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Striking the Right Balance: Air vs. Water Calorics for Vestibular Assessment

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In this edition of "Striking the Right Balance," Michael Vekasi, AuD, R.Aud, Aud(C), FAAA, shares a poster presentation on air versus water calorics he prepared during graduate school and given an updated literature search.

Michael Vekasi, AuD, R.Aud, Aud(C), FAAA and Erica Zaia, MSc, RAUD are coordinating the "Striking the Right Balance," feature which will cover the latest information on 'all things vestibular.'

If you would like to be more involved in all things vestibular, please check out and like our Facebook page by searching for "CAA National Vestibular Special Interest Group" within Facebook. You can also reach us by email at CAAvestibular@gmail.com.

Introduction

Dizziness is one of patients' most common complaints when seeing their healthcare professional. However, the generic use of the word dizziness requires the healthcare professional to pinpoint what this means and make the necessary referrals to determine if there is an underlying vestibular dysfunction.

Caloric testing is a key component of the electronystagmography (ENG) or videonystagmography (VNG) test battery in the assessment of vestibular function. Water has long been viewed as the "gold standard" for caloric stimulation, while air has been used as an alternative. However, high-cost of equipment necessitates the inquiry to determine an evidence-based approach to caloric stimulation.

This article has been prepared from a poster presentation created during graduate school at Western University – School of Communication Sciences and Disorders, with an updated literature review. I would like to acknowledge Dr. Sheila Moodie for her guidance and support during the original creation of this poster presentation.

Question

PICO Elements	PICO Question
Patient	Adult dizzy patients
Intervention	Water caloric stimulation
Comparison	Air caloric stimulation
Outcome	Vestibular assessment of the horizontal semicircular canal

Is water caloric stimulation more accurate for vestibular assessment of the horizontal semicircular canal than air caloric stimulation in dizzy adults?

Search Terms

	PICO Question	Search Terms
P	Adult dizzy patients	adult, adults, dizzy, dizziness, vertigo, vertiginous
I	Water caloric stimulation	water caloric testing, water calorics, water caloric stimulation
C	Air caloric stimulation	air caloric testing, air calorics, air caloric stimulation
O	Vestibular assessment of the horizontal semicircular canal	vestibular assessment, vestibular diagnostics, vestibular function, vestibular evaluation, horizontal SCC, lateral SCC

The plural version of search terms were used if appropriate.

Inclusion/Exclusion Criteria

The following **inclusion** criteria was used for selecting articles to review from the returned literature search results:

- Intervention includes water and/or air caloric stimulation
- Subjects/participants are human
- Subjects/participants are adults (defined as being 18 years of age or older)
- Can be easily accessed through Western University libraries

The following **exclusion** criteria was used for selecting articles to review from the returned literature search results:

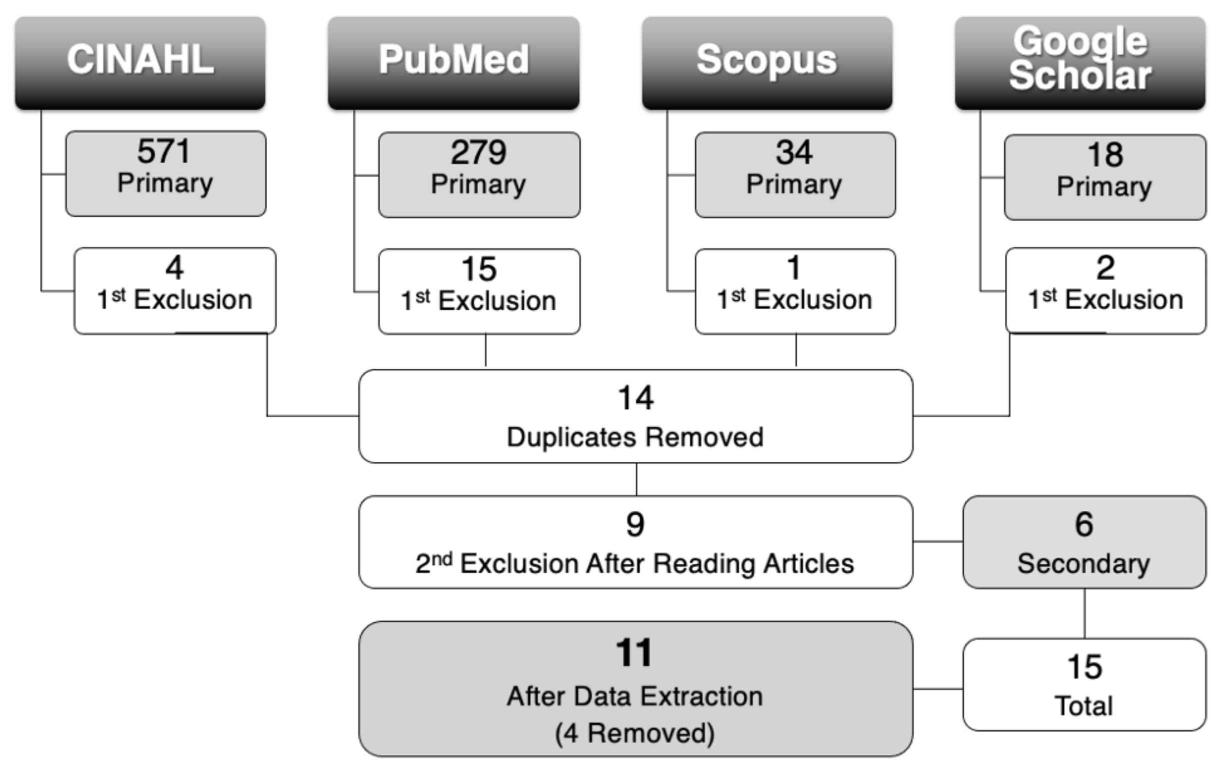
- Cannot be easily accessed through Western University libraries
- Subjects/participants are not humans (e.g., animal models)
- Duplicates from different database search results

- Not available in English*

** Normally this would not be an exclusion criterion; however, it was necessary due to project time constraints*

Literature Search

A systematic review of the literature was conducted. Search terms were run through several databases: CINAHL, PubMed, Scopus and Google Scholar for the primary literature search. A secondary search was completed using references from the highest-scoring quality appraised article; additional sources were identified. The primary and secondary searches yielded 908 articles. The number of results from each search is outlined in the flowchart below.



After reading and appraising the quality of the 'Total' 15 retrieved articles, the key data was extracted using a data extraction tool. The data extraction tool is illustrated in the **Results** section of this poster. An additional 4 articles were removed after data was extracted because they did not provide sufficient information relevant to this project's question.

Results

From the literature search, 11 retrieved articles were appraised for their quality using the Crowe Critical Appraisal Tool (CCAT) Version 1.4 and the CCAT form (Crowe, 2013). In addition, a data extraction tool was generated to capture each article's key pieces of information. Categories on the data extraction tool included: authors, name of study, year of study, year of publication, country, research question/objective, setting (lab vs. clinic), research design, research methods, sample size, participant characteristics, description of the intervention, outcomes measured, statistical analyses performed, results, findings/conclusions, and CCAT quality score. Select data from the 11 retrieved articles are shown in the abbreviated data extraction table below.

#	Research Question/Objective	Sample Size	Description of Intervention	Results	Findings/Conclusions	CCAT Quality Score
1	Compare dry air and wet air calorics with the gold standard water calorics.	50	Water (WAT) 100ml irrigated 30s at 30°C and 44°C. Dry air (DAI) 27°C and 45°C for 45s. Wet air (WAI) air flow 6L/min 85% humidity and 65% humidity.	SPV values highest for WAT and lowest for DAI. SPV value differences were lower for WAT/WAI than WAT/DAI (warm air more similar to water). Less discomfort with DAI/WAI (no difference) than WAT.	Wet air is superior to dry air as an alternative to water calorics.	73% or (29/40)
2	(1) Identify magnitude and origin of the order effect. (2) Identify whether consecutive tests inducing nystagmus in same direction result in any adaptation of response.	32	Monocular ENG/VNG recording following five consecutive caloric irrigations. 8 different order of irrigations - each order done on 4 subjects, alternating stimulated ears in some, alternating direction of nystagmus in others.	Mean peak VNG SPV is 21.1°/s. Mean CP or unilateral weakness is -2.7%. No ear effect, no age effect. No effect of physiological adaptation. Change in CRP (corneo-retinal potential) between initial and final calibration highly significant - leads to ENG recording errors. Highly significant order effect in subjective rating of vertigo (effect greatest between first and all other irrigations).	No evidence of physiological adaptation of caloric response. Subjective vertigo exhibits a strong order effect. Significant changes in CRP were seen, especially with occluded eyes (pattern and extent depends on test timing issues, level of room lighting, and whether patients' eye closure between tests is controlled).	73% or (29/40)
3	Establish a population-based description of the caloric response evoked by water and air stimuli at both cool and warm temperatures.	2587	Water caloric irrigator calibrated to meet ANSI s3.45-199 standards. Air caloric irrigator calibrated so it induced responses similar to water irrigator.	Cool water induced responses that were weaker than both cool or warm air induced responses. Tendancy for warm air induced caloric responses to show higher MSPVs than those induced by cool air. Neither air nor water show trend as function of age (no age effect). Sensitivity/specificity was good but not ideal.	Warm and cool water MSPV distributions differ substantially from each other. Distributions of warm and cool air MSPVs were similar and tighter than water. Calculations such as directional preponderance and unilateral weakness may be similar - regardless of medium of caloric irrigation	88% or (35/40)
4	Shed light on problem of air caloric reliability.	25	Either water and air caloric testing or water only testing.	No significant difference for latency, duration, or maximum frequency. Significant difference for MSPV (particularly warm stimulation). MSPV slightly higher for water. Duration slightly longer for air.	Position of the irrigating tip should be controlled carefully to reduce variability. Only approximate comparability for air vs. water. Water calorics should remain the most often used caloric test.	50% or (20/40)
5	Assess test-retest reliability of SPV response for air calorics. Effect of duration of air calorics on SPV.	30	Air caloric testing only (24&50°C, 8L/min); the duration of irrigation is either 45, 60, or 75 seconds.	SPVs largest for 60-second irrigation (28°/s). SPV deviation between warm/cool smallest for 75-seconds, largest for 45-seconds.	Test-retest reliability ~4°/s for all SPV calculations (similar to other research). Data do not allow recommendation of preferred stimulus duration.	70% or (28/40)
6	Construct and compare two different caloric protocols, both for water and air.	42	Water (30°C and 44°C, 250ml, 45sec) & air (5L/min, 24°C and 47°C, 60sec).	No priming effect demonstrated. SCV higher for water than air, higher for warm than cool. Majority of subjects preferred water.	Statistically higher SCV values, higher frequency, and higher SDs for water compaired to air. Authors prefer water because of better subject tolerance and higher SCV values.	73% or (29/40)
7	Compare the reliabilities of air and water caloric responses.	8	Water (30°C or 44°C, 250ml, 30sec) & air (8L, 24°C or 50°C, 60sec).	No difference between air and water responses. Nearly significant difference between warm and cool responses. Warm provoked significantly stronger responses than cool. Water provoked stronger responses than air, but difference not significant.	Air caloric responses are no less reliable than water responses. Air is a suitable alternative to water as an irrigating medium in the quantitative bithermal caloric test.	68% or (27/40)
8	Not applicable (n/a) – this was a column from a professional magazine.	n/a	Water (30°C and 44°C, 400cm/min, 40sec) & air (21.1°C and 50.1°C, 400cm/min, 70sec cold, 60sec warm).	Little difference in performance of air or water in terms of max SPV. Calibration for equivalent responses is essential, generating clinics own normative data also important.	With careful control and proper calibration, both the air and water-based caloric tests can yield reliable and equivalent data.	n/a
9	(1) Comparison of responses obtained from air and from ice water stimulations. (2) Comparison of standard bithermal water test and a bithermal air caloric.	(i) 8 (ii) 10	(i) 5ml ice water + 0°C air for 60sec. (ii) 50°C air, 44°C water, 24°C air, 30°C water (air 60sec, water 30sec).	No significant difference between cool stimuli on any measures. No significant difference between warm stimuli and SPV. 44°C water responses significantly greater than 50°C air response. Responses to air consistently shorter in duration than water - difference most between warm calorics.	Air caloric test is a reliable method of vestibular evaluation	68% or (27/40)
10	Compare nystagmic responses obtained with three commercially available caloric irrigators (air, water, closed-loop).	24	Three different caloric irrigator systems (air, water, closed-loop water). Warm & cool measured with each.	Water irrigator yielded consistently stronger responses than either of the other units. Differences between warm and cool, cool producing stronger responses (disagreement with literature). Significant difference between male and female - male showing stronger responses. Short-term test-retest reliability was fair (long-term was lower than expected). Subjective responses: closed-loop system more comfortable, warm more unpleasant than cool.	Traditional water system preferred type of irrigator for routine clinical use. All three irrigators produced acceptable responses to cool and warm irrigations on normal subjects.	75% or (30/40)
11	Compare ENG results for air with water (calorics) on larger clinical populations.	675	Water (350cc, 30°C and 44°C, 40sec) & air (24°C, 50°C, 6L/min, 60sec - some also 14°C).	No significant difference was found between air and water. Those 19 tested by air AND water, difference between air and water remained within 5%. No tendency for either air or water to give larger DPs or ELs.	Air caloric stimulation is as clinically effective in evoking nystagmus as comparable water caloric stimulation.	53% or (21/40)

Legend: SPV – slow phase velocity, CP – canal paresis, ENG – electronystagmography, MSPV – maximum slow phase velocity, SD – standard deviation, DP – directional preponderance, EL – excitability of labyrinth, L/min – air flow rate, °/s – unit for slow phase velocity

Conclusions

Data extracted from the 11 retrieved articles suggest that the evidence is varied for whether water caloric stimulation is more accurate for vestibular assessment than air caloric stimulation. Of the 11 articles retrieved: three offer no concluding remarks that further the research question of this systematic review, four support water caloric stimulation as being more accurate than air caloric stimulation, and four indicate no difference between responses from water and air caloric stimulation. The CCAT quality scores for the highest quality article supporting (Zapala, 2008) and refuting (Karlsen, 1992) the question of this systematic review differ by approximately ten percent, demonstrating that there is quality evidence both for and against. Based on the findings from this systematic review, it can be concluded that water caloric stimulation is no more accurate for vestibular assessment of the horizontal semicircular canal than air caloric stimulation in dizzy adults. The caveat to this conclusion is that appropriate irrigation/stimulation equipment calibration must be completed before use.

A major limitation of this systematic review is the inclusion or exclusion of journal titles in database searches. It is not always transparent which journals are included in a database collection or what years of a journal are included. By only using databases to search for articles, there may still be additional articles that are not found – which is a limitation of this systematic review. For example, the secondary search was performed using the reference list from the paper with the highest scoring CCAT quality appraisal; an additional six articles were obtained which had not previously appeared in the database searches. This limitation could be improved by inquiring which journal titles (and years of publication) are included in a database or by doing additional searches from the most common journals in a particular field of study.

Future research for the topic of this systematic review could look at using larger sample sizes, to increase the external validity of the study and make the findings more generalizable. Additionally, future research could look toward creating a more standardized approach to the caloric stimulation used in vestibular assessment.

This systematic review was completed as a term research project for evidence-based practice in CSD 9523 – Professional Practice III. Thank you to Dr. Sheila Moodie for her guidance with this project.

Author Remarks

An updated literature search was completed using the same databases and search terms as the original literature search but limited to studies completed between 2014 and 2023 (to account for the time after the original literature search). Based on the original inclusion and exclusion criteria there were no additional articles to be added to the results.

It is important to note that use of air caloric irrigators has a variety of controversies within the vestibular audiology community. Two prominent organizations have varying stances on air calorics – the American National Standards Institute (or ANSI) does not include air caloric irrigators in their most recent set of standards. At the same time, the British Society of Audiology (or BSA) considers air caloric irrigators suitable for use clinically (McCaslin *et al.*, 2021). While both air and water caloric irrigators can (and are) used in clinical practice today, it is very important to understand that the clinician must have the technical skills to appropriately use each type of irrigator to ensure an accurate caloric response is being measured. A final consideration is that the original literature search and project was completed during graduate school, before having experience with vestibular audiology.

Original Poster

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