



Preventing Middle Ear Barotrauma in Submariner Recruits Undergoing Pressurized Escape Training

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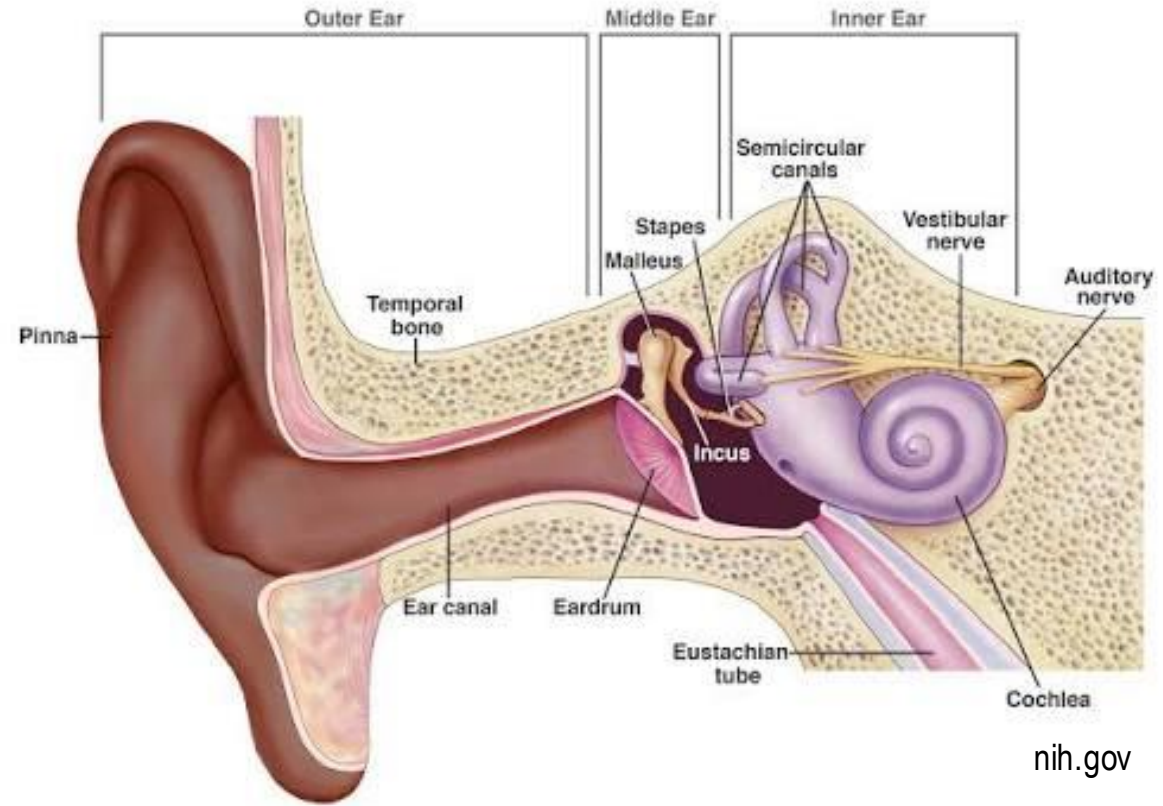
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Navy Relevance

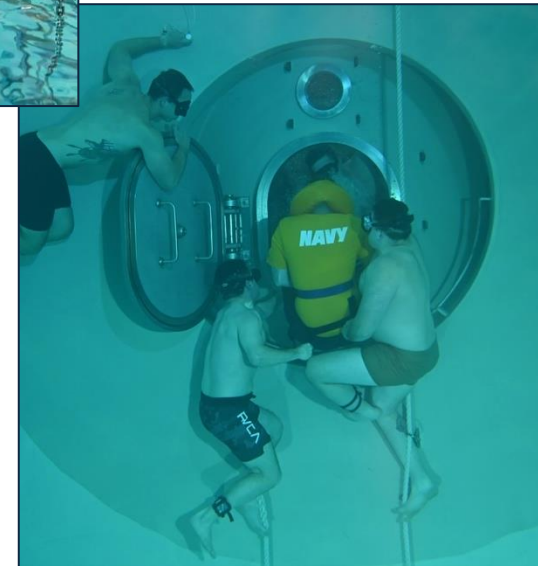
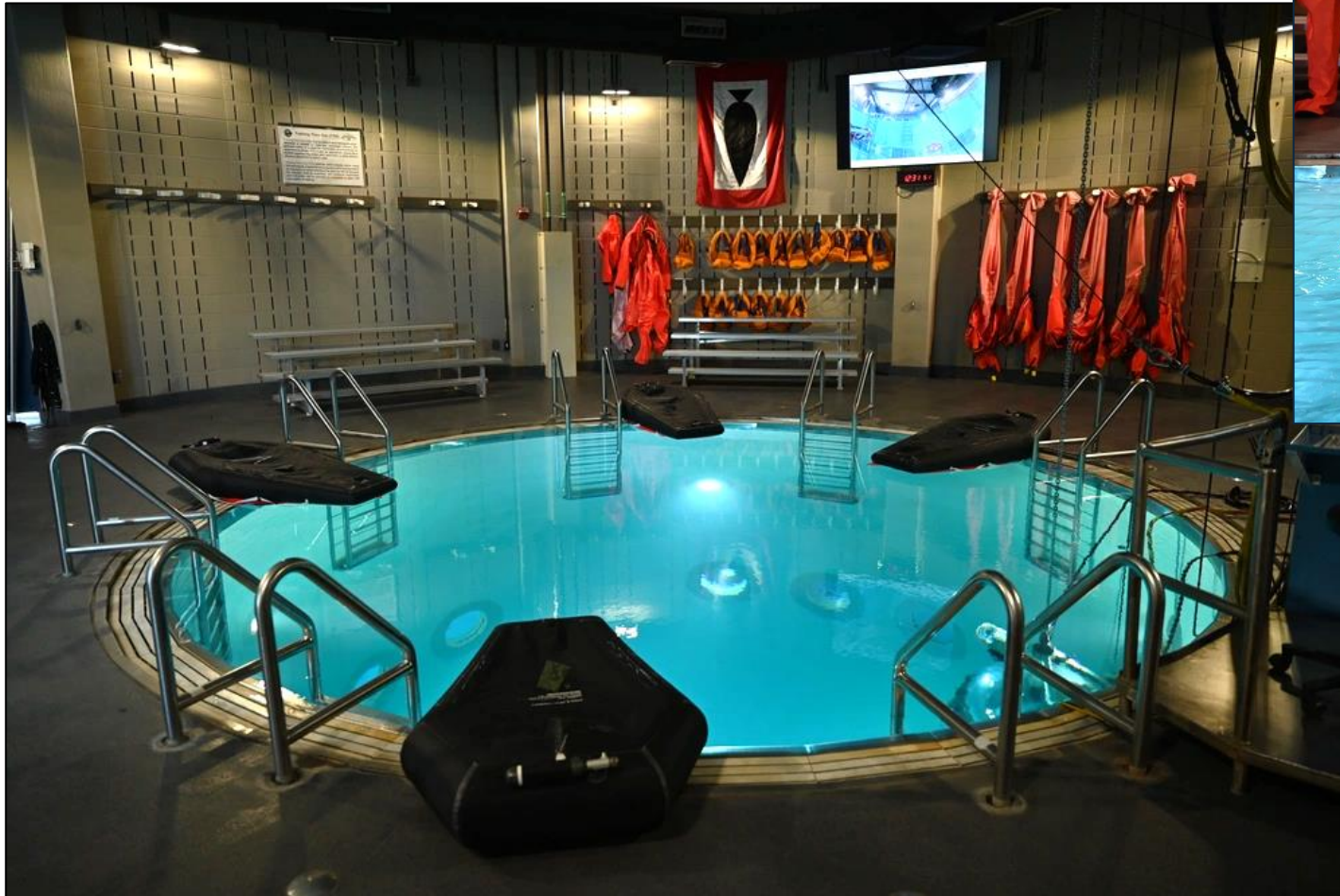
- Middle ear barotrauma (MEB)
 - **Most common** dive injury^{1,2}
 - Major cause of attrition among pressurized submarine escape trainer (PSET) students³
 - 52% disqualified after chamber screening, with 82% due to MEB
- Eustachian tube dysfunction (ETD) increases the risk of MEB, among other conditions^{4,5}



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Pressurized Submarine Escape Trainer (PSET)



U.S. Navy Photos



Required Screenings (Auditory-related)

- Manual Medicine Chapter 15-106, Medical Examinations:
 - Eardrum movement during Valsalva →
 - No upper respiratory infection/allergies, no ear disease or sinus disease
 - Successful 60' hyperbaric chamber screening

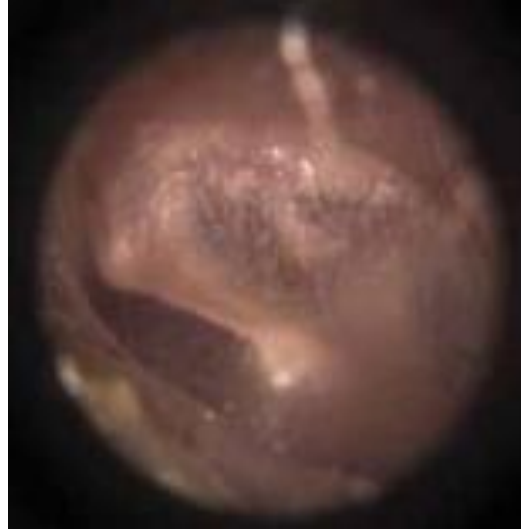


U.S. Navy Photo

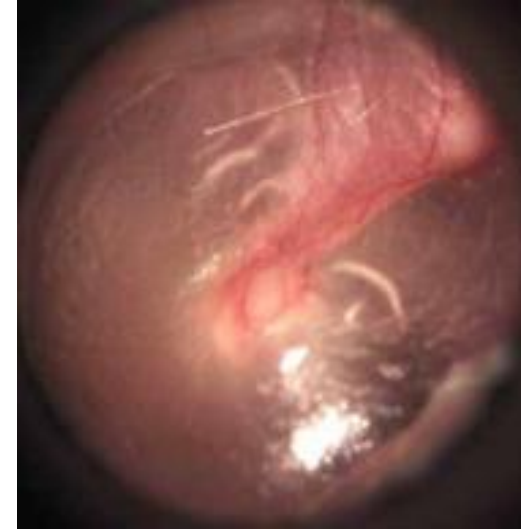


Middle Ear Barotrauma: The TEED Scale⁶

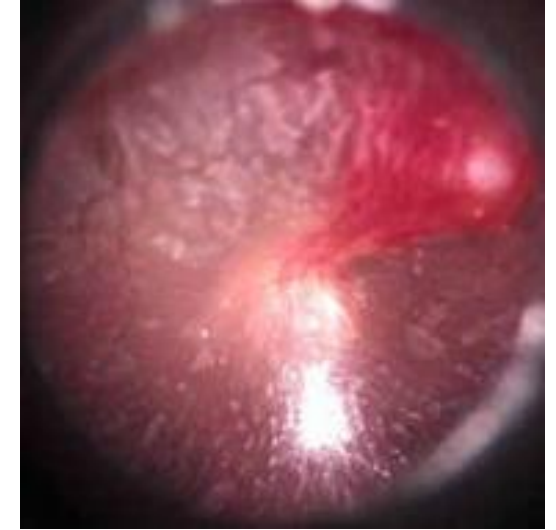
GRADE 0



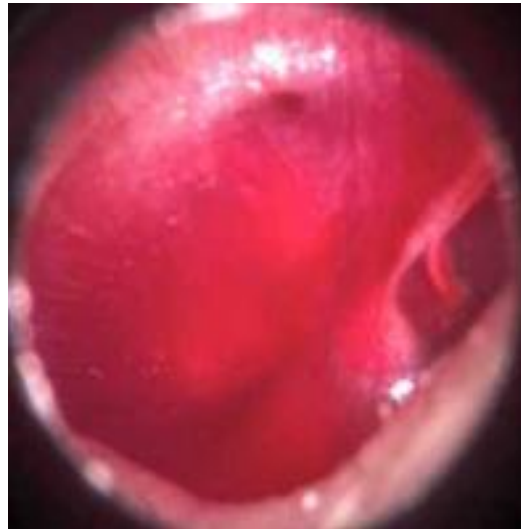
GRADE 1



GRADE 2



GRADE 3



GRADE 4



GRADE 5



Photos retrieved from Blake et al. (2015)



Study Objective

- Determine accuracy and sensitivity of ETD measures
- Predict the risk of MEB in PSET students



ETDQ-7

Pressure in ears?

Pain in ears?

Underwater clogged sensation?

Pre-occurring cold/sinusitis?

Crackling/popping sounds in ears?

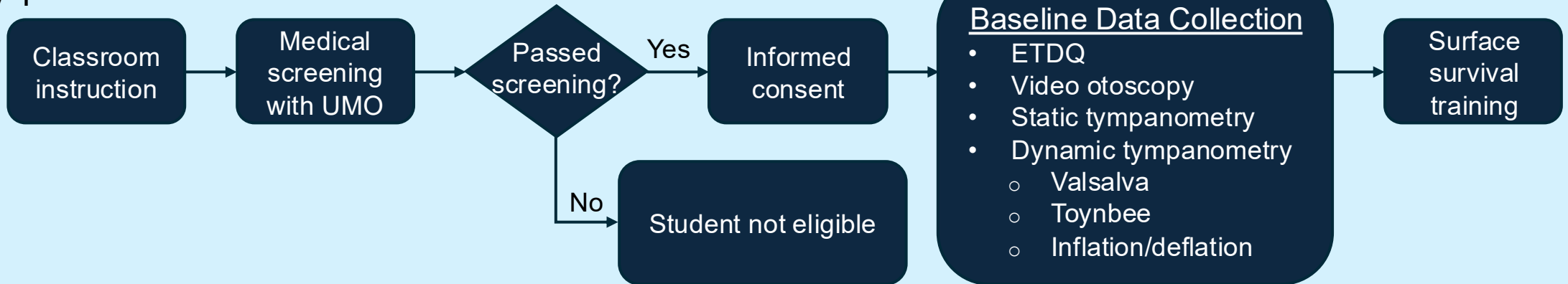
Ringing in ears?

Muffled hearing?

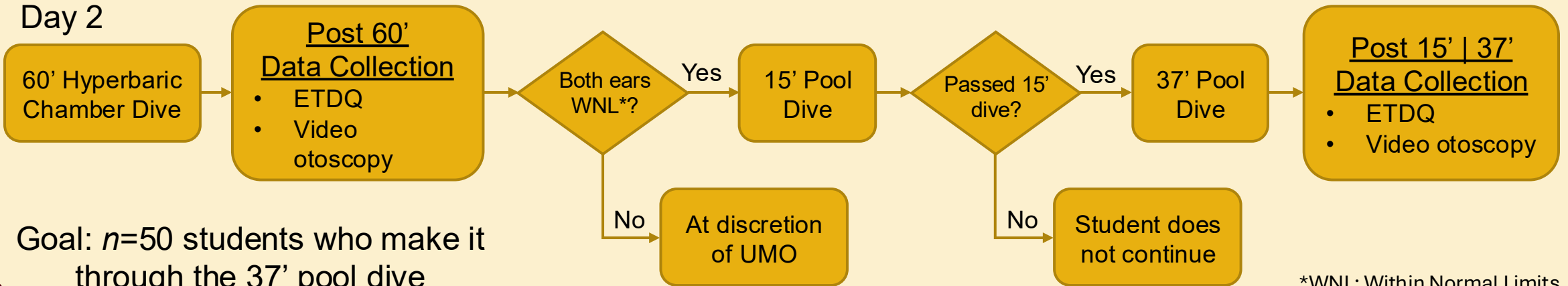


Methods

Day 1



Day 2



Goal: $n=50$ students who make it through the 37' pool dive

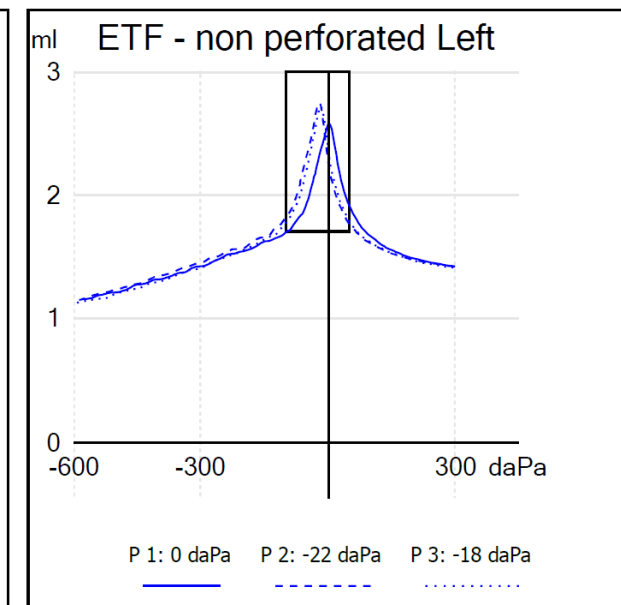
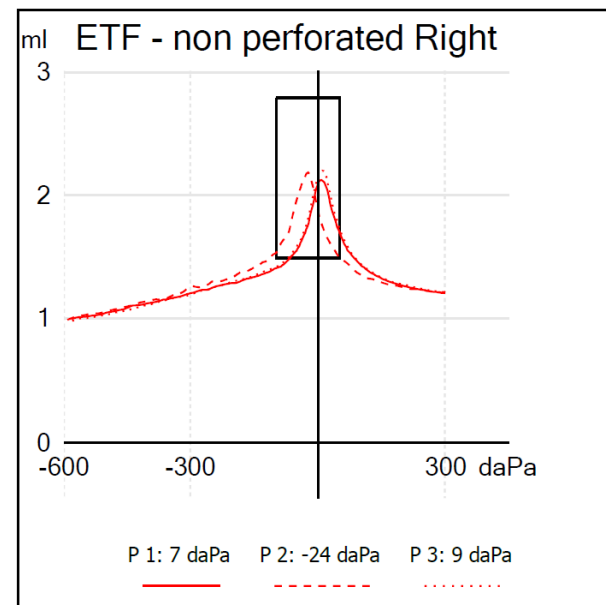
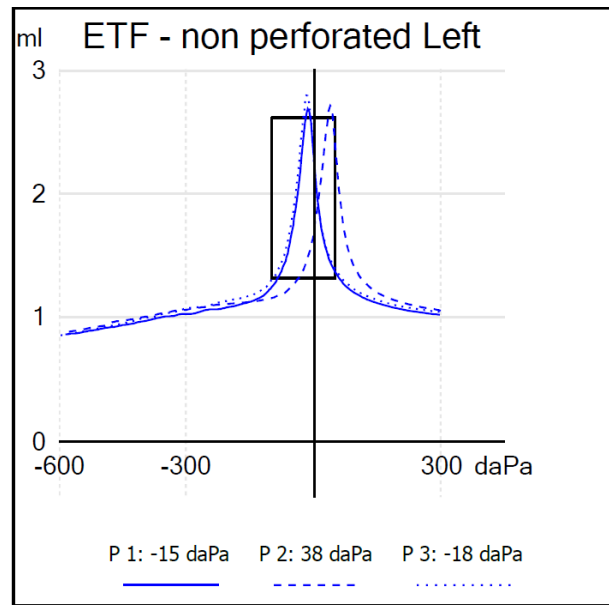
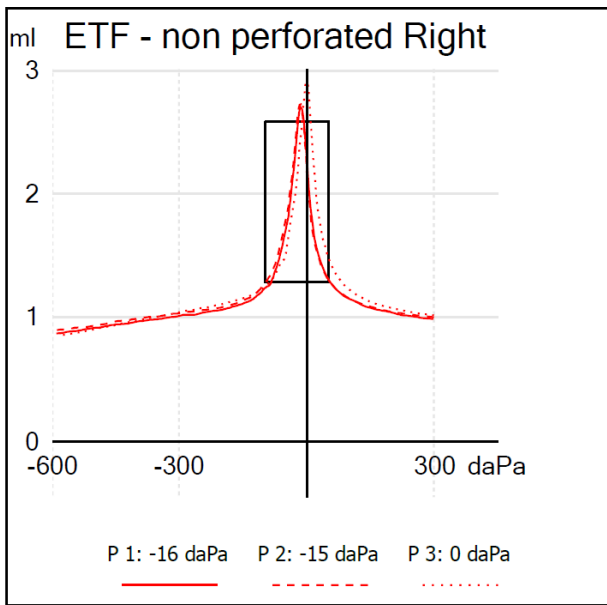
*WNL: Within Normal Limits



Dynamic Tympanometry

Valsalva

Toylnbee



U.S. Navy Photos



PRE

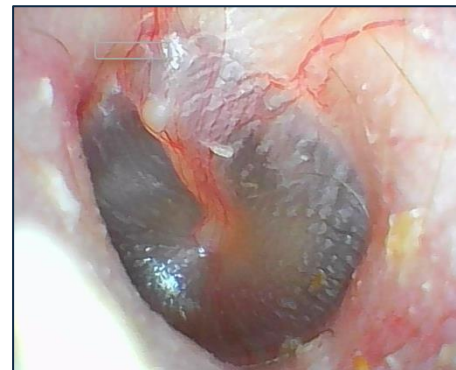
POST

T1

T2

T3

MEB



U.S. Navy Photos

READINESS THROUGH RESEARCH & DEVELOPMENT



Analysis Approach: Predictive Model

Models considered:

- Logistic Regression
- Support Vector Machine (SVM) with:
 - Linear kernel
 - Radial basis function (RBF) kernel
- K-Nearest Neighbors (KNN)

Model creation:

- Looked for predictors
- Defined univariate datasets
- Performed a 70-30 train test split
 - Maintained proportion of WNL to MEB samples in each set
- Optimized hyperparameters
- Trained model & evaluated performance



Initial Trends (n=78 ears, $\alpha=.05$)

Independent Variable	Data type	Test performed	Test statistic	p-value	Effect size (Cliff's Delta)
TM movement observed	Categorical (0, 1)	Chi-Square Test	$\chi^2 = 0.384$	.536	0.057
Self reported "ears clearing"	Categorical (0, .5, 1)	Chi-Square Test	$\chi^2 = 7.470$	.0239	0.237
Average Valsalva	Continuous (-52.5 – 316 daPa)	Mann-Whitney U	U = 696	.535	-0.082
Average Toynbee	Continuous (-199 – 97 daPa)	Mann-Whitney U	U = 623.5	.178	-0.178
Average inflation (+300 dPa)	Continuous (-45 – 11 daPa)	Mann-Whitney U	U = 665	.352	-0.123
Average deflation (-300 dPa)	Continuous (-5.5 – 75 daPa)	Mann-Whitney U	U = 845	.384	0.115
ETDQ-7 score baseline	Continuous (0-7)	Mann-Whitney U	U = 500.5	.00682	-0.340
ETDQ-7 score under pressure	Continuous (0-7)	Mann-Whitney U	U = 438.5	.000986	-0.422



Results - Model Performance

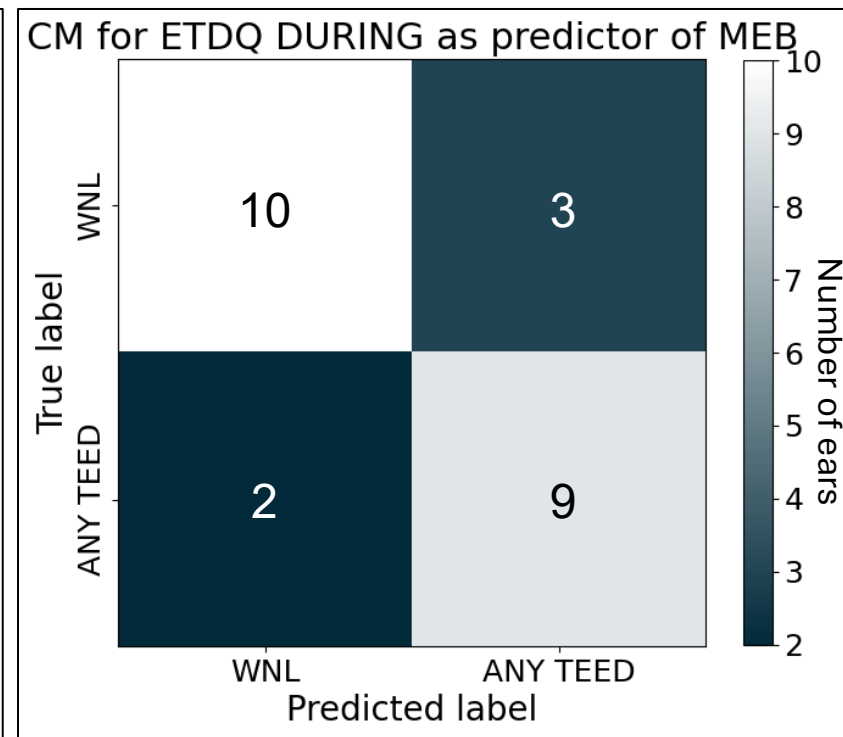
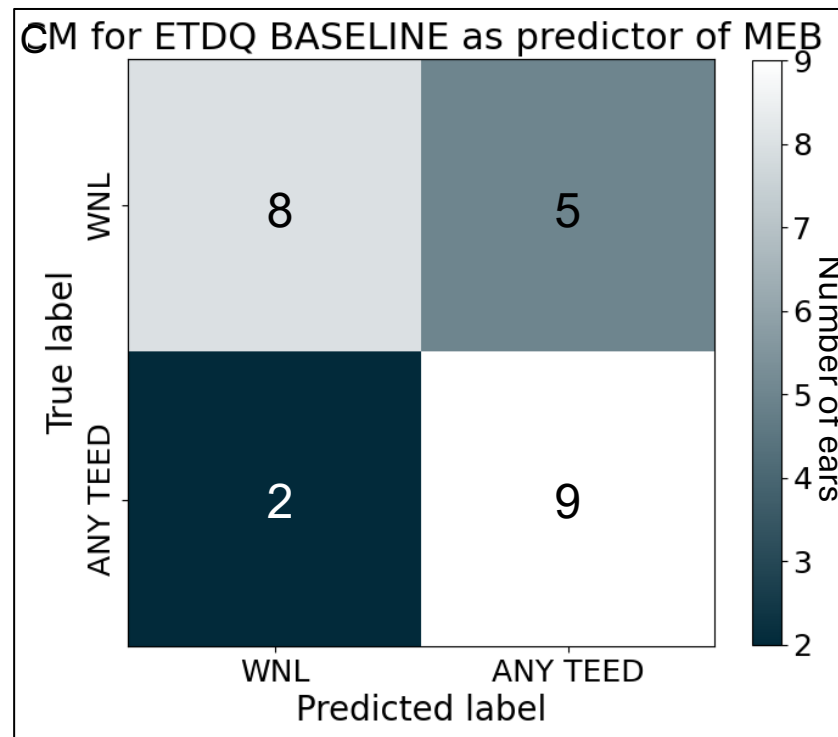
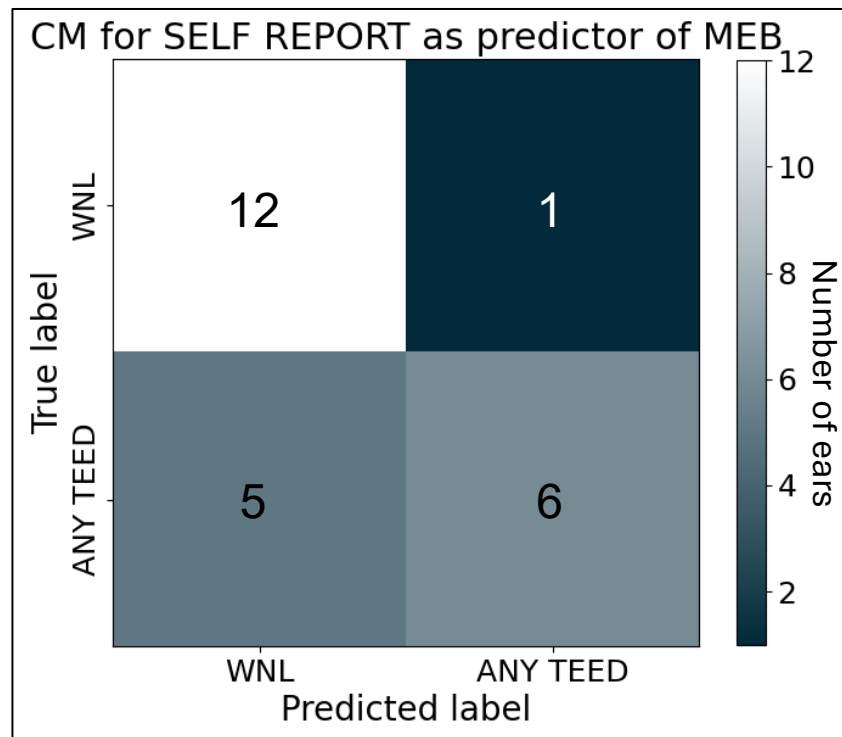
- Preliminary results show self-report and the ETDQ as possible predictors of MEB (data collection ongoing)

Predictor	Model Type	Accuracy	Sensitivity	Geometric Mean
Self reported "ears clearing"	*	0.750	0.545	0.640
ETDQ baseline	KNN (k=3)	0.708	0.818	0.761
ETDQ during	SVM (linear)	0.792	0.818	0.805

*Same performance regardless of model type, possibly due to categorical nature of data



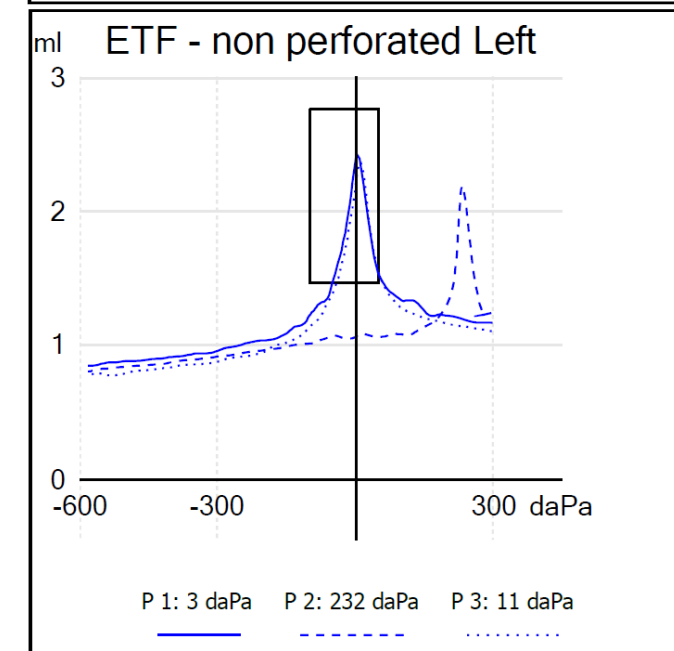
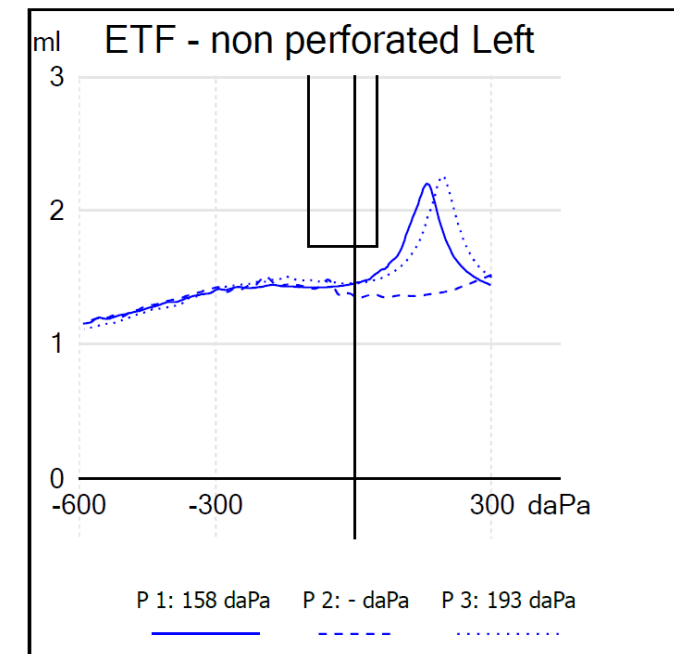
Results - Model Performance





Discussion/Conclusions

- Potential MEB predictors:
 - Self-report of “ears clearing”
 - ETDQ scores
 - KNN model trained on baseline ETDQ scores
- Comparison to dive manual requirements
 - Adding ETDQ won't disrupt training
- Limitations
 - Variability, attrition rates, logistics





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