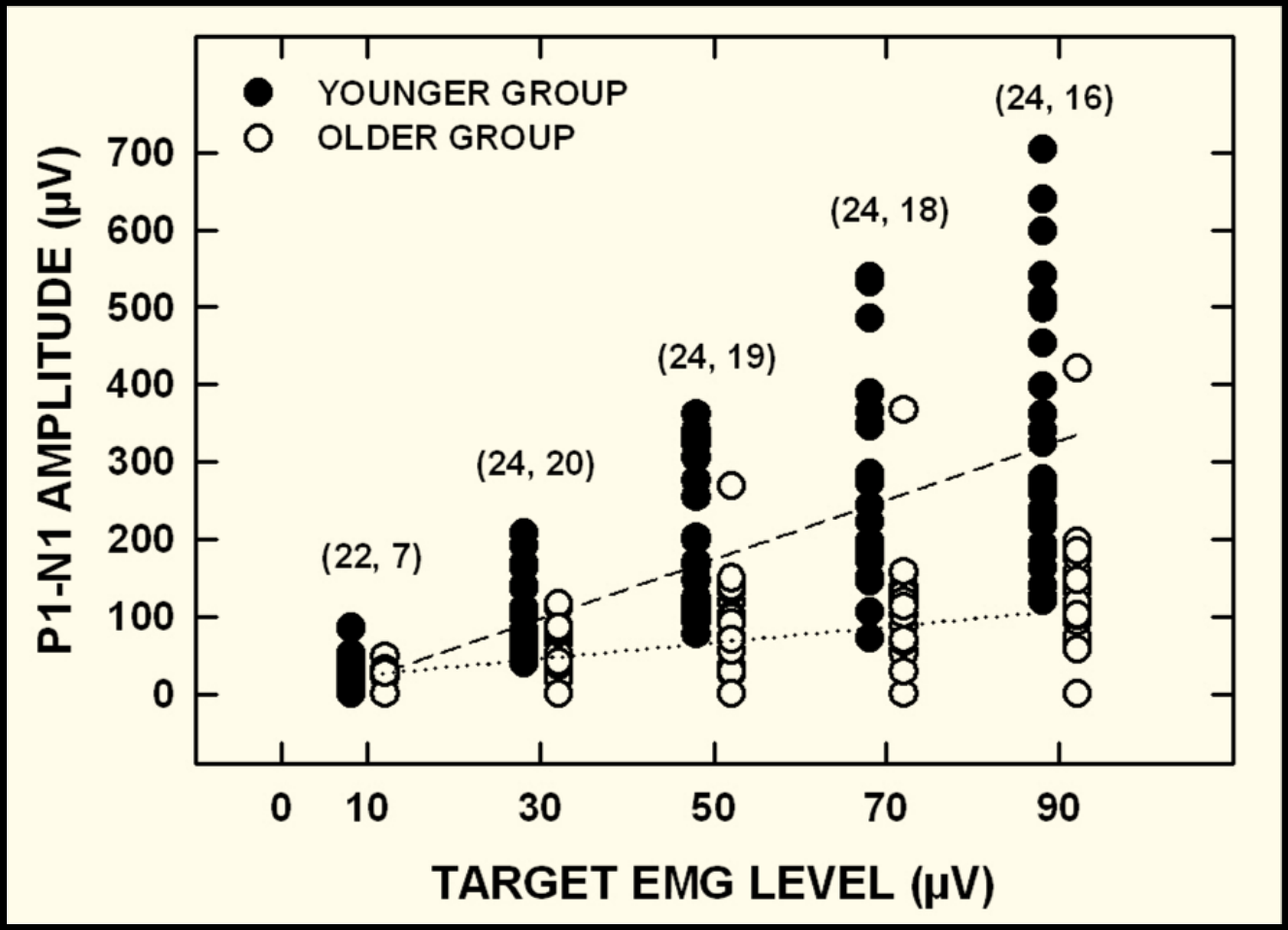

*Akin, Murnane, et al., 2011*

# cVEMPs Recorded at Various EMG Levels




*Akin, Murnane, Tampas, Clinard, 2011*

# Effect of Age on cVEMP Amplitude



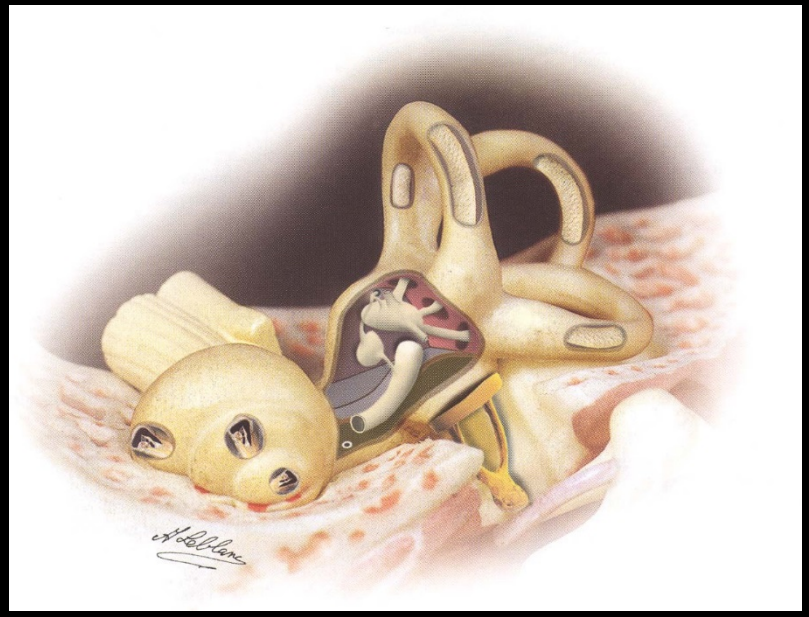

*Akin, Murnane, Tampas, Clinard, 2011*

# Age Trends for VEMP Clinic Findings

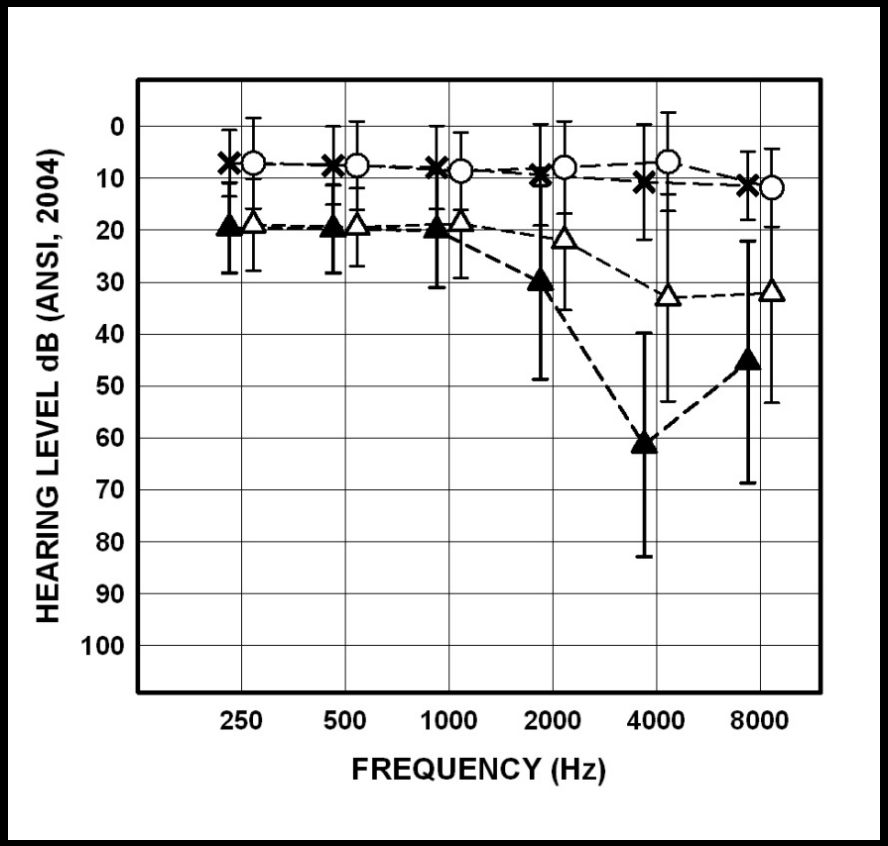
| | Mean Age (years) | |
|---|---|---|
| | AC cVEMP | BC oVEMP |
| NORMAL | 57 ±15 | 59±15 |
| BILATERAL | 65 ±12 | 67±11 |
| UNILATERAL | 63 ±17 | 62±15 |
| | | |
| CNT | 65 ±17 | 70±8 |
| 50 µV / 30° GAZE | 52 ±16 | 58±15 |
| MVC/ MAX GAZE | 63 ±12 | 64±13 |

# Effect of Noise Exposure on cVEMP

# Effect of Noise Exposure on cVEMP



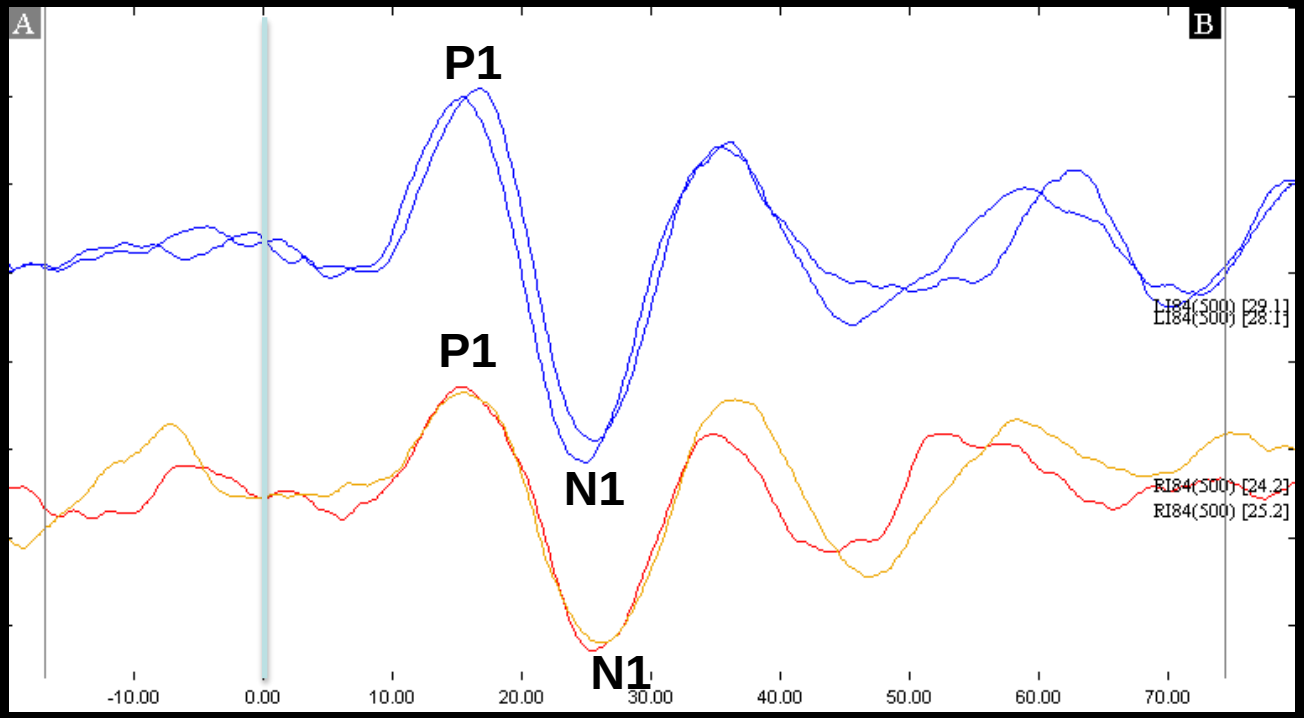
# *Akin, Murnane et al. 2012* The Effect of Noise Exposure on the cVEMP



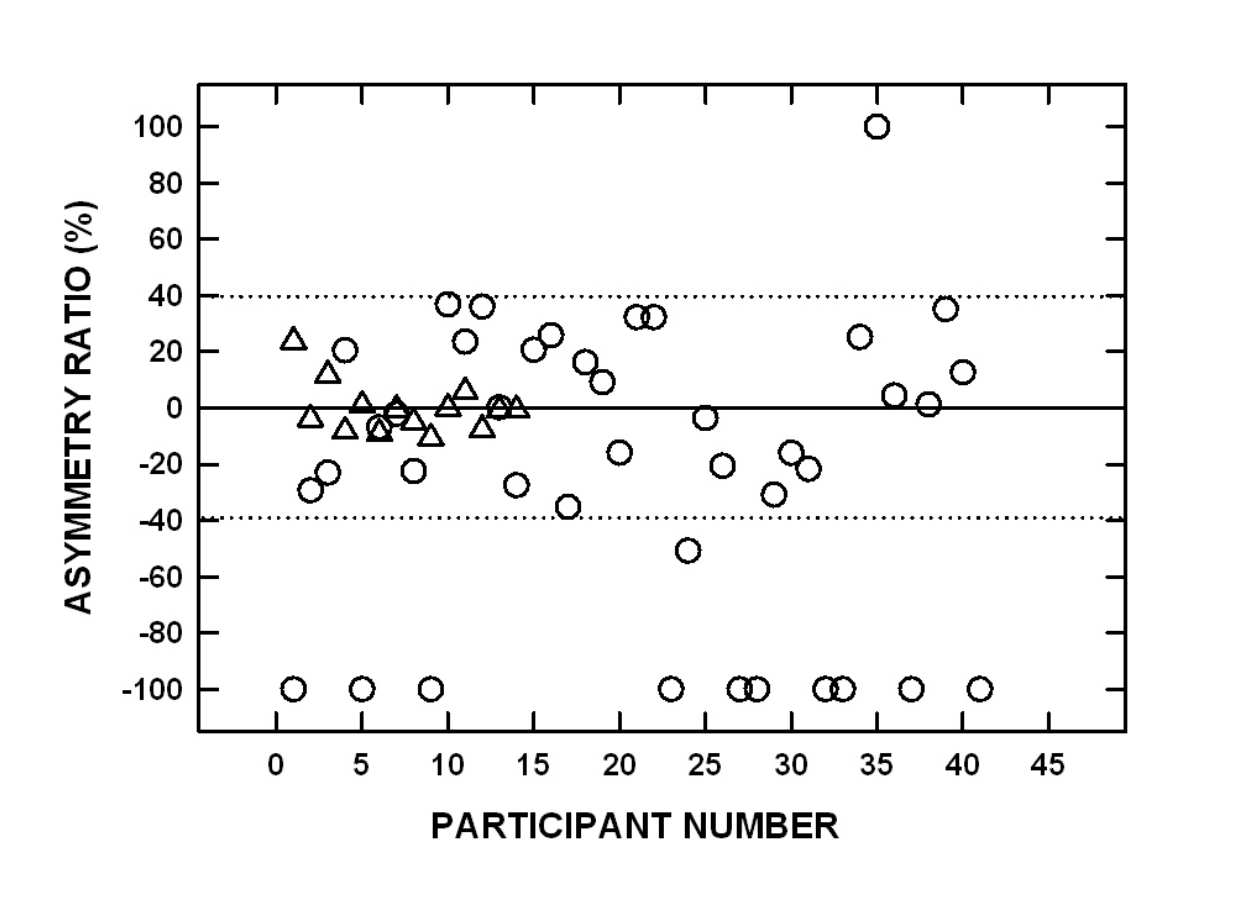

- 43 subjects with asymmetric NIHL and history of asymmetric noise exposure
- (25 – 63 years, X = 52 yrs)
- 14 age-matched controls

# Signed Asymmetry Ratio

$$\frac{\text{(Poorer-Hearing Ear P1-N1 – Better-Hearing Ear P1-N1)}}{\text{(Poorer-Hearing Ear P1-N1 + Better-Hearing Ear P1-N1)}} \times 100$$

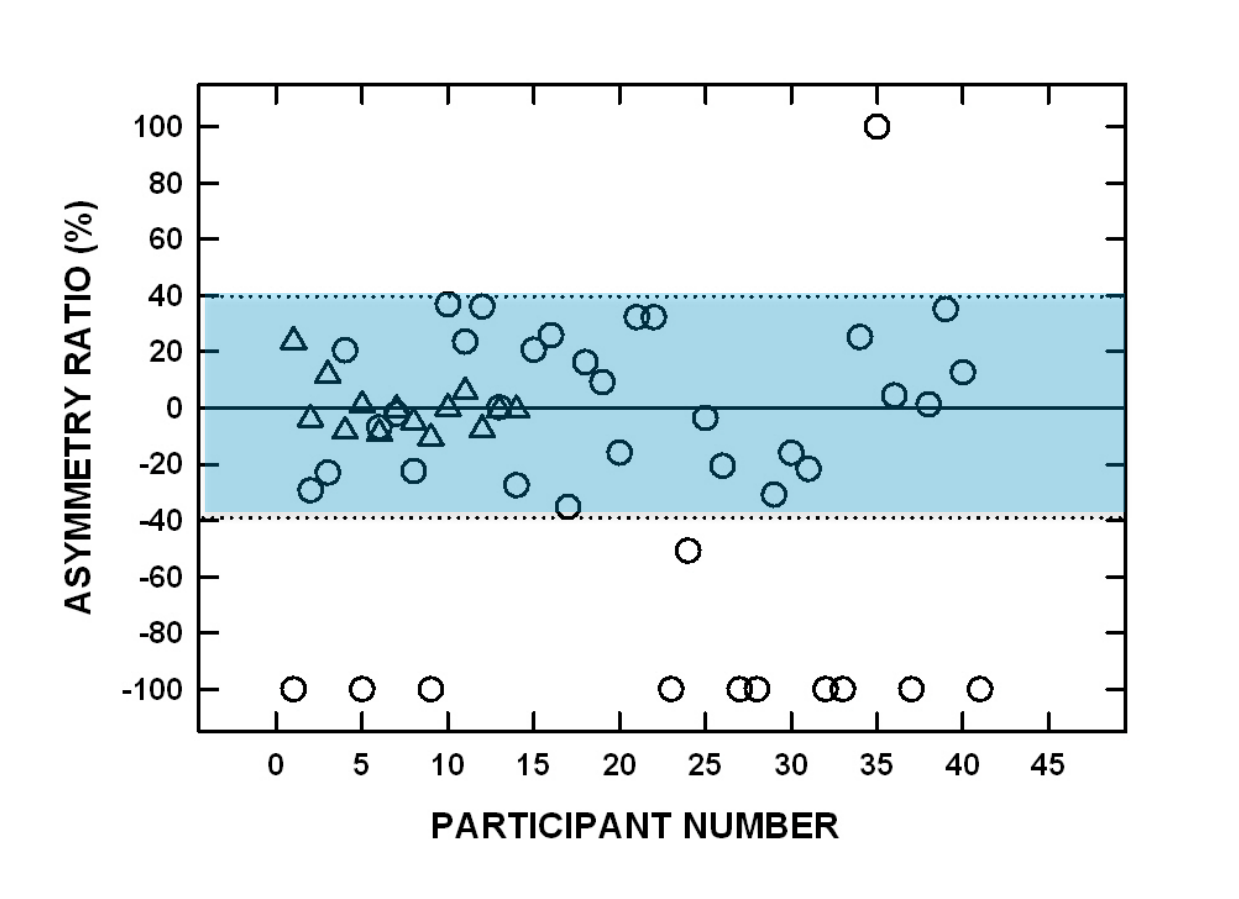


# Asymmetry Ratios: Control and Noise Exposure Groups



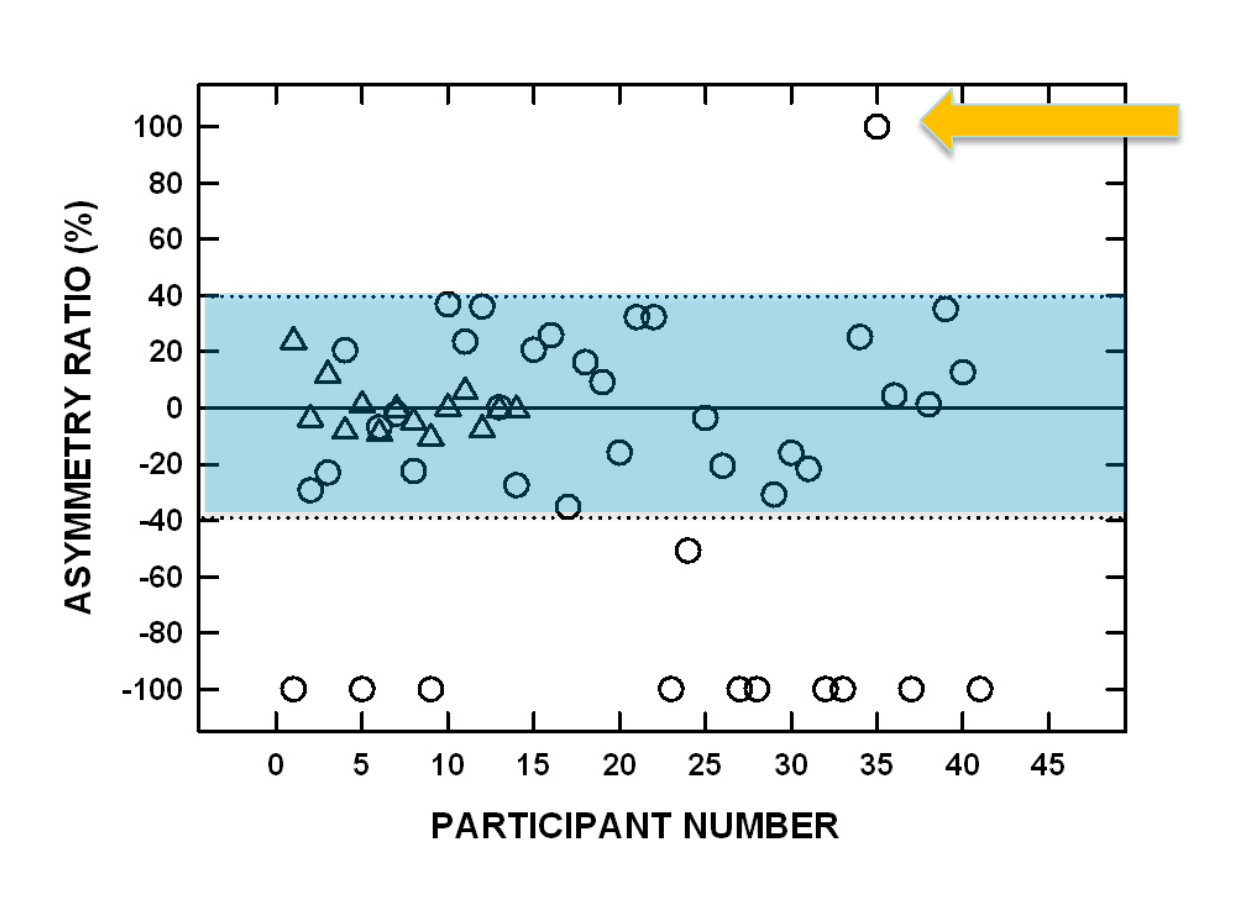

*Akin, Murnane et al., 2012*

# Asymmetry Ratios: Control and Noise Exposure Groups



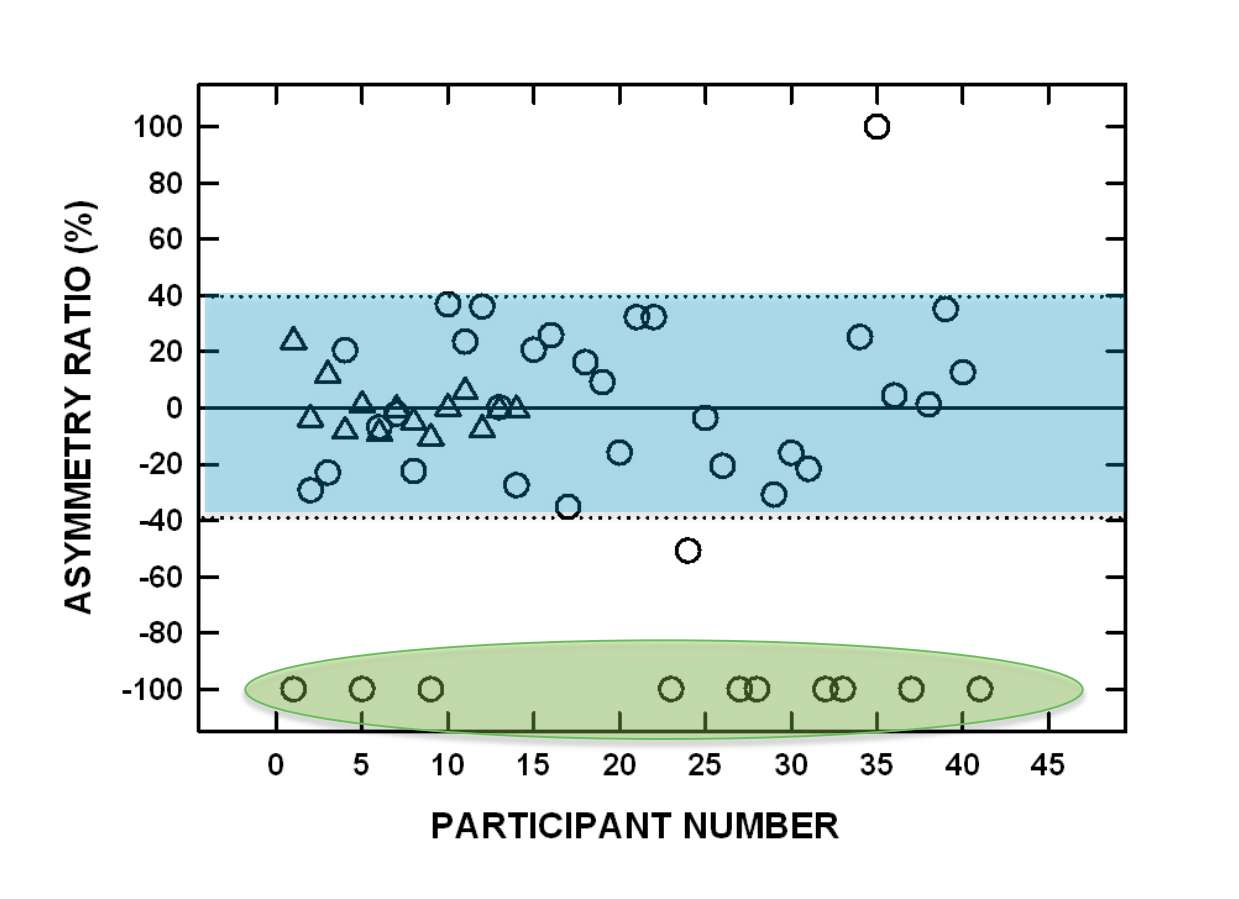

*Akin, Murnane et al., 2012*

# Asymmetry Ratios: Control and Noise Exposure Groups



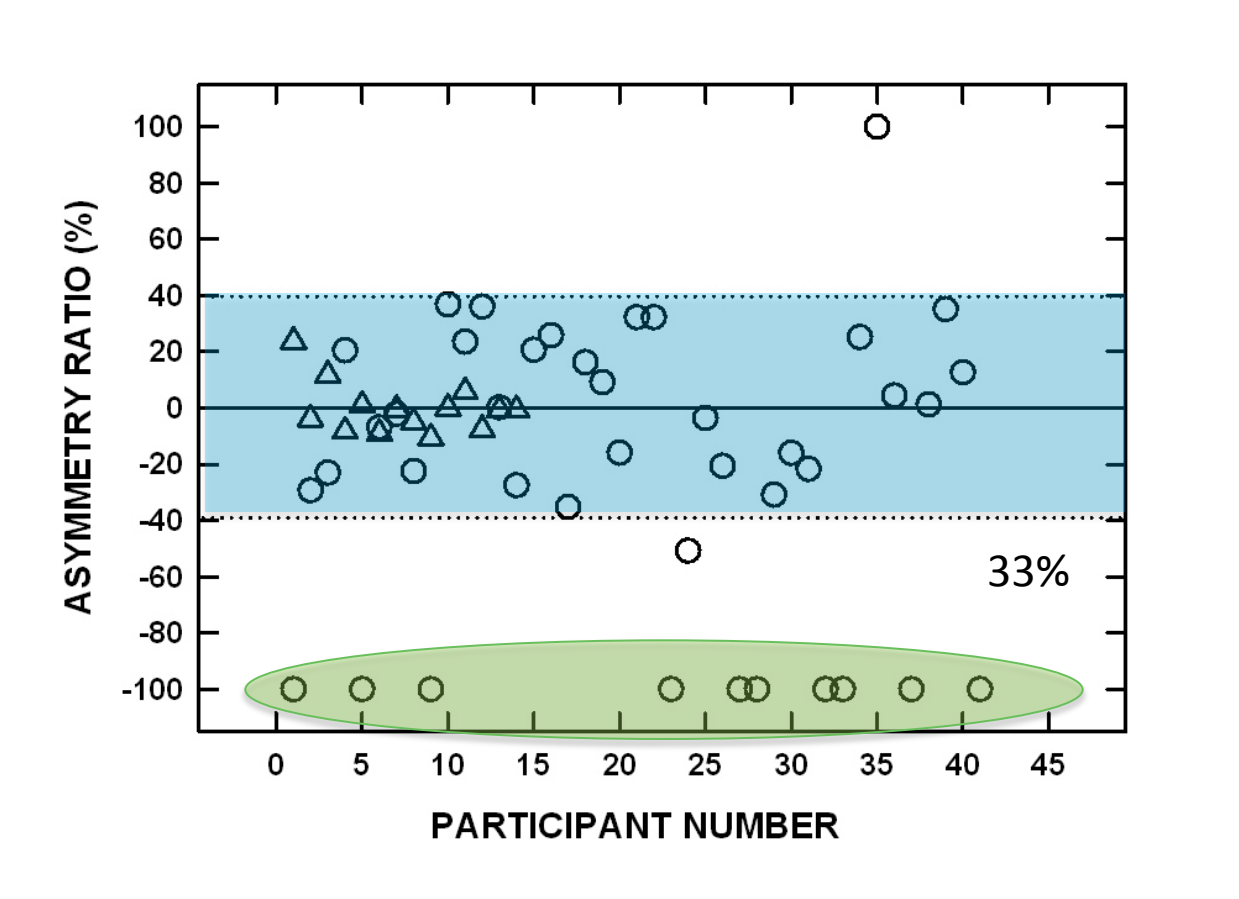

*Akin, Murnane et al., 2012*

# Asymmetry Ratios: Control and Noise Exposure Groups



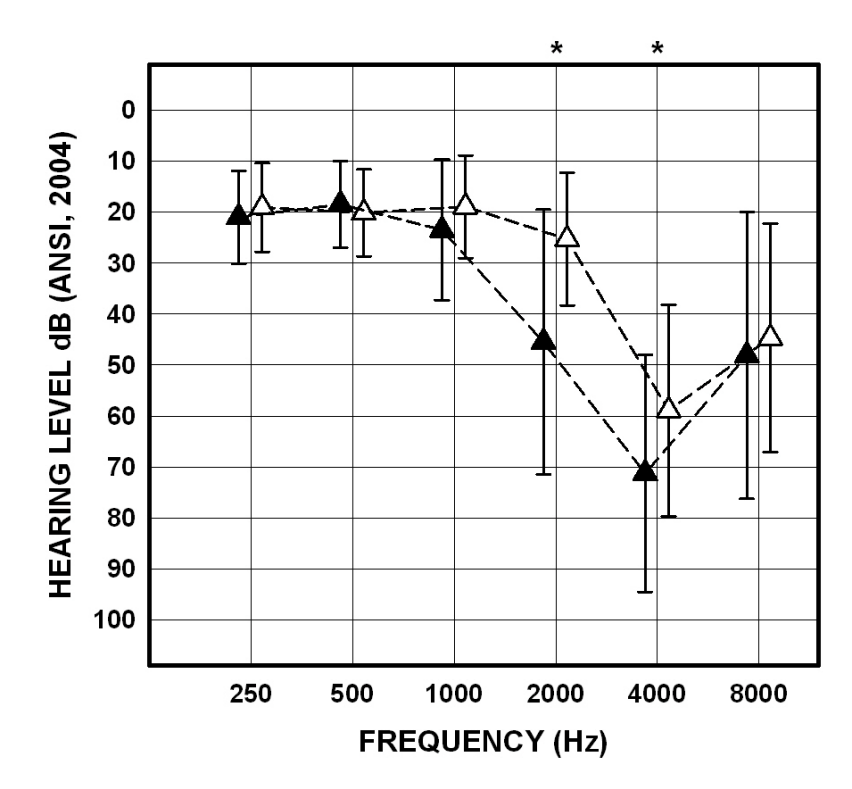

*Akin, Murnane et al., 2012*

# Asymmetry Ratios: Control and Noise Exposure Groups




*Akin, Murnane et al., 2012*

# Are there differences in hearing loss between noise-exposed subjects with cVEMPs present and the noise-exposed subjects with cVEMPs absent?




*Akin, Murnane et al., 2011*

# Effect of mTBI/Blast Exposure

# Abnormal vestibular function test findings in individuals with dizziness/imbalance related to TBI/blast exposure

| | N | hSCC | Otolith organ | Ocular motor | Gait/ balance |
|---|---|---|---|---|---|
| Davies & Luxon 1995 | 100 | 51% | - | 8% | - |
| Ernst et al. 2005 | 63 | 19% | 25% | 5% | 27% |
| Dae Lee et al. 2011 | 28 | 7% | 54% | - | - |
| Shupak et al. 1993 | 5 | 40% | - | - | - |
| Van Campen et al. 1999 | 30 | 7% | - | 7% | 37% |
| Cohen et al. 2002 | 17 | 0% | - | - | 4% |
| Scherer et al. 2011* | 11 | 27% | 17% | 45% | - |

# Mountain Home VAMC Study: Preliminary Findings

| | TBI/Blast N = 51 | Control N = 21 |
|---|---|---|
| Age | 37 (10) | 26 (5) |
| MMSE | 29 (1.8) | 30 (.4) |
| PTSD | 92% | 0% |
| Tinnitus | 98% | 14% |
| Sensorineural Hearing Loss | 67% | 0% |

# Symptom Characteristics of mTBI/Blast Group (n = 51)

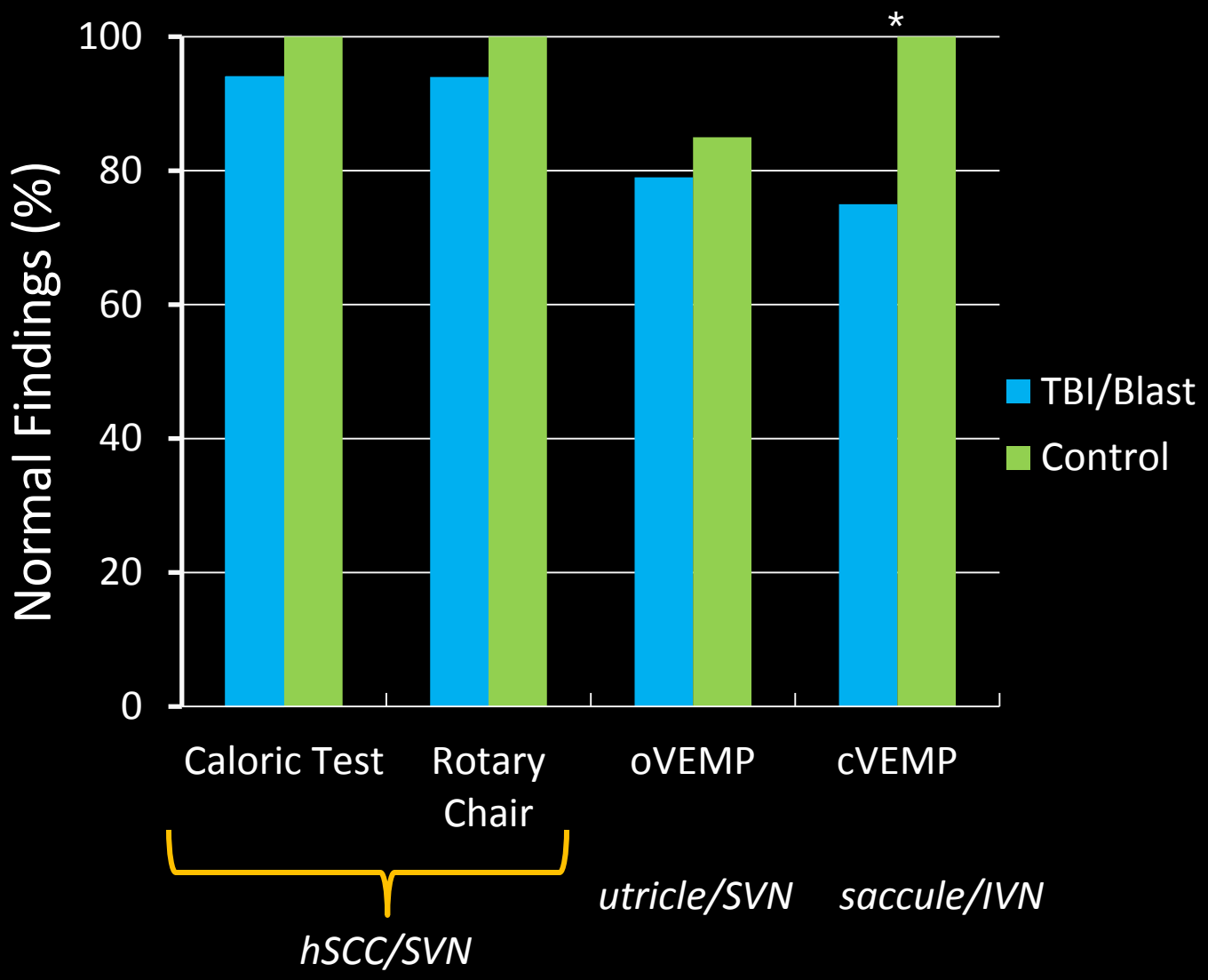
| Symptom | N (%) |
|---|---|
| Vertigo | 25 (49%) |
| Imbalance | 45 (88%) |
| Lateropulsion | 26 (52%) |
| Lightheadedness | 37 (73%) |
| Oscillopsia | 3 (6%) |

# History of Blast Exposure for 51 Veterans

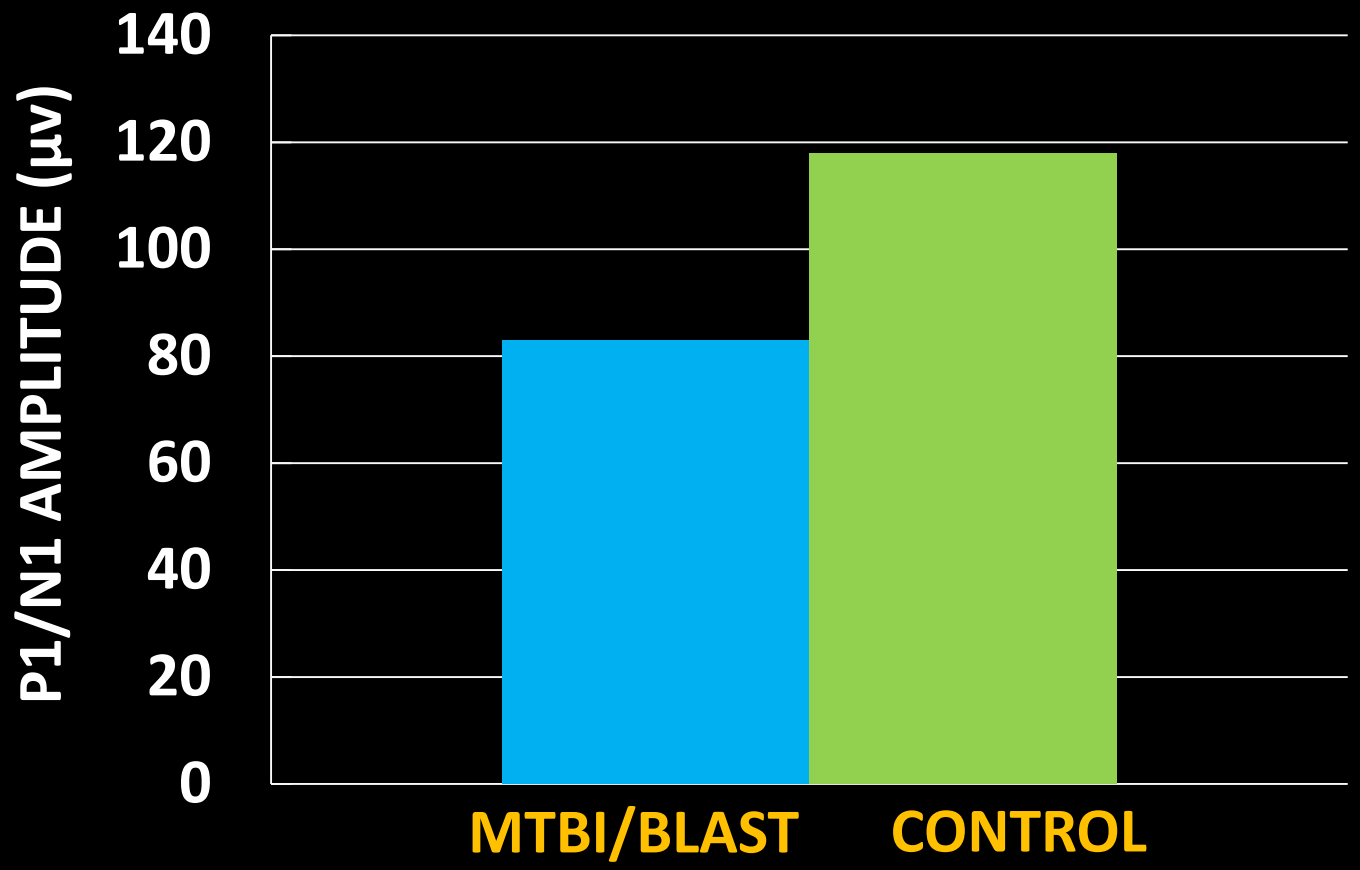
| Number of blasts | Number of Veterans |
|---|---|
| 0 | 3 |
| 1-2 | 13 |
| 3-5 | 6 |
| 5+ | 29 |

| Time since worst exposure |
|---|
| Range = 6 months – 10 years |
| Mean (SD) = 5 years 9 mos (30 mos) |
| 4 Veterans with symptoms ≥ 20 years |

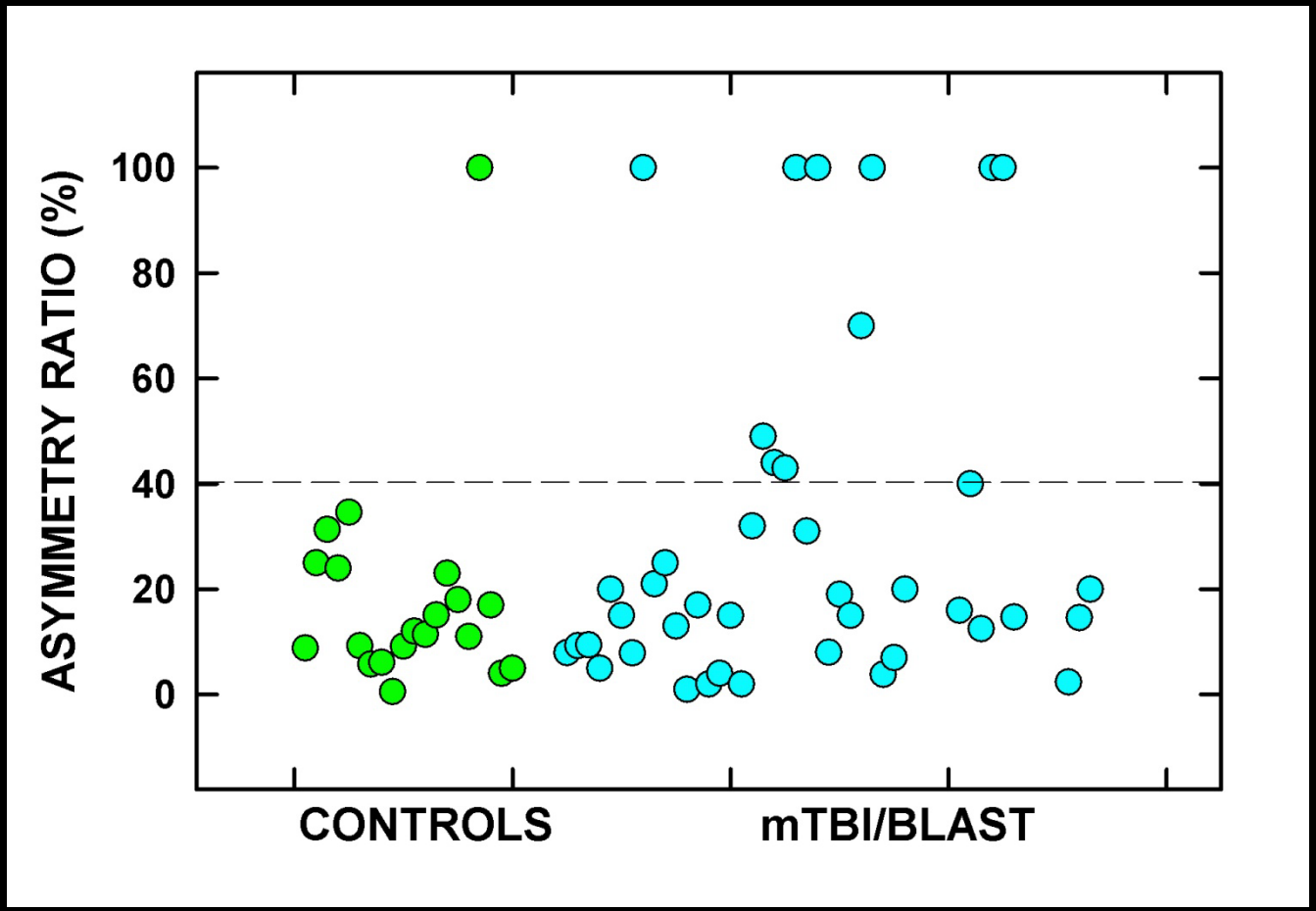
# Tests of Peripheral Vestibular Function



# cVEMP Amplitude in mTBI/Blast and Control Groups



# cVEMP Asymmetry Ratios in Control and mTBI/Blast Groups



# Future Directions

- Role of VEMPs in diagnosis of common vestibular disorders – need clinical trials
- How do VEMPs correlate with patient symptoms and other tests of vestibular function?
- How does otolith loss affect postural stability and rehabilitation outcomes?

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