Effect of Aging on Vestibular Function

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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.

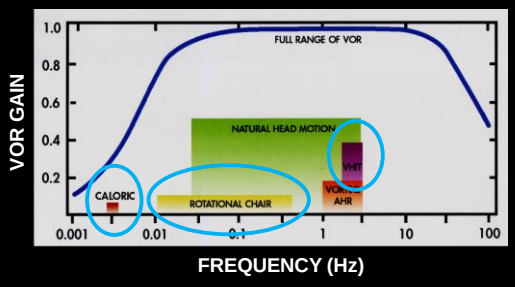
Outline

- Vestibular laboratory tests
  - Semicircular canal function
  - Otolith organ function
- Healthy individuals

Physiological evidence for age-related vestibular effects

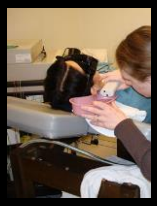
- Less conclusive than anatomical evidence.
- Early studies focused on the semi-circular canal function via measurement of the vestibulo-ocular reflex (VOR) (rotary chair or caloric test).

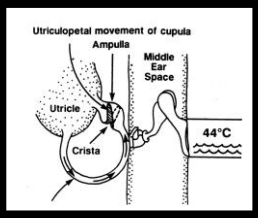
Vestibulo-ocular reflex: frequency response



Bithermal caloric test

"Gold standard" for detecting unilateral loss of horizontal semicircular canal/superior vestibular nerve





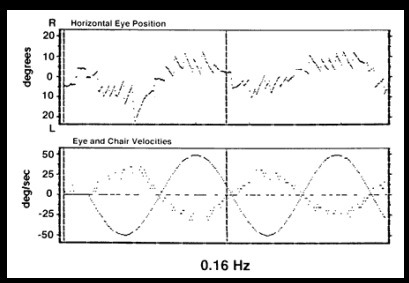
Effect of aging on the caloric test

- No systematic trend with age has been shown for caloric response across 29 studies (1932 – 2010)
  - Increase = 6
  - Decrease = 18
  - No change = 5

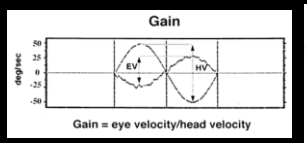
Rotary Chair Testing

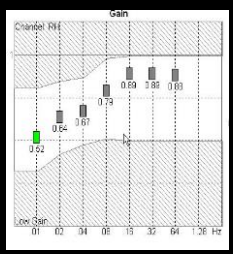
- "Gold standard" study for detecting bilateral vestibular loss
- Measures horizontal semicircular canal function
- Slow harmonic acceleration protocol

SHA Response Analysis

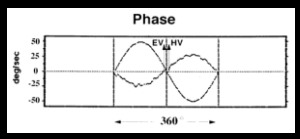


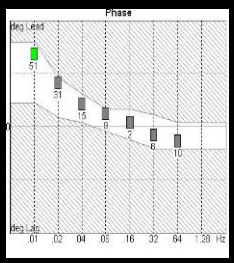
Gain = peak eye velocity/peak head velocity





Phase: timing difference between head and eye velocity





Effect of aging on rotational testing

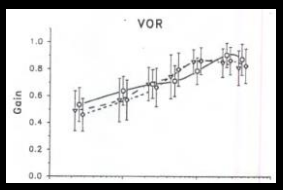
- A small decrease in gain and an increase in phase lead has been demonstrated

  Yagi et al., 1983; Peterka et al., 1990

- Wall et al. (1984), however, found no influence of age on the VOR response to sinusoidal rotation.

Paige (1992)
Journal of Vestibular Research

81 healthy individuals
18 to 89 years



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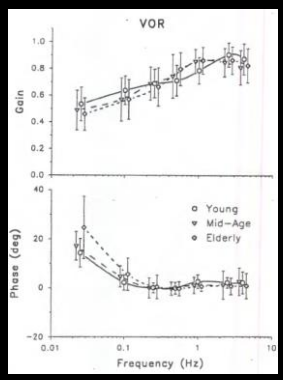
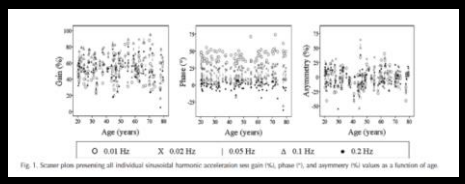


The Effect of Age on the Sinusoidal Harmonic Acceleration Test, Pseudorandom Rotation Test, Velocity Step Test, Caloric Test, and Vestibular-evoked Myogenic Potential Test

Leen Maes, Ingeborg Dhooge, Wendy D'haenens, Annelies Bockstael, Hannah Keppler, Birgit Philips, Freya Swinnen, and Bart M. Vinck

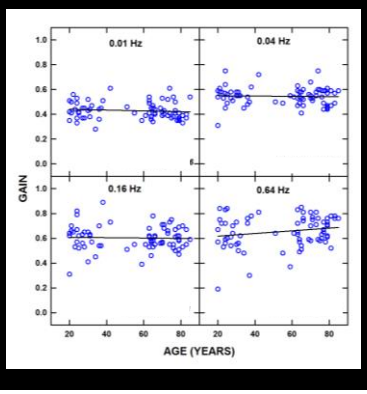
Ear & Hearing, 2010

80 individuals
Ranged in age from 18 to 80 years
No significant age correlations for SHA



Mountain Home SHA data: Gain

N = 74
22 to 85 years
(X = 55 ± 22)



p = .398

Mountain Home SHA data: Phase

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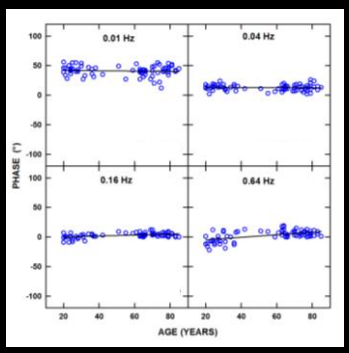
(X = 55 ± 22)



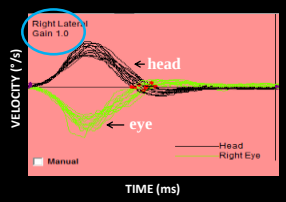
p = .456

Video Head Impulse Test

- Objective test of dynamic SCC function
  - High-speed video cameras & angular velocity sensors embedded in goggles
  - Recording of eye & head movement during and after head rotation

vHIT Interpretation

- Recording of corrective saccades
- Calculation of VOR gain

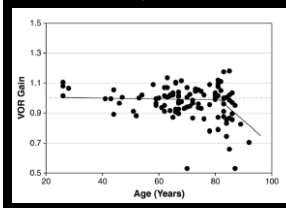


Relative to calorics and rotary chair…

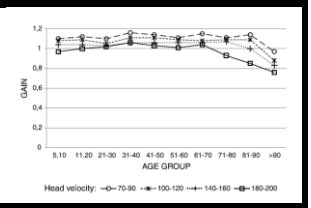
- Decreased test time and cost
- Increased patient comfort
- Portable and limited space requirements
- More natural head velocity

Age Effect on vHIT

Li et al., 2015



Matino-Soler et al., 2014



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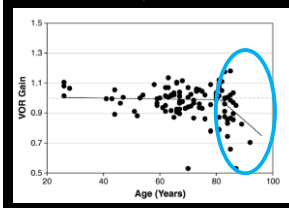

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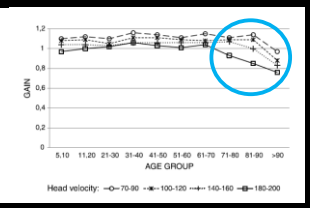
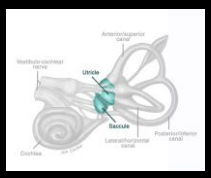
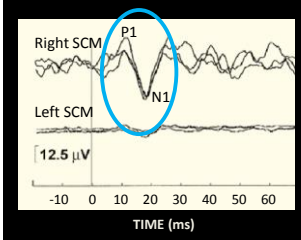


Tests of Otolith Organ Function

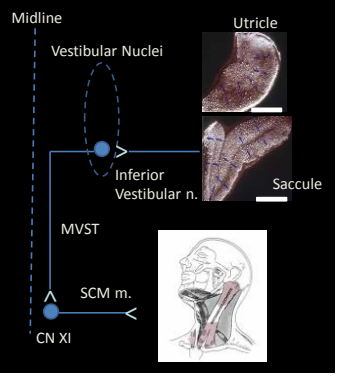
Vestibular Evoked Myogenic Potentials
Cervical (cVEMP)
Ocular (oVEMP)



Cervical Vestibular Evoked Myogenic Potential



cVEMP Pathway



What is the impact of age on the cVEMP response rate in healthy individuals?

	N	Age Range (Years)	Response Rate (% Present)
Clicks			
Welgampola et al., 2001	70	25 - 85	91% > 60 yrs
Ochi and Ohashi 2003	60	20 - 77	100%
Su et al., 2004	80	7 - 75	98%: 20-40 yrs; 90%: 41-60 yrs; 60% > 60 yrs
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500 Hz TBs			
Basta et al., 2005, 2007	64	20 - 76	100%
Maes et al., 2010	80	18 - 80	100%: < 65 yrs; 31%: > 65 yrs
Rosengren et al., 2011	61	20 - 80	96%
Akin et al., 2011	48	22 - 86	100 % 22 – 31 yrs; 83%: > 60 yrs
Singh et al., 2013	280	10 - 85	100% < 50 yrs ; 93%: 50-60 yrs; 75% :60-70 yrs, 60% >70 yrs

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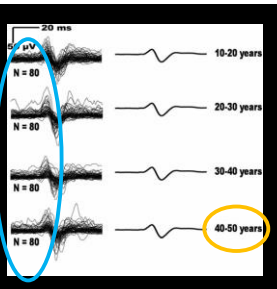
Decrease in number of healthy individuals with present cVEMPs as age increases

Singh et al., 2013
N = 280



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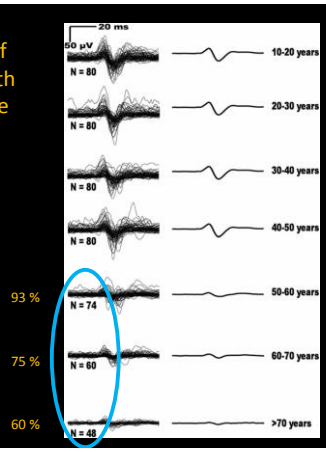

Impact of stimulus frequency

TABLE 2. Cervical vestibular-evoked myogenic potential response rates across stimulus frequencies

	125 Hz	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz
Young adult (n = 13)	69%	92%	100%	100%	100%	100%	46%
Middle age (n = 13)	38%	92%	100%	100%	100%	85%	38%
Old adult (n = 13)	23%	46%	92%	100%	100%	53%	31%

Piker et al., 2013

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What is the impact of age on other cVEMP response parameters?

Impact of Age on cVEMP Response Parameters

	N	Age Range (years)	P1/N1 Amplitude	Threshold	Latency	AR
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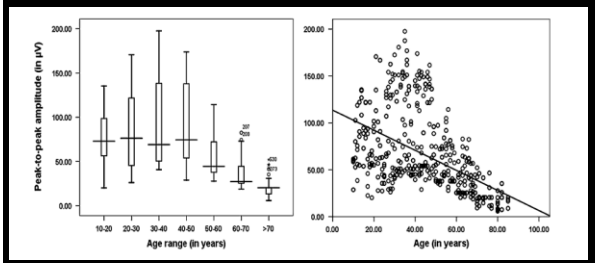
P1/N1 amplitude decreases with age



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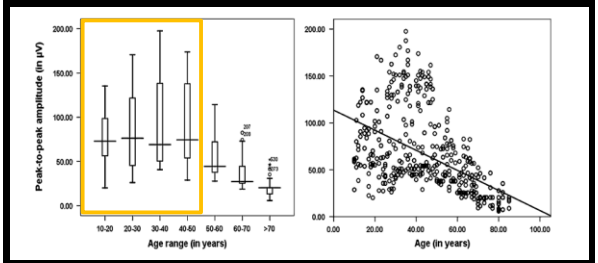

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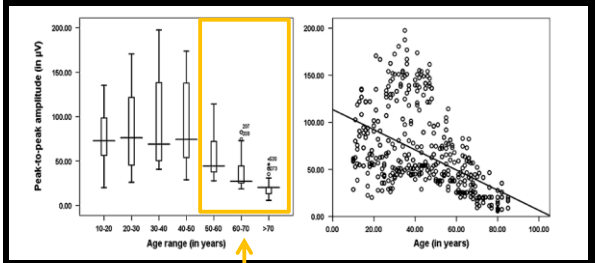

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Asymmetry Ratio =

$$\frac{\text{Left VEMP Amplitude - Right VEMP Amplitude}}{\text{Left VEMP Amplitude + Right VEMP Amplitude}} \times 100$$

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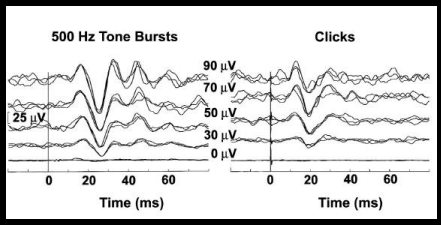
JRRD Journal of Rehabilitation Research & Development

The influence of voluntary tonic EMG level on the vestibular-evoked myogenic potential

Faith W. Akin, PhD; Owen D. Murnane, PhD; Peter C. Panus, PhD, PT; Stacy K. Caruthers, MPT; Amy E. Wilkinson, MPT; Tina M. Proffitt, MS

James H. Quillen Department of Veterans Affairs (VA) Medical Center, Mountain Home, TN; Departments of Surgery and Communicative Disorders, East Tennessee State University, Johnson City, TN; Department of Physical Therapy, East Tennessee State University, Johnson City, TN

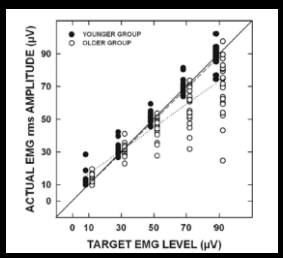
cVEMP amplitude is proportional to SCM m. EMG level



The Effect of Age on the Vestibular Evoked Myogenic Potential and Sternocleidomastoid Muscle Tonic Electromyogram Level

Faith W. Akin,[1,2] Owen D. Murnane,[1,2] Joanna W. Tampas,[1] and Christopher G. Clinard[3]

Ear & Hearing, 2011



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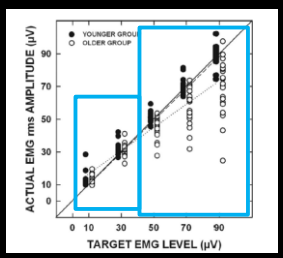
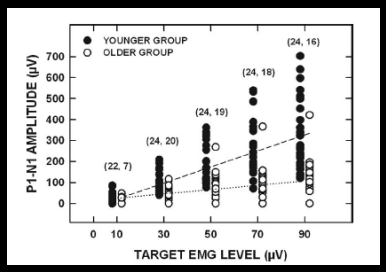
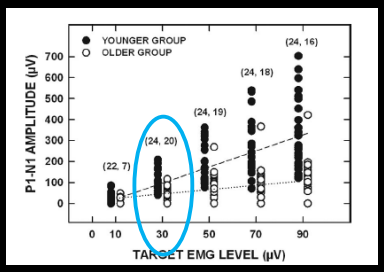
Ear & Hearing, 2011



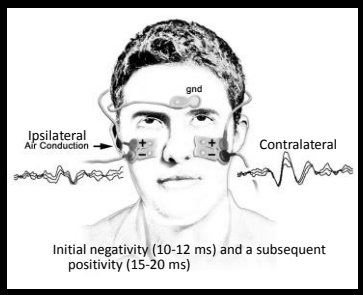


Decrement in cVEMP amplitude is related to age-related changes in the vestibular system and SCM m.



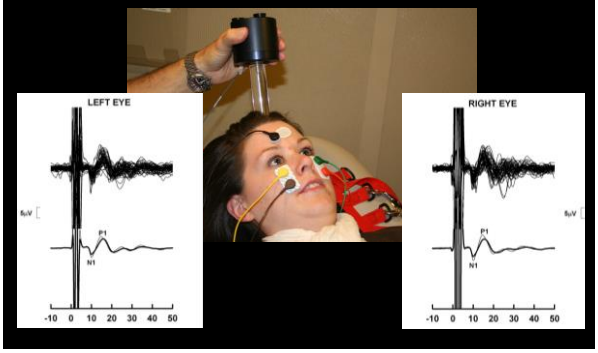
Ocular VEMP: Air Conduction

Recorded from electrodes beneath the eyes with patient looking up *Todd et al., 2007*

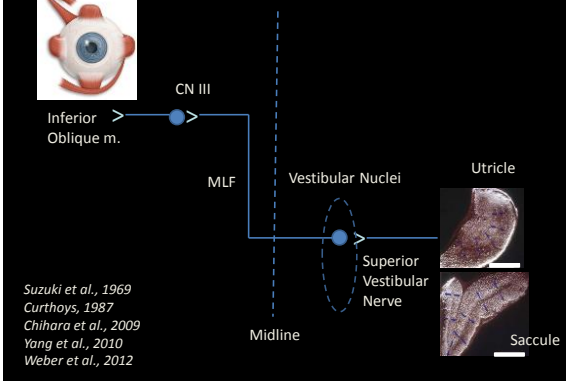


adapted from Murnane & Akin, 2009

oVEMP: B&K 4810 Minishaker



oVEMP Pathway



Suzuki et al., 1969
Curthoys, 1987
Chihara et al., 2009
Yang et al., 2010
Weber et al., 2012

What is the impact of age on oVEMP response rate?

	N	Age range (years)	Response Rate (% Present/Contra Eye)
Air Conduction			
Chang et al., 2012	69	22-69	100% < 50 yrs; 86% 50-59 yrs; 63% 60-69 yrs
Rosengren et al., 2011	61	20-80	59 – 97%*
Piker et al., 2013	39	22-78	100%**
Bone Conduction Vibration (mini-shaker)			
Iwasaki et al., 2008	67	20-83	100%
Tseng et al., 2010	70	24-76	100% < 60 yrs; 55% 60-69 yrs; 40% ≥ 70
Rosengren et al., 2011	61	20-80	95%

*Higher response rate with increase in stimulus level and eye gaze
**at 750 and 1k Hz

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Decrease in number of healthy individuals with present oVEMPs as age increases

TABLE 1. *Comparison of response rates of ocular vestibular-evoked myogenic potentials among various age groups*

Age (yr)	n (eyes)	Response rate (%)
20–29	20	100
30–39	20	100
40–49	20	100
50–59	20	100
60–69	40	55[a]
>70	20	40[a]

[a] $p < 0.001$, Fisher's exact test, when compared with groups younger than 60 years.

Tseng et al., 2010

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Impact of stimulus frequency

TABLE 4. Contralateral ocular vestibular-evoked myogenic potential response rates across stimulus frequencies

	125 Hz	250 Hz	500 Hz	750 Hz	1000 Hz	1500 Hz	2000 Hz
Young adult (n = 13)	46%	69%	92%	100%	100%	69%	31%
Middle age (n = 13)	15%	54%	100%	100%	100%	46%	31%
Old adult (n = 13)	0%	23%	92%	100%	100%	31%	8%

Piker et al., 2013

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Effect of age on oVEMP response parameters

	N	Age Range (Years)	Amplitude	Threshold	Latency	AR
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Tseng et al., 2010	70	24-76	+		+	-
Nguyen et al., 2010	53	20-70	+		-	-
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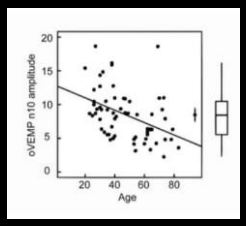
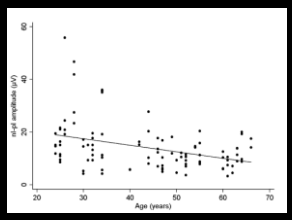
oVEMP amplitude decreases with age



Iwasaki et al., 2008



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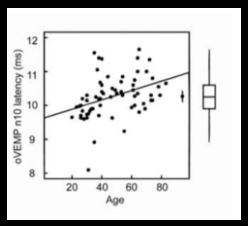
N10 latency increases with age



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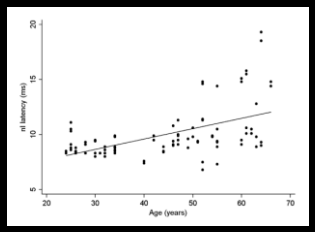

Tseng et al., 2010

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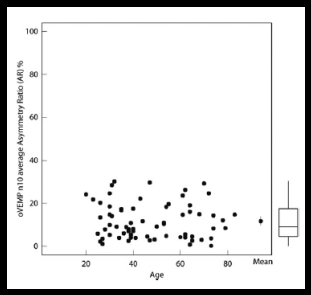
No effect of age on oVEMP asymmetry ratio



Tseng et al., 2010

Aging across vestibular pathways

- Cross-sectional study: Maes et al., 2010
  - 80 healthy individuals 18-80
  - SHA, caloric test, cVEMP
  - Subtle changes with caloric and rotational chair
  - Largest age trends were detected with cVEMP

Summary

- Greater evidence of age-related otolith organ loss than canal/VOR loss
- Why?
  - Vestibular adaptation of VOR response
  - Less neuronal redundancy in VEMP versus VOR pathways
- Clinical or functional significance?