Age-Related Changes in Vestibular Evoked Myogenic Potentials (VEMP) Utilizing a Modified Feedback Method

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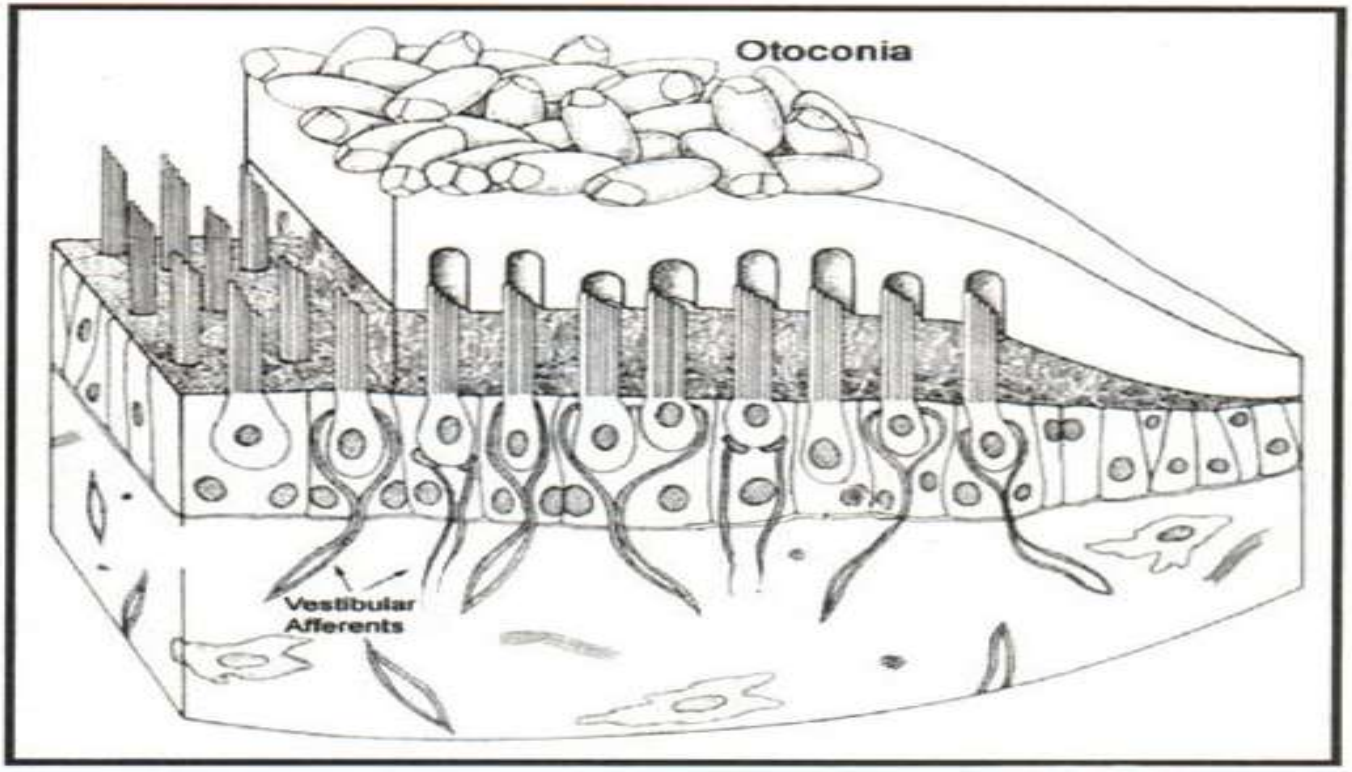
Overview

- VEMP review/history
- Problem
- Objectives
- Methods
- Results/Discussion
- Conclusion
- Future Research

Hearing Exam

Linear Motion



Schubert & Minor, 2004

Saccule and Utricle sense linear motion, otoconia embedded in macula provide mass that moves and stimulates hair cells.

Otolith Organs

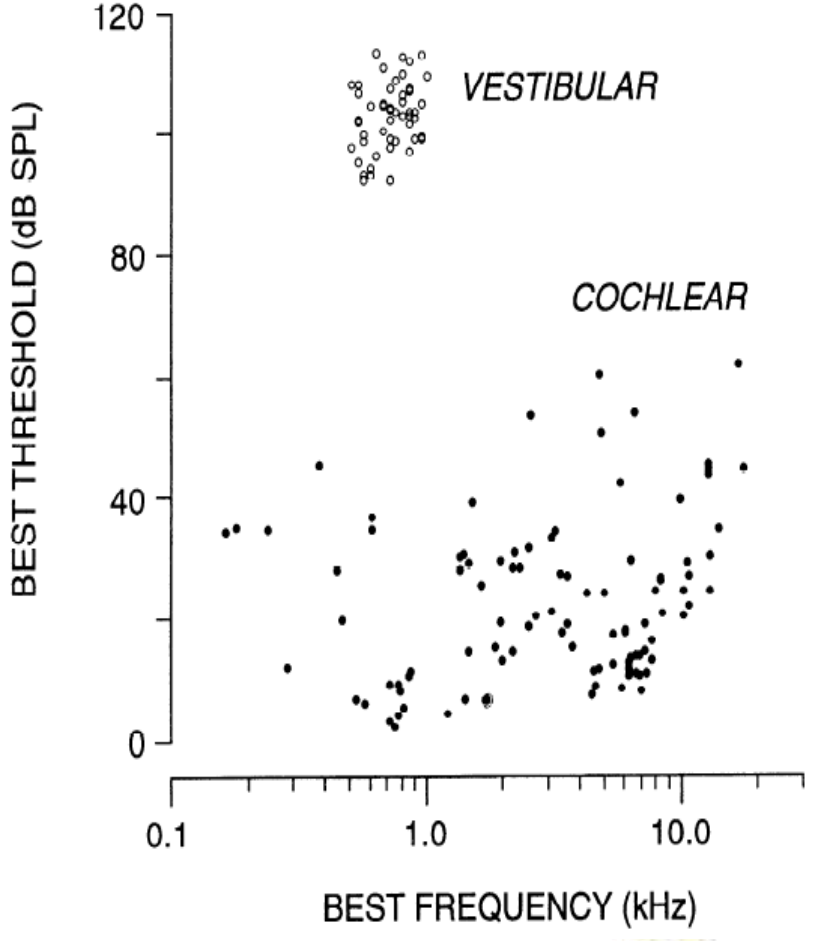
- The saccule lies in the vertical plane, while the utricle is positioned horizontally.

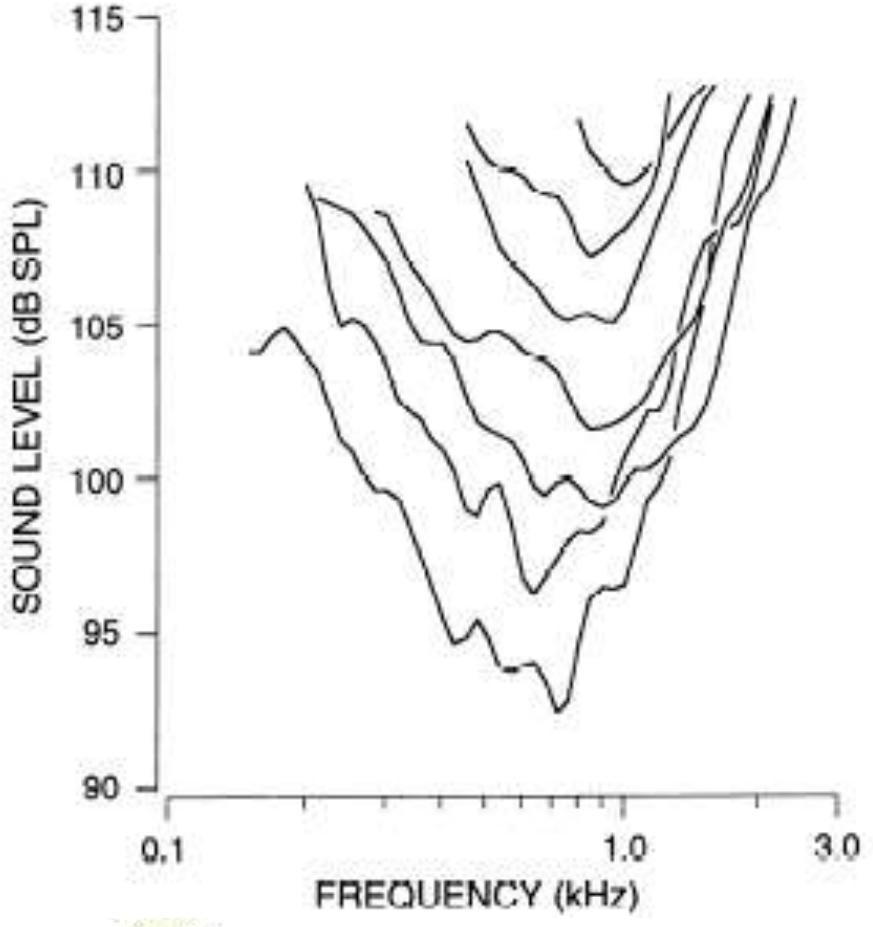
Vestibular Stimuli

- Physiologic or natural stimuli
  - Angular acceleration (semicircular canals)
  - Linear acceleration (otoliths)
  - Head tilts (otoliths)

- Non-physiologic stimuli
  - Galvanic
  - Skull taps
  - Acoustic

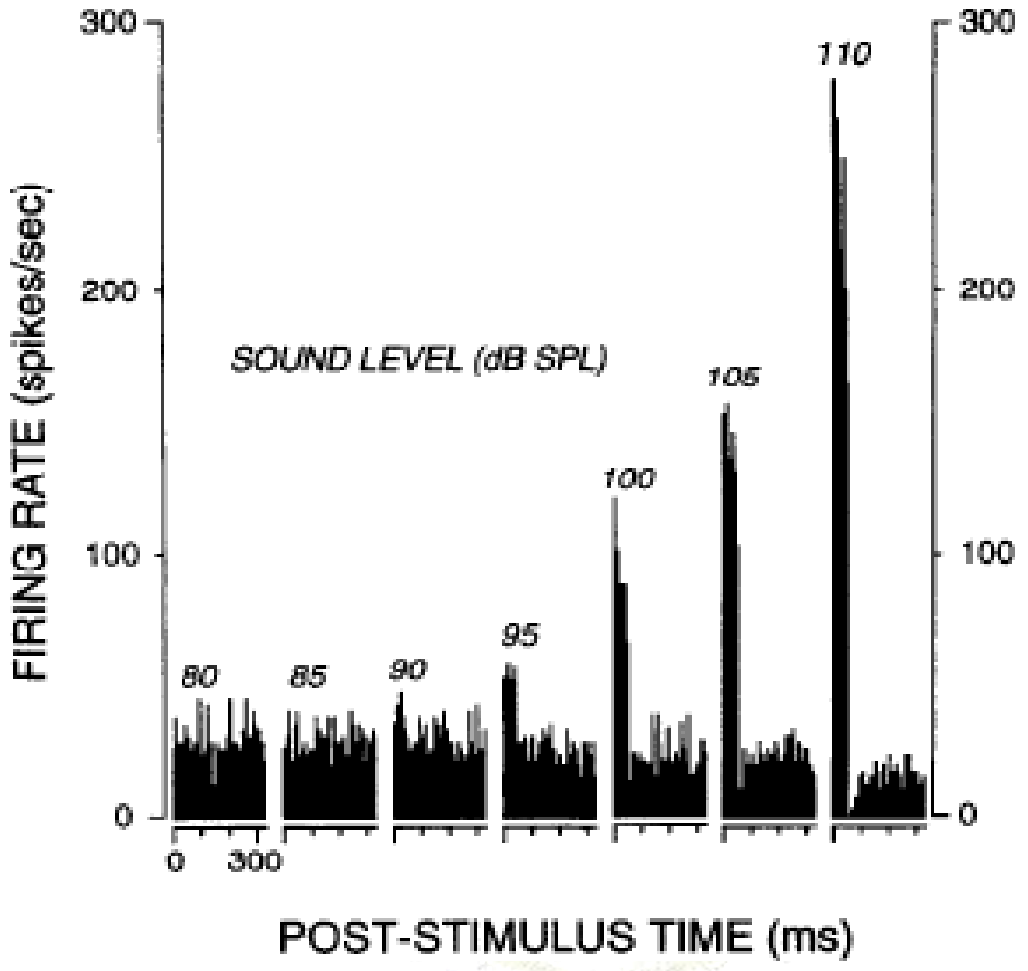
Vestibular Response to Acoustic Stimuli





McCue & Guinan, 1995

Vestibular Afferents



McCue & Guinan, 1994

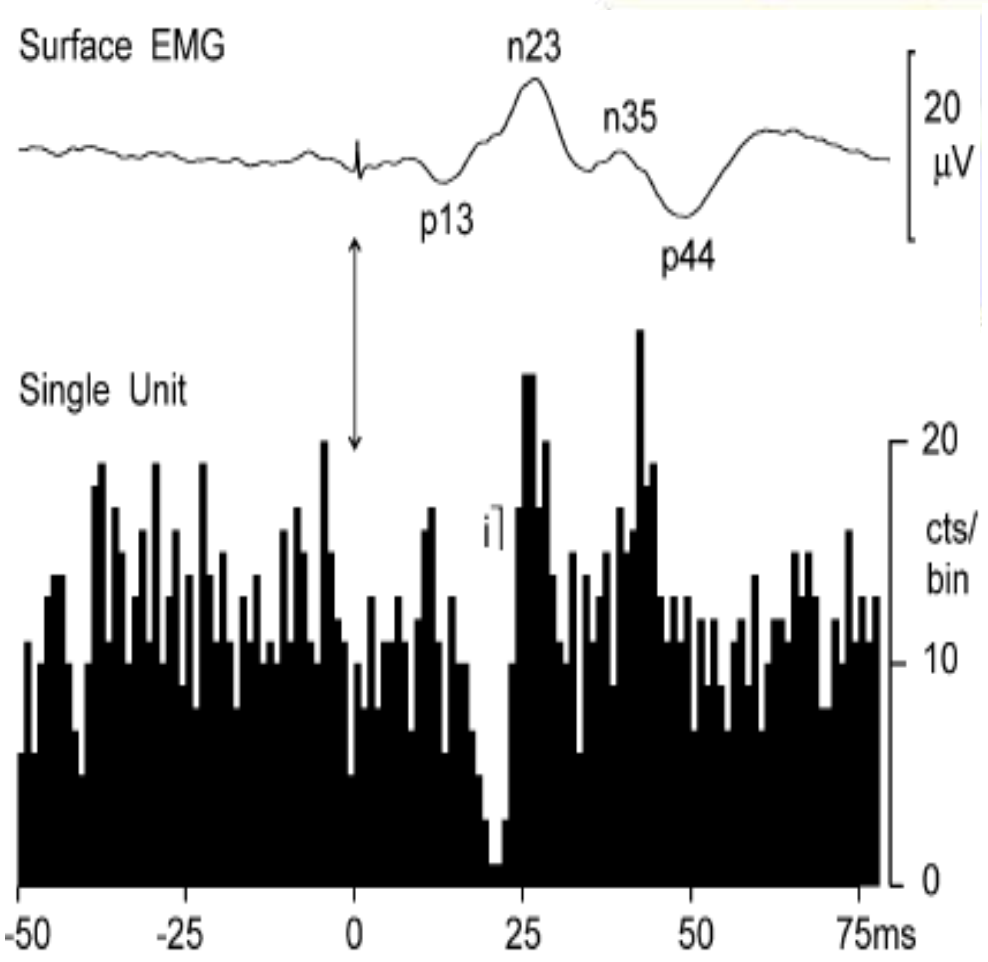
VEMP History

- Tulio (1929) studied vestibular responses to acoustic stimuli.

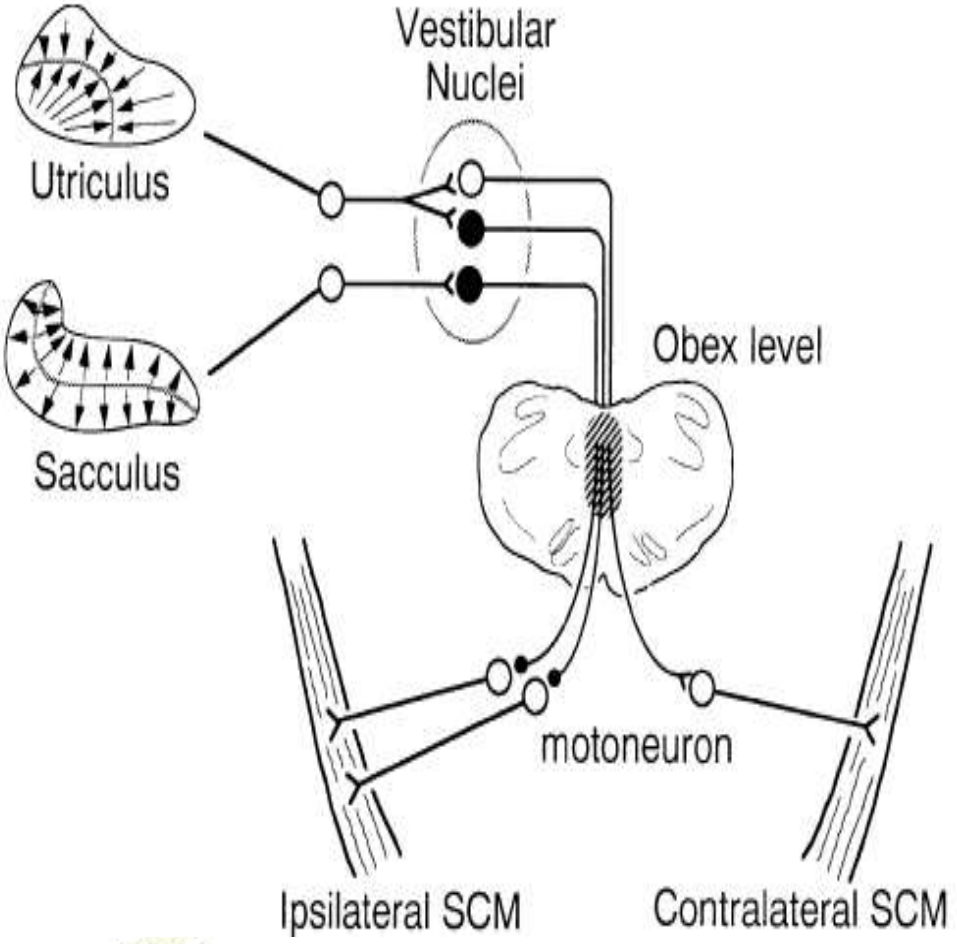
- Short latency myogenic responses to loud clicks with active electrode below the inion *(Bickford et al.,1964; Cody et al., 1964;Townsend & Cody, 1971).*

- New recording method from neck flexor muscles *(Colebatch & Halmagyi, 1992).*

VEMP Inhibitory Pathway



(Colebatch & Rothwell 2004)

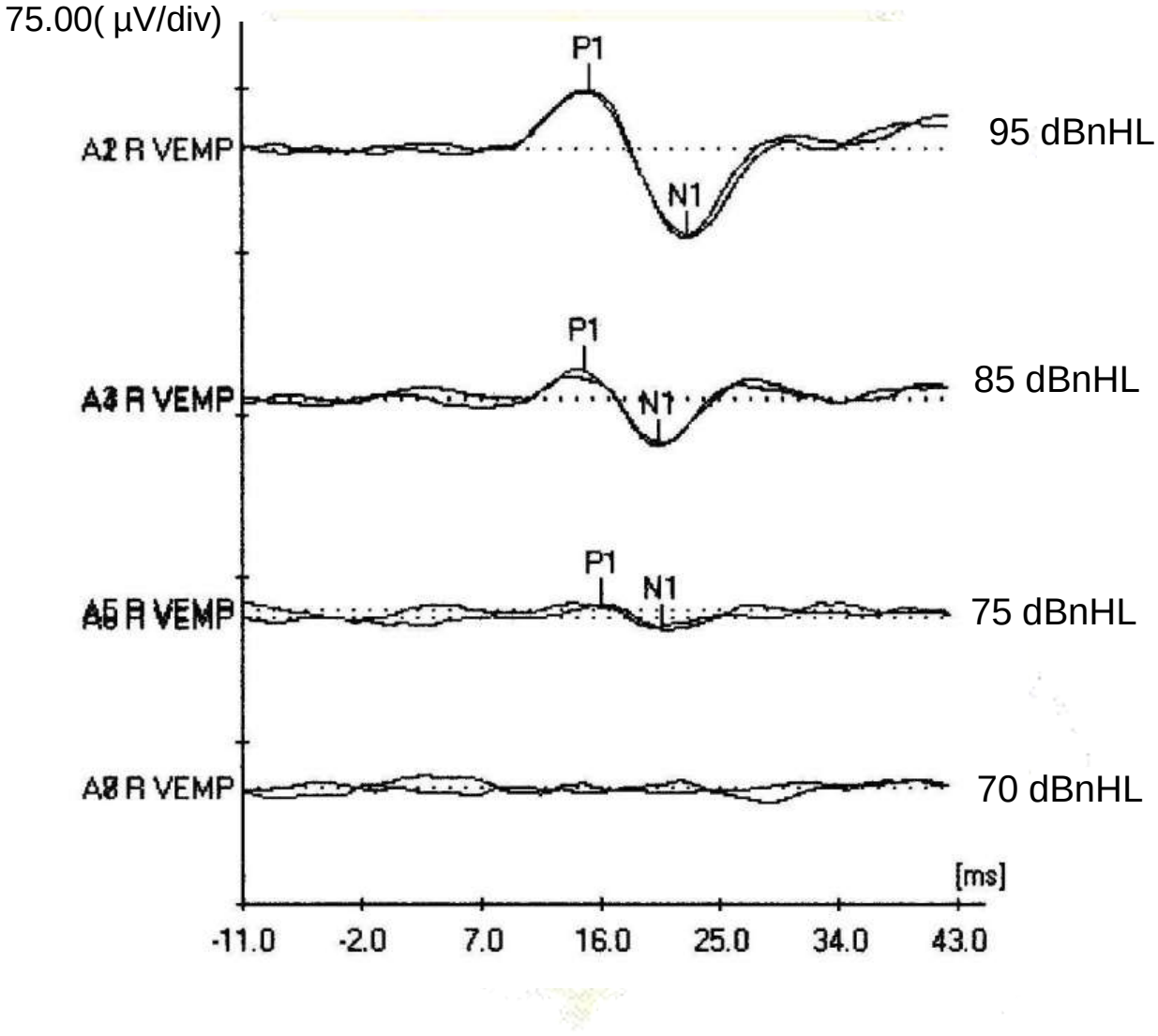


(Kushiro et al., 1999)

VEMP Pathway

- Disynaptic pathway originating in Saccule traveling through:
  - Scarpa's Ganglion
  - Inferior portion of Vestibular Nerve
  - Lateral Vestibular Nucleus
  - Medial Vestibulo-spinal Tract
  - Motor Neurons of Sternocleidomastoid (SCM) muscle

Example VEMP Waveforms

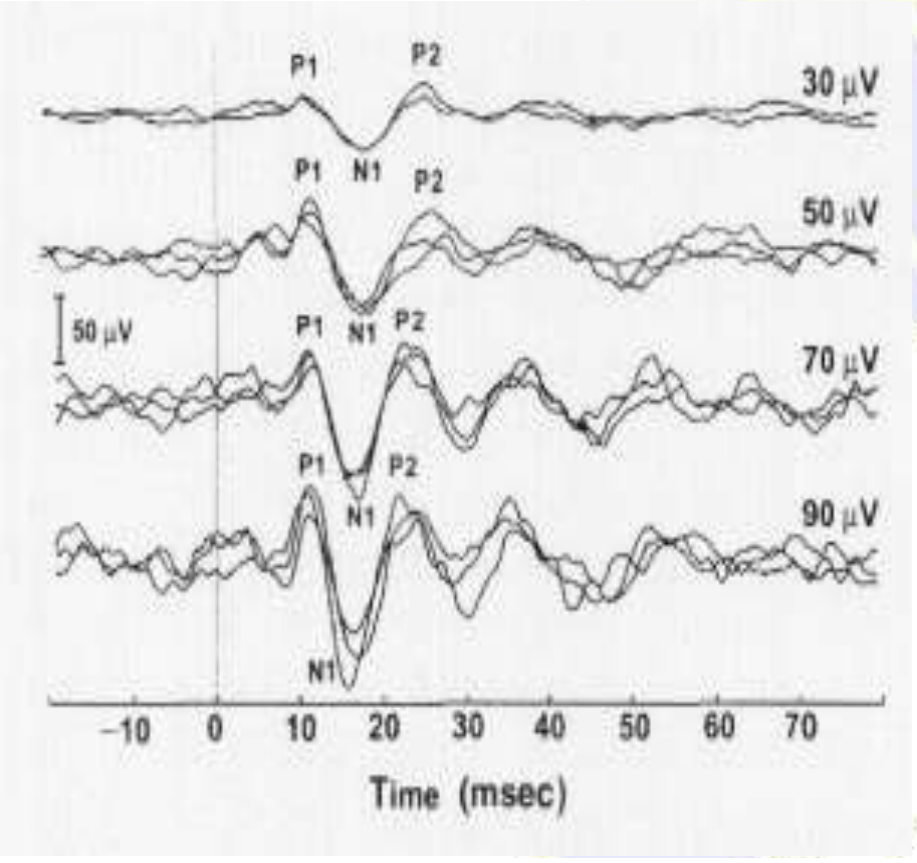


Monitoring Muscle Contraction

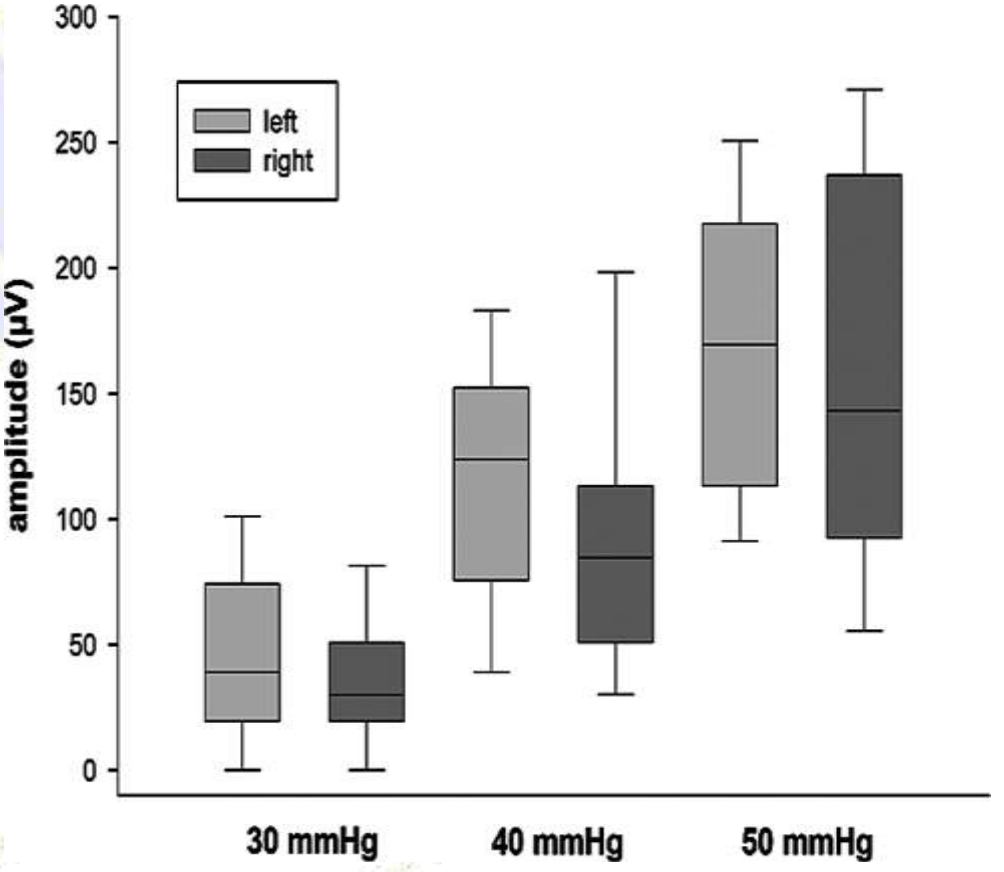
- Traditionally been accomplished with EMG:
  - Provide visual EMG target on laptop.
  - Not clinically integrated with AEP systems.
  - No standardization of EMG targets in literature.

- Blood Pressure Cuff method introduced in 2006:
  - Comparable amplitude results shown.
  - More clinically available procedure.
  - No standardization yet on procedure.
  - No age-related studies using this procedure (Maes 2009 now available).

Muscle Contraction and VEMP



(Atkin & Murname, 2001)



(Vanspauwen et al., 2006)

Muscle Contraction

Hand Held Blood Pressure Cuff
(Vanspauwen et al., 2006)

Lateroflexion Movement
(Maes et al. 2009)

Age-Related Changes

- Age-related morphological changes in the vestibular system exist:
  - Schuknecht (1965) cochleo-saccular degeneration.
  - Rosenhall (1973) vestibular hair cell loss.
  - Bergstrom (1973) vestibular nerve fiber loss.
  - Velazquez (2000) cell body loss in Scarpa's Ganglion.
  - Tang et al. (2001) loss of neurons in vestibular nucleus.
- Tests of VOR function have shown only small changes with age and have often been inconsistent.

Age-Related Changes

- Negative changes in VEMP parameters with age:
  - Reduced peak-to-peak amplitudes.
  - Increased thresholds.
  - Possible increased latencies.
- Age must be considered in VEMP analysis.
- Previous studies:
  - Limited healthy aging subjects.
  - No standardization of recording protocol.
  - No age-related studies using the BPM (at time this study).

Vestibular Testing

Tests of VOR

- DVA, VNG, Rotary chair
- Functions of:
  - Semi-circular canals.
  - Superior vestibular nerve fibers.
  - Ascending vestibular pathway (upper brainstem).

VEMP

- Test of Vestibulo-colic reflex
- Functions of:
  - Saccule.
  - Inferior vestibular nerve fibers.
  - Descending vestibular pathway (lower brainstem & cervical spinal cord).

Problem

- Dizziness/Balance Disorders are major public heath concern.
- Incidence of dizziness is 5.5% in U.S.
  - >15 million Americans develop symptoms annually.
- >30% of U.S. population will have dizziness symptoms by the age of 65.
- Many etiologies exist for dizziness but abnormal vestibular function represents a major cause.
- As population ages this trend will most likely continue to grow and become more of an issue.

Problem

- Balance disorders increase probability of injury related falls.
- Falls are leading cause of death in individuals > 65 years.
- Two keys for avoiding injury-related falls:
  - Adapting quickly to unexpected changes.
  - Maintaining clear vision during head movements.
- Especially important to the elderly population due to a less responsive and weaker muscular system.

Objectives

- Quantify physiologic changes which occur in the vestibular (specifically saccular pathways) system with aging utilizing the VEMP.

- Establish preliminary age-related data for VEMPs utilizing the BPM method with 500 Hz tone bursts.

Subjects

- Non-probability group assignment based on age
  - Group 1 - (n=12, range 20-30, mean = 26.8)
  - Group 2 - (n=10, range 65-71, mean = 67.7)
  - Group 3 - (n=10, range 75-84, mean = 78.7)
- Recruitment
  - Young subjects from student population
  - Older subjects from Grayhawk Database
- Subjects signed informed consent

Subjects

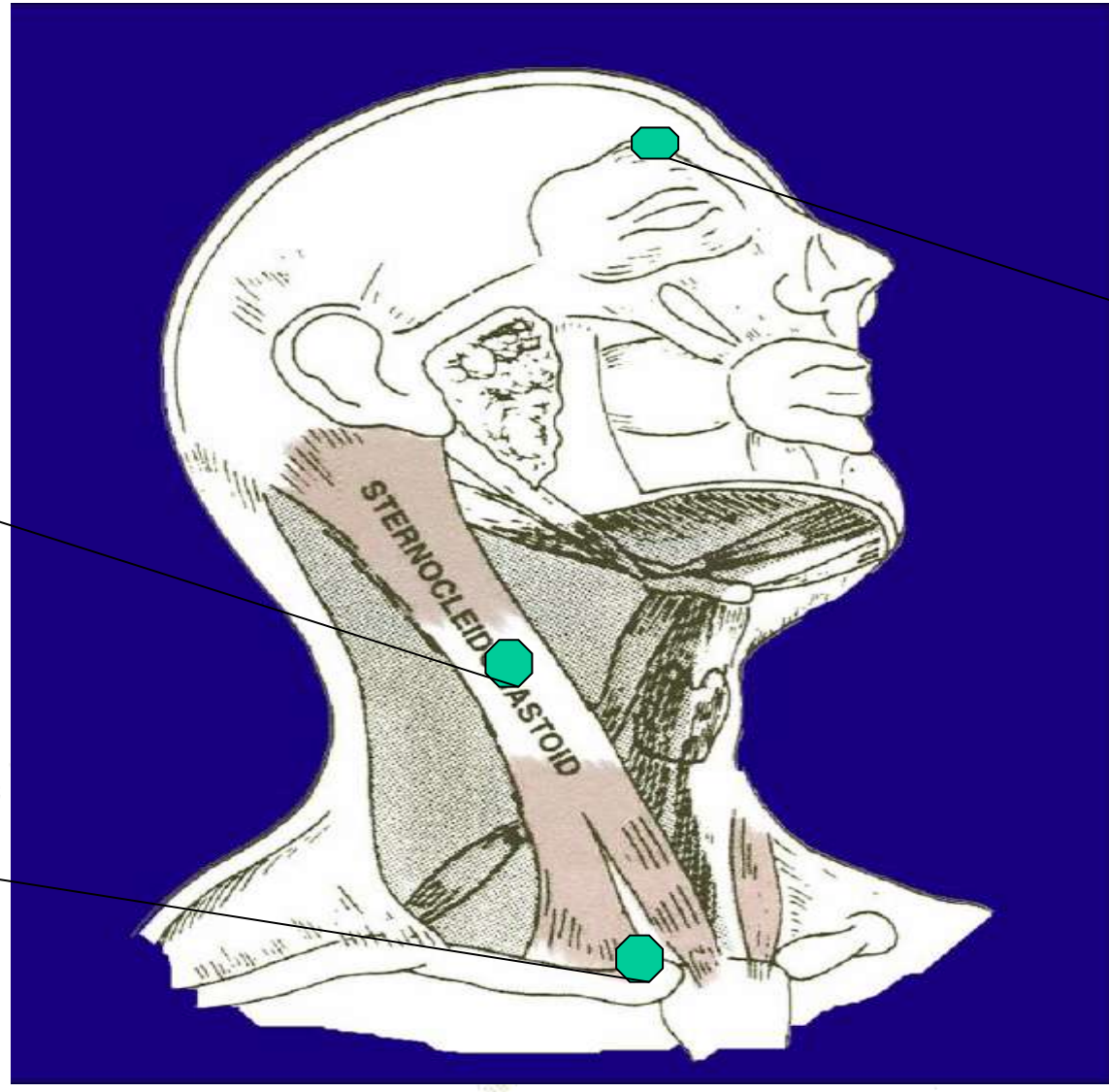
- Prescreened:
  - Vestibular/Neuromuscular Pathology.
  - Mini-Mental State Exam (MMSE).
  - Average walking speed.
  - Extensor knee torque.
  - Vibration and touch sensation.
  - Weekly physical activity.
  - Falls in past year.
  - Rotary chair function.
  - Middle ear function.
  - Pure tone audiometry.

VEMP Protocol

Stimuli:

- 500 Hz rarefaction tone bursts.
- Rise/Fall = 2 ms.
- Plateau = 1 ms.
- Band Pass Filtered = 15-1500 Hz.
- Amplified = 5000x.
- Starting level: 95 dBnHL.
- Presented through ER-3A insert earphone.
- Reduced in 10 dB steps.
- Increased in 5 dB steps to find threshold.
- Threshold = lowest dB level the VEMP can. (visually be detected and repeated)

VEMP Setup



Primary Electrode

Secondary Electrode

Common Electrode

Zemlin, 1998

VEMP Setup

Response Parameters

- Repeatable/visually detectable averaged wave forms were used in the analysis.
- P1-N1 peak to peak amplitude (µV).
- First positive peak labeled P1.
- First negative labeled N1.
- Absolute wave latencies (ms).
- Inter-amplitude difference (IAD) ratios will be calculated
  - 100 [(AR-AL) / (AR+AL)] = %.
- Thresholds were obtained for each ear.

Results/Discussion

- VEMP parameters were obtained at 95 dBnHL.
  - Bilateral recordings were obtained on 29 of 32 pts.
    - 3 subjects had an air/bone gap in 1 ear (1 from each group).
  - Overall mean IAD ratio was 15.7 ± 13.9 µV for this study.
    - 33.80 ± 28.33 µV (Maes et al., 2009).
    - 40.2 ± 29.5 µV (Vanspauwen et al., 2006).
  - Only BPM study using aging subjects.
  - More scrutinized recording procedure.
  - Subjectively “simpler” muscle contraction procedure.

VEMP Gender/Ear Data

	P1 (ms)	N1 (ms)	Amplitude (μV)	Threshold (dBnHL)	IAD (%)
Overall (n = 61)	16.0 2.2	24.2 2.7	103.1 75.6	80.6 5.2	15.7 13.9
Right (n = 32)	16.1 2.1	24.3 2.8	104.0 75.3	80.8 5.4	
Left (n = 29)	15.9 2.3	24.2 2.8	99.2 69.0	80.2 5.2	
	p = 0.698	p = 0.975	p = .349	p = 0.475	
Male (n = 30)	15.8 1.4	23.5 1.8	93.3 60.7	80.3 4.1	18.2 14.4
Female (n = 31)	16.3 1.9	24.8 2.8	114.1 92.3	80.9 5.1	13.1 13.3
	p = 0.399	p = 0.156	p = 0.464	p = 0.741	p = 0.323

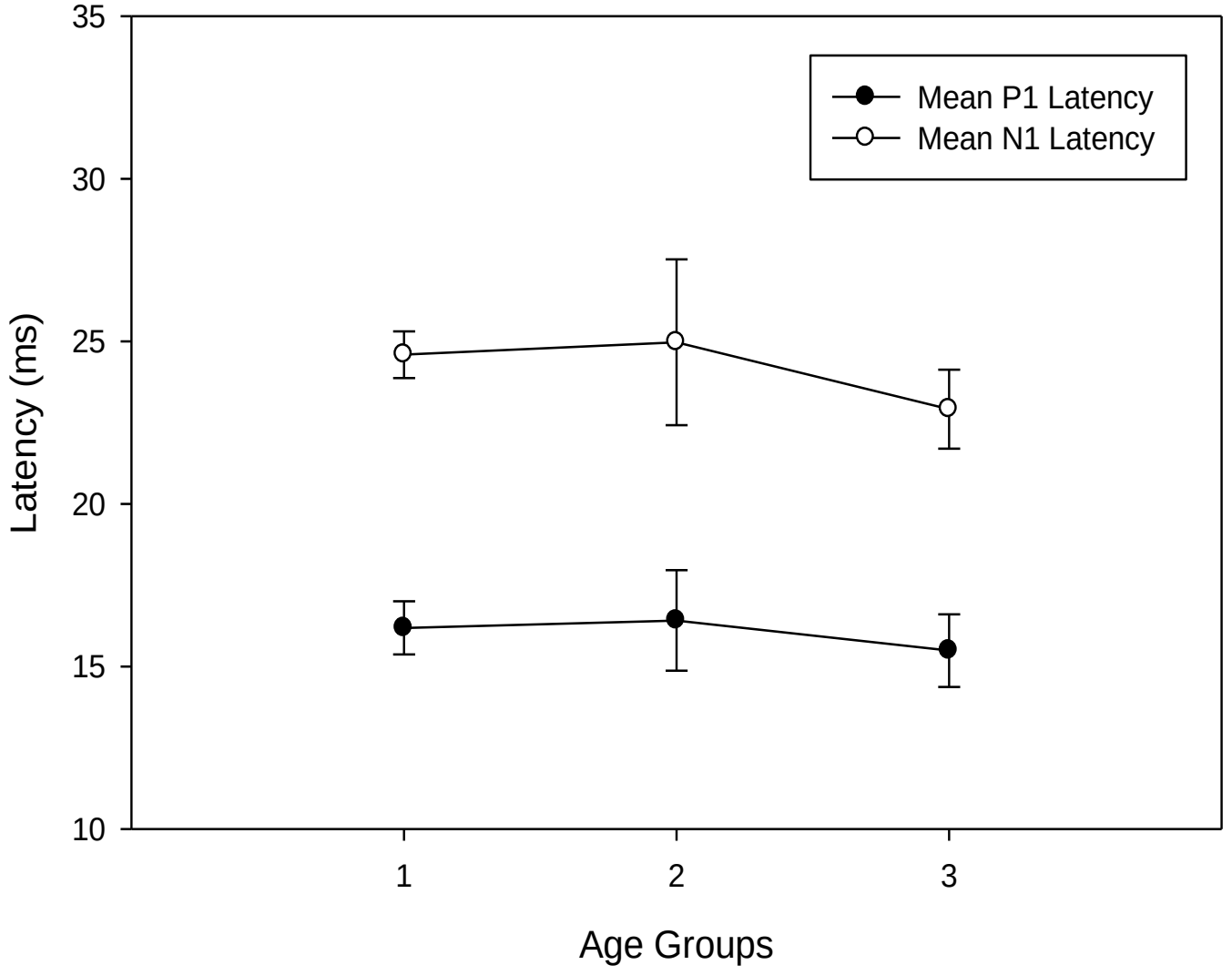
IAD, Interaural Amplitude Difference. (n = ears)
*Data are expressed as mean ± SD, *p < 0.05.*

Results/Discussion

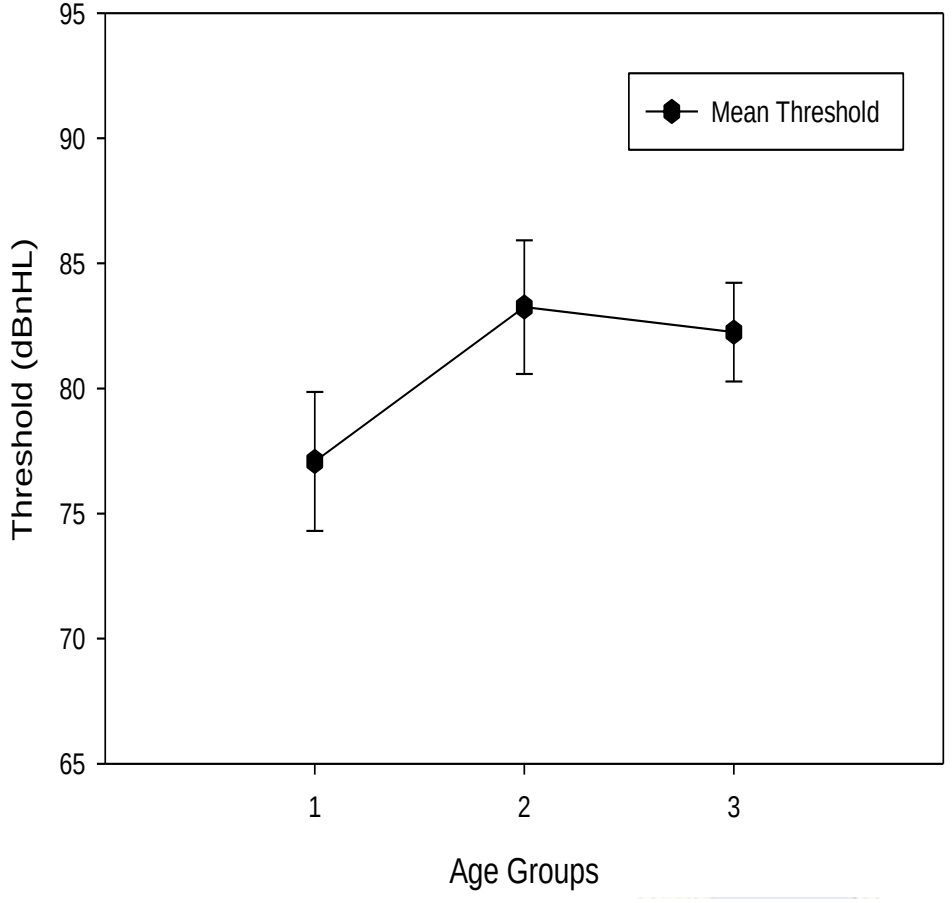
Age Groups	P1 (ms)	N1 (ms)	Amplitude (μV)	Threshold (dBnHL)	IAD
1 (20-30 yrs)	16.2 1.3	24.6 1.1	180.1 67.9	77.1 4.4	10.1 7.0
2 (65-74 yrs)	16.5 2.3	25.0 3.6	59.9 40.3	83.3 3.7	18.8 15.4
3 (75-85 yrs)	15.5 1.5	22.9 1.7	57.9 41.8	82.3 2.8	19.6 17.5
p value	p = 0.446	p = 0.119	p = 0.000*	p = 0.001*	p = 0.234

Group 1 (n=12), Group 2 (n=10), Group 3 (n=10).
*Data are expressed as mean ± SD, *p < 0.05.*

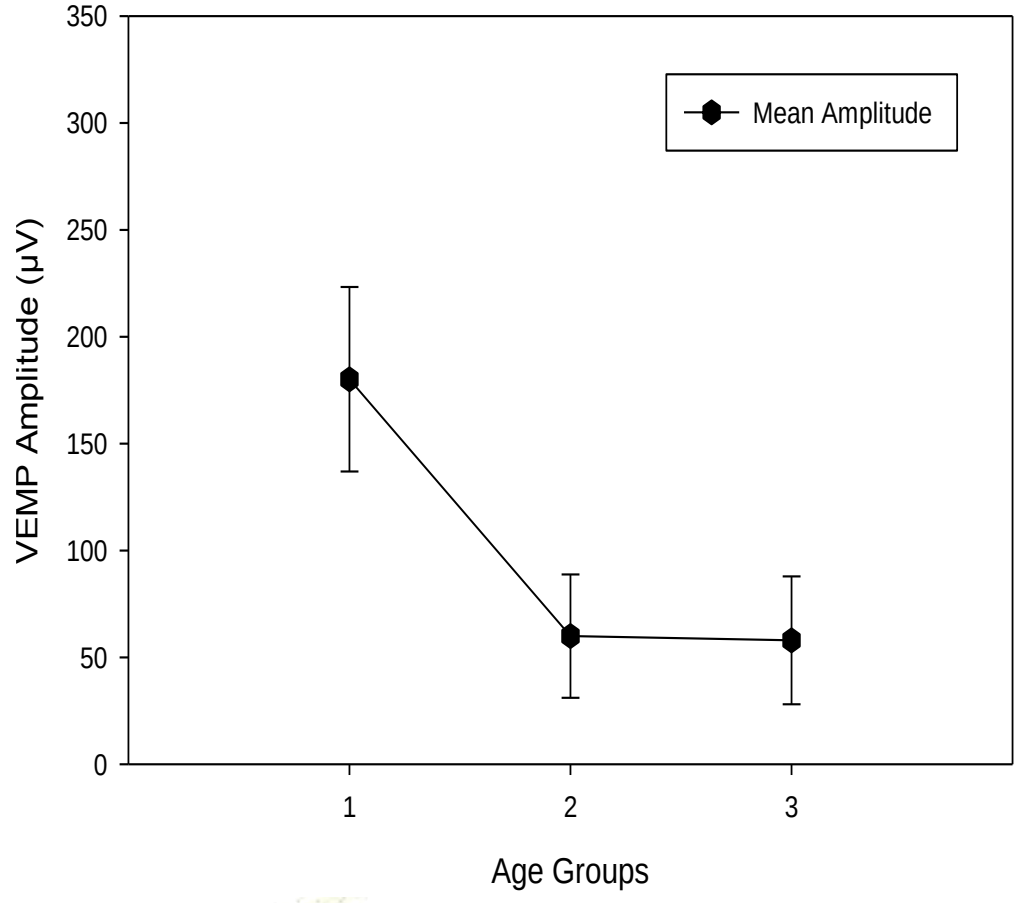
Results/Discussion



Results/Discussion



VEMP thresholds. Mean ± SEM. Group 1 & 2 (p = 0.002) and Group 1 & 3 (p = 0.008)



VEMP peak-to-peak amp. Mean ± SEM. Group 1 & 2 (p = 0.000) and Group 1 & 3 (p = 0.000).

Results/Discussion

- Amplitude:
  - Decline in older groups compared to younger.
    - Unrelated to possible muscle declines with age.
  - Steady decline - increased slope after 6th decade.
    - Contrary to most VOR data.
    - More pronounced than anatomical changes.
    - Possible functional loss prior to histological changes.
    - Similar declines gait/walking patterns have been shown.
  - Possible increased aging affects Otoliths vs SCCs.
    - Saccular Hair Cells.
    - Inferior Vestibular Nerve Fibers.
  - Possible less central adaptive mechanisms in linear system

Findings

- There is a significant age-related decline in VEMP amplitude and increase in VEMP threshold likely due to neuronal degeneration in the vestibular system.

- The BPM method utilized for controlling SCM muscle contraction provided less variability than previous BPM methods (Maes et al., 2009; Vanspauwen et al., 2006) while detecting age appropriate declines in healthy aging adults.

- Results were consistent with previous EMG monitored VEMP recordings.

Future Research

- Use current protocol to provide more continuous spectrum of age categories for normative data.
- Initiate direct comparisons between current improved BPM strategies and EMG monitored testing to bridge gap between current clinical and research data.
- Development of standardized parameter settings for the VEMP for better cross study comparisons.
- Develop techniques for differentially testing semicircular canal versus otolith function for vestibular evaluation.

Questions?