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

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

Schubert & Minor, 2004
• 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

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(Colebatch & Rothwell 2004)

(Kushiro et al., 1999)
VEMP Pathway

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

500 Hz Tone bursts

- A2 R VEMP
  - P1
  - N1
  - 95 dBnHL

- A3 R VEMP
  - P1
  - N1
  - 85 dBnHL

- A5 R VEMP
  - P1
  - N1
  - 75 dBnHL

- A8 R VEMP
  - P1
  - N1
  - 70 dBnHL

75.00 (µV/div)
• 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

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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 Scarpas’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 health 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)
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VEMP Setup

Zemlin, 1998
VEMP Setup

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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

<table>
<thead>
<tr>
<th></th>
<th>P1 (ms)</th>
<th>N1 (ms)</th>
<th>Amplitude (µV)</th>
<th>Threshold (dBnHL)</th>
<th>IAD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (n = 61)</td>
<td>16.0</td>
<td>2.2</td>
<td>103.1</td>
<td>75.6</td>
<td>15.7</td>
</tr>
<tr>
<td>Right (n = 32)</td>
<td>16.1</td>
<td>2.1</td>
<td>104.0</td>
<td>75.3</td>
<td>80.8</td>
</tr>
<tr>
<td>Left (n = 29)</td>
<td>15.9</td>
<td>2.3</td>
<td>99.2</td>
<td>69.0</td>
<td>80.2</td>
</tr>
<tr>
<td>Male (n = 30)</td>
<td>15.8</td>
<td>1.4</td>
<td>93.3</td>
<td>60.7</td>
<td>80.3</td>
</tr>
<tr>
<td>Female (n = 31)</td>
<td>16.3</td>
<td>1.9</td>
<td>114.1</td>
<td>92.3</td>
<td>80.9</td>
</tr>
</tbody>
</table>

**p** = 0.698  
**p** = 0.975  
**p** = 0.349  
**p** = 0.475

**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

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### Age Groups

<table>
<thead>
<tr>
<th></th>
<th>P1 (ms)</th>
<th>N1 (ms)</th>
<th>Amplitude (µV)</th>
<th>Threshold (dBNHL)</th>
<th>IAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (20-30 yrs)</td>
<td>16.2</td>
<td>1.3</td>
<td>24.6</td>
<td>180.1</td>
<td>77.1</td>
</tr>
<tr>
<td>2 (65-74 yrs)</td>
<td>16.5</td>
<td>2.3</td>
<td>25.0</td>
<td>59.9</td>
<td>83.3</td>
</tr>
<tr>
<td>3 (75-85 yrs)</td>
<td>15.5</td>
<td>1.5</td>
<td>22.9</td>
<td>57.9</td>
<td>82.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>P = 0.446</th>
<th>P = 0.119</th>
<th>P = 0.000*</th>
<th>P = 0.001*</th>
<th>P = 0.234</th>
</tr>
</thead>
</table>

Group 1 (n=12), Group 2 (n=10), Group 3 (n=10).

Data are expressed as mean ± SD, *p < 0.05.
Results/Discussion

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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?

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