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Validation of sobriety tests for the marine environment

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ABSTRACT

The objective of this project was to develop sobriety tests that can be administered in the seated position to assist water patrol officers in detecting alcohol-related impairment in boaters. Four seated sobriety tests were administered to 330 boaters to determine the tests' usefulness in classifying boaters as having blood alcohol concentrations (BACs) below the illegal limit (BAC < .08%) or above the illegal limit (BAC ≥ .08%). Data were obtained by a team of four marine officers and two civilian observers on Lake of the Ozarks in central Missouri. The overall correct percentages, sensitivity, and specificity of the tests were consistent with what is typically reported in literature on the roadside sobriety tests. The tests' reliability was also consistent with what is typically reported in literature on the roadside sobriety tests. Thus, the four tests may assist marine officers with assessments of alcohol-related impairment in boaters.

1. Introduction

Over the past few decades, the number of recreational boaters has increased steadily (Tseng et al., 2009). There is evidence that alcohol consumption is elevated among recreational boaters (Khiabani et al., 2008; Logan et al., 1999) and that alcohol consumption significantly increases the risk of dying while boating (Driscoll et al., 2004; Lunetta et al., 1998; Smith et al., 2001). Some studies indicate that up to 70% of drowning victims test positive for alcohol (Browne et al., 2003; Driscoll et al., 2004).

The responsibility of detecting boating under the influence of alcohol (BUI) falls on water patrol officers. Their job, however, is fraught with difficulties. First, on some waterways, it is not illegal to drink while boating. An open container, therefore, is not probable cause for a stop. Second, on some waterways, there are no speed limits, making excessive speed not necessarily a clue of impairment. Third, environmental conditions (wind, water choppiness, and glare) can make it difficult to determine boaters' impairment. Finally, unlike land-based officers, water patrol officers do not have a validated battery of sobriety tests to be used on water.

To examine the type of tests water patrol officers currently use, a nationwide request was made to all agencies with water patrol duties to provide their BUI arrest records for the previous year. A total of 1146 BUI reports from agencies in Alaska, Arizona, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Nevada, Ohio, Tennessee, Texas, Virginia, and Wisconsin were received and analyzed. With the exception of the three tests that constitute the standardized field sobriety tests (SFSTs), it was found that no test was uniformly administered from state to state or, often, from agency to agency within a state. This lack of standardization may result in uneven application of sanctions and penalties for BUI.

The SFSTs are not suitable for use on the water because walking and balance tests need to be administered on a firm, flat surface. Marine officers who use these tests must bring the suspected boater to shore and wait a pre-established period of time to get the suspect adapted to being on land (usually 15 min). This can be inconvenient for both officers and boaters. Tests that can be administered without bringing the suspect ashore will save time, but safety concerns mandate that they be performed with the suspect seated. Previous efforts examined a variety of seated tests on boats and found encouraging results (Sussman et al., 1990).

1.1. Prior research on sobriety tests

Two laboratory studies established the scientific basis of the roadside sobriety tests in the late 1970s and early 1980s. The first examined the usefulness of six candidate tests in detecting BACs of .10% and above (Burns and Moskowitz, 1977). In that study, 238 subjects were semi-randomly assigned to one of the four BAC groups: .00%, .05%, .10% and .15%. Note that the positive BAC groups represented half the legal limit, the legal limit, and 1.5 times the legal limit of the time. Law enforcement officers administered six tests to the subjects. The six tests were One-Leg Stand (OLS), Finger to Nose (FTN), Walk and Turn (WAT), Finger Count (FC), Tracing, and Horizontal Gaze Nystagmus (HGN). Based on the results, the authors recommended a reduced battery of tests which included the OLS, WAT, and HGN.

Nystagmus is an involuntary jerking of the eyeball that can occur for a variety of reasons (Dell'Osso, 1990), including pathology, trauma, vestibular disturbances, and other neural disorders. Within

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the impaired driving/boating context, however, HGN specifically refers to a lateral jerking of the eyeball affected by alcohol, certain nervous system depressants, inhalants, and dissociative anesthetics, including phencyclidine. The HGN test consists of six clues, three for each eye: lack of smooth pursuit, maximum deviation, and angle of onset (National Highway Traffic Safety Administration, 1999). Four out of six possible clues indicate impairment. The WAT test requires a person to assume a heel-to-toe position on a real or imaginary line, arms at the sides, and to listen while instructions are given. The person is then required to make nine heel-to-toe steps along the line, turn around keeping one foot on the line, and return with another nine heel-to-toe steps. Two out of eight possible clues indicate impairment. The OLS test requires a person to stand, feet together, and arms at the sides. The person is then required to raise one leg up about 6 in. off the ground (15 cm), foot parallel to the ground, toes pointed forward, and count aloud for 30 s. Two out of four possible clues indicate impairment. The WAT and OLS are commonly referred to as divided attention tests. In both tests, the person is asked to maintain equilibrium while receiving fairly complex instructions. It is the combination of physical and cognitive demands that make the tests sensitive to the effects of alcohol.

In the second study (Tharp et al., 1981), 297 subjects were administered enough alcohol to reach peak BACs of .00%, .05%, .11%, and .15%. Again, .05% was half the legal limit, .11% was slightly above the legal limit, and .15% was 1.5 times the legal limit at the time (.10%). A combination of HGN, WAT, and OLS correctly identified 81.2% of the subjects.

Since the development of the roadside sobriety tests, they have been routinely used by law enforcement officers throughout the US to identify BACs above the legal limit. Three validation studies have confirmed their usefulness. The first (Burns and Anderson, 1995), is unique because it was conducted in Colorado, which had a two-tiered system, one for drivers with BACs between .05% but less than .10% (now .08%), who were charged with driving-while-ability-impaired; and one tier for drivers with BACs of .10% and above (now .08%), who were charged with driving-under-the-influence. Thirty-one officers from six law enforcement agencies collected the data, accompanied on approximately half the stops by observers who verified that data were collected according to study procedures. In general, the officers stopped drivers suspected of being BAC .05% and above and administered the three sobriety tests (HGN, WAT, and OLS). The accuracy of the arrest/release decision was verified with a portable breath alcohol screener, which was always administered following the sobriety tests. Complete data were collected from 234 drivers, with BACs ranging from .00% to .34%, with an average BAC of .15%. With the .05% criterion, Colorado officers using the sobriety tests had an overall correct percentage of 85.9%, .89 sensitivity, and .76 specificity.

The second validation study was conducted in Florida (Burns and Dioquino, 1997), which already had a .08% statute. Eight officers from Pinellas County Sheriff's Office collected the data, at times accompanied by observers. In general, the procedures were similar to the Colorado study (Burns and Anderson, 1995). Complete data were collected from 256 drivers, with BACs ranging from .00% to .28%. Florida officers using the sobriety tests had an overall correct percentage of 93.0%, .96 sensitivity, and .82 specificity.

The third validation study was conducted in California (Stuster, 2006), which also had a .08% statute. Seven officers from the San Diego Police Department collected the data. In general, the procedures were similar to the Colorado and Florida studies (Burns and Anderson, 1995; Burns and Dioquino, 1997). Complete data were collected from 297 drivers, with an average BAC of .12%. California officers using the sobriety tests had an overall percent correct of 91.2%, .98 sensitivity, and .73 specificity.

Note that the prevalence of BAC $\geq$ .08% in the field studies is dramatically higher than the prevalence in the earlier laboratory studies. In the laboratory, the distribution of BACs is dictated by practical and ethical considerations. In the field, the range of BACs is much greater.

1.2. Current project

The objective of this project was to develop sobriety tests that can be administered in the seated position to assist water patrol officers in detecting impairment caused by BACs of .08% and above. As in the roadside tests, the seated tests must be easy to administer, so as to not overburden law enforcement officers, who must continually monitor the environment for their own safety and the safety of the boaters suspected of impairment. The tests must discriminate impaired performance without the knowledge of the individual suspect's baseline performance. Most importantly, the tests must be useful for an arrest/release decision. Unlike the roadside tests, however, the seated tests cannot make use of any measure of equilibrium.

In prior validation studies of the SFSTs, the general approach has been to have officers stop drivers suspected of driving under the influence of alcohol, administer three standardized sobriety tests, and make an arrest/release decision on the basis of the three tests. The accuracy of the arrest/release decision was verified with a portable breath alcohol screener, which was administered following the sobriety tests by trained civilian observers. This study followed the same approach. Marine officers stopped boaters suspected of BUI, asked them to come aboard the patrol vessel, and administered four sobriety tests. The four sobriety tests, described in detail elsewhere (Fiorentino et al., 2011), were horizontal gaze nystagmus (HGN), finger to nose (FTN), palm pat (PP), and hand coordination (HC). Lastly, an alcohol breath test was obtained to verify the accuracy of the tests in detecting BACs of .08% and above.

Unlike previous SFSTs validation studies, the alcohol breath tests were administered by the marine officers, not the civilian observers. This was required for practical and safety reasons due to the small size of the deck on the police vessel. The space limitation made it cumbersome for the marine officer and the observer to switch places in order for the observer to interact with the BUI suspect and administer the alcohol breath test. The switch would have created a potentially unsafe situation in which the officer could not guarantee the safety of the boater and the observer. The role of the observers, therefore, was limited to ensuring that the alcohol breath test consistently followed the four sobriety tests in the examination.

2. Method

2.1. Study site

The study was conducted on the Lake of the Ozarks in central Missouri. The Missouri State Water Patrol (MSWP) was the collaborating agency. MSWP is based in Jefferson City, but the study site was in Osage Beach.

The Lake of the Ozarks was selected as the study site for two reasons. The first was the cooperation of MSWP, which provided study officers. The second was that the lake is a popular boating destination, with enough cases of BUI to support data collection for the study.

2.2. Study officers

Four marine officers were selected by the MSWP for participation in the study. All four officers had prior experience administering the HGN test.

2.3. Officers' training

Officer training spanned four days, beginning Thursday, June 18, 2009. Day 1 consisted of an 8-h in-class explanation and demonstration of the four sobriety tests (HGN, FTN, PP, and HC). During that class, conducted by SCRI staff, the officers became familiar with the administration and scoring of the tests. Two volunteers drank until their BACs were over .08%. The four officers then practiced on the volunteers while the SCRI staff provided feedback. Days 2, 3, and 4 consisted of 10-h shifts, in patrol boats on the water, with the sole purpose of allowing the marine officers to become proficient with the tests.

2.4. Civilian observers

There were two observers for all study activities. They were based in Osage Beach for the duration of the study. For the observers' safety, the officer was always positioned between them and the suspect. The observers were close enough to observe the suspects' performance but far enough as to not interfere (about 5 ft away, or 1.5 m).

2.5. Sobriety tests

2.5.1. Horizontal gaze nystagmus

The HGN test requires three separate checks, administered independently to each eye. Four or more clues indicate impairment due to BAC $\geq$ .08%.

2.5.2. Finger to nose

The FTN test requires the subject to bring the tip of the index finger to touch the tip of the nose. It is performed with eyes closed and head tilted slightly back. Nine or more clues indicate impairment due to BAC $\geq$ .08%.

2.5.3. Palm pat

The PP test requires the subjects to place one hand extended, palm up, out in front of them. The other hand is placed on top of the first with the palm facing down. The top hand rotates 180° and pats the bottom hand, alternating between the back of the hand and the palm of the hand. The bottom hand remains stationary. The subjects count out loud in relation with each pat. Two or more clues indicate impairment due to BAC $\geq$ .08%.

2.5.4. Hand coordination

The HC test requires the subjects to perform a series of tasks with their hands. It is very loosely adapted from the Walk-And-Turn test performed on land. Three or more clues indicate impairment due to BAC $\geq$ .08%.

2.6. Equipment

Officers used a pen, pencil, or small flashlight as the stimulus for the HGN test. Four Alco Sensor FST (Intoximeter, Inc., St. Louis, MO) breath alcohol testing instruments were used as the alcohol screeners. The observers were required to meet the MSWP's water safety requirements while on the patrol boat.

2.7. Study dates and shifts

Data were collected from Friday, June 26, 2009 to Monday, September 7, 2009, inclusive. Data were collected during the expected busiest boating days: Fridays, Saturdays, Sundays, and holidays. Shifts started at 12 p.m. and lasted from 10 to 12 h, depending on the workload.

2.8. Procedures

The general procedures for the study were as follows. The officers stopped boaters suspected of BUI and asked them to come aboard the patrol boat. The suspects sat on a bench seat on the stern of the boat. After a few agency-specific questions, the officer administered the sobriety tests in the following order: HGN, FTN, PP, and HC. The tests were scored during administration (Fig. 1). Following the tests, two successive alcohol breath tests were administered. At this point, based on evidence from the sobriety tests and the breath alcohol tests, the officer either released or arrested the boater. The observers ensured that the sobriety tests' data were collected prior to the alcohol breath tests.

In case the BUI suspect was released, the officer and the observer resumed patrolling the assigned area. In case of an arrest, the suspect was brought ashore and processed for arrest by the officer. Because that took some time, the observer often teamed up with another available study officer.

Of the 331 study cases, 251 (76%) were obtained with observers present and 80 (24%) were obtained without observers. When possible, given the limitations of operating in a small space on the patrol boat, the observers also scored some of the sobriety tests while the officers were administering them. Only a portion of the FTN, PP, and HC tests could be scored by the observers. No HGN test could be scored by the observers because it was impossible to clearly see the suspects' eyes from their position on the boat. The observers and the officers never shared their results prior to the administration of the alcohol breath tests.

3. Results

3.1. Stop characteristics

With observers, data collection hours ranged from 1:59 pm to 6:04 am. Without observers, data collection hours ranged from 10:20 am to 7:04 am.

There were two types of stops in the study. A probable cause stop involved a boater suspected of BUI by the officer. A checkpoint stop involved a boater selected at random from the flow of boats. With observers, 221 (88%) of the stops were probable cause and 30 (12%) of the stops were checkpoint. Without observers, 41 (51.3%) of the stops were probable cause, 14 (17.5%) were checkpoint, and 25 (31.3%) were unknown.

Stops were conducted under clear, cloudy, and rainy conditions; with winds ranging from zero to 16+ mph; with air temperature ranging from the 60 s to the 100 s; with water temperature ranging from the 70 s to the 90 s; on calm, choppy, or rough waters; and with daylight, dusk, and dark lighting conditions.

3.2. Sample characteristics

Occasionally, it was necessary to release control of a boat to a suitable passenger. Some passengers, therefore, were administered the tests to determine their level of impairment. Although the passengers were not tested for the purpose of an arrest/release decision, their data were included in the analyses.

Boaters on jet skis, pontoons, cruisers, and other vessels were stopped. Stopped boaters tended to be white males between the ages of 18 and 80.

3.3. Blood alcohol concentrations

BACs ranged from .00% to .32% (N = 330, M = .072, SD = .061, Median = .060).

Table 1
BAC and HGN, FTN, PP, HC total clues by BAC status and observer status.

Variable		With observers		Without observers		Combined	
		BAC < .08%	BAC ≥ .08%	BAC < .08%	BAC ≥ .08%	BAC < .08%	BAC ≥ .08%
BAC	Mean	.028	.134	.028	.125	.028	.133
	SD	.025	.040	.025	.041	.028	.041
	N	141	109	49	31	190	140
HGN	Mean	1.45	4.98	1.94	4.97	1.58	4.98
	SD	1.57	1.53	1.68	1.54	1.61	1.52
	N	141	109	48	31	189	140
FTN	Mean	5.72	8.17	6.29	8.59	5.86	8.26
	SD	3.34	3.72	3.42	5.00	3.36	4.02
	N	141	109	49	31	190	140
PP	Mean	1.30	2.34	1.41	2.35	1.33	2.34
	SD	.93	1.18	1.02	1.28	.95	1.20
	N	141	109	49	31	190	140
HC	Mean	2.34	3.00	2.29	2.52	2.33	2.89
	SD	1.49	1.42	1.62	1.21	1.52	1.39
	N	141	109	49	31	190	140

Horizontal Gaze Nystagmus

	Left	Right
Lack of smooth pursuit	□	□
Distinct nystagmus at maximum deviation	□	□
Onset prior to 45 degrees	□	□
Total		
Note: **Four or more clues indicate BAC ≥ .08%.**		

Finger to Nose

Compliance with Instructions		*Accuracy*						
			Left	*Right*	*Left*	*Right*	*Right*	*Left*
		Wrong hand	□	□	□	□	□	□
Unable to follow instructions	□	Wrong finger	□	□	□	□	□	□
Started at wrong time	□	Hesitated	□	□	□	□	□	□
Did not close eyes	□	Searched	□	□	□	□	□	□
Did not tilt head	□	Missed fingertip	□	□	□	□	□	□
Moved head during test	□	Missed tip of nose	□	□	□	□	□	□
Opened eyes during test	□	Did not bring hand down	□	□	□	□	□	□
Total								
Note: **Nine or more clues indicate BAC ≥ .08%.**								

Palm Pat

Starter position		
	Unable to follow instructions	□
	Started at wrong time	□
Palm Pats		
	Did not count as instructed	□
	Rolled hands	□
	Double pat	□
	Chopped pat	□
	Other improper pat (document)	□
	Did not increase speed	□
Rotated hands		□
Stopped before being told		□
Total		
Note: **Two or more clues indicate BAC ≥ .08%.**		

Hand Coordination

Starter position		
	Unable to follow instructions	□
	Started at wrong time	□
Forward steps		
	Improper count	□
	Improper touch	□
	Did not perform	□
Hand clapping		
	Improper count	□
	Improper touch	□
	Improper return	□
	Did not perform	□
Return steps		
	Improper count	□
	Improper touch	□
	Did not return fist to chest	□
	Did not perform	□
End position		
	Improper position	□
	Did not perform	□
Total		
Note: **Three or more clues indicate BAC ≥ .08%.**		

BrAC

BrAC 1	□ Refused □ Breath □ Blood □ Urine (Time: , BAC:)
BrAC 2	□ Refused □ Breath □ Blood □ Urine (Time: , BAC:)

Fig. 1. Officers' data collection form.

3.4. BACs and tests' differences by BAC status

The tests were examined by BAC Status (BACs < .08% v. BAC ≥ .08%). Note that this is a very conservative approach as it classifies cases on the basis of the criterion rather than the behavioral characteristics of the subject. One of the 251 cases from the observer data was missing a BAC, as the boater refused to provide a breath or blood specimen. That case was dropped from the analyses. One case from the without observer data was missing the HGN test. That case was included in the analyses.

Analysis of variance (ANOVA) was conducted on each of the variables to determine whether BAC, HGN, FTN, PP, and HC varied as a function of BAC Status. Table 1 reports the means, standard deviation and number of cases for each of those variables by BAC Status and observer status. Because there were only minor differences between the data set obtained with observers and the data set obtained without observers, only the ANOVAs for the combined data set are reported here.

As expected, the differences between lower BACs (M = .028%) and higher BACs (M = .133%) were statistically significant, $F(1, 328) = 837.36$, $p < .001$. There were statistically significant differences in total scores as a function of BAC Status for all four tests: HGN, $F(1, 327) = 377.10$, $p < .001$; FTN, $F(1, 328) = 34.76$, $p < .001$; PP, $F(1, 328) = 73.15$, $p < .001$; and HC, $F(1, 328) = 12.03$, $p < .01$.

3.5. Correlations between BAC, BAC status, HGN, FTN, PP, and HC

The correlations between the four tests, BAC, and BAC Status are shown in Table 2. The test with the highest correlation to BAC was HGN, followed by PP, FTN, and HC. There was no statistically significant difference in the HGN-BAC correlation between data collected with observers and data collected without observers, $z = -.65$, $p = .51$. There was no statistically significant difference in the FTN-BAC correlation between data collected with observers and data collected without observers, $z = .56$, $p = .58$. There was no statistically significant difference in the PP-BAC correlation between data collected with observers and data collected without observers, $z = .47$, $p = .64$. There was no statistically significant difference in the HC-BAC correlation between data collected with observers and data collected without observers, $z = 1.27$, $p = .20$.

3.6. Positive/negative classifications

Because there were no statistically significant differences between the data collected with observers and the data collected without observers in the correlations between BAC and each of the four tests, it was possible to conduct the classification analyses on the combined data set. Table 3 summarizes the classification analyses.

3.6.1. Horizontal gaze nystagmus

A test of the full model with HGN Positive/Negative scores against a constant-only model was statistically significant, χ^2 (1, N = 329) = 174.31, $p < .001$. HGN alone correctly predicted BAC Status in 85% of the cases. Sensitivity was .86 and specificity was .84. The positive predictive value was .80 and the negative predictive value was .89. Positive likelihood ratio and negative likelihood ratio were 5.27 and .16, respectively.

Table 2
Correlations between BAC, BAC status and HGN, FTN, PP and HC by observer status.

Variable	With observers		Without observers		Combined	
	BAC	BAC status	BAC	BAC status	BAC	BAC status
HGN	.757**	.750**	.791**	.581**	.761**	.715**
FTN	.396**	.324**	.333**	.228	.375**	.298**
PP	.471**	.428**	.422**	.299*	.458**	.403**
HC	.297**	.207**	.139	.030	.265**	.182**

* $p \le .05$.
** $p \le .01$.

3.6.2. Finger to nose

A test of the full model with FTN Positive/Negative scores against a constant-only model was statistically significant, χ^2 (1, N = 330) = 32.85, $p < .001$. FTN alone correctly predicted BAC Status in 67% of the cases. Sensitivity was .49 and specificity was .81. The positive predictive value was .65 and the negative predictive value was .68. Positive likelihood ratio and negative likelihood ratio were 2.56 and .63, respectively.

3.6.3. Palm pat

A test of the full model with PP Positive/Negative scores against a constant-only model was statistically significant, χ^2 (1, N = 330) = 37.74, $p < .001$. PP alone correctly predicted BAC Status in 65% of the cases. Sensitivity was .76 and specificity was .57. The positive predictive value was .57 and the negative predictive value was .77. Positive likelihood ratio and negative likelihood ratio were 1.77 and .41, respectively.

3.6.4. Hand coordination

A test of the full model with HC Positive/Negative scores against a constant-only model was statistically significant, χ^2 (1, N = 330) = 12.37, $p < .001$. HC alone correctly predicted BAC Status in 59% of the cases. Sensitivity was .62 and specificity was .57. The positive predictive value was .52 and the negative predictive value was .67. Positive likelihood ratio and negative likelihood ratio were 1.46 and .66, respectively.

3.6.5. Combined tests

HGN and FTN were the best combination of two tests. Combined, they correctly predicted BAC Status in 75% of the cases, χ^2 (1, N = 329) = 86.44, $p < .001$. Sensitivity was .46 and specificity was .96. The positive predictive value was .89 and the negative predictive value was .70. Positive likelihood ratio and negative likelihood ratio were 10.80 and .57, respectively.

HGN, FTN, and PP were the best combination of three tests. That combination correctly predicted BAC Status in 72% of the cases, χ^2 (1, N = 329) = 72.62, $p < .001$. Sensitivity was .39 and specificity was .97. The positive predictive value was .90 and the negative predictive value was .68. Positive likelihood ratio and negative likelihood ratio were 12.15 and .63, respectively.

The four tests combined correctly predicted BAC Status in 68% of the cases, χ^2 (1, N = 329) = 50.71, $p < .001$. Sensitivity was .28 and specificity was .98. The positive predictive value was .91 and the negative predictive value was .65. Positive likelihood ratio and negative likelihood ratio were 13.16 and .74, respectively.

HGN and any one of the FTN, PP, and HC correctly predicted BAC Status in 85% of the cases, χ^2 (1, N = 329) = 165.67, p < .001. Sensitivity was .81 and specificity was .87. The positive predictive value was .82 and the negative predictive value was .86. Positive likelihood ratio and negative likelihood ratio were 6.36 and .22, respectively.

Without HGN, the best predictor of BAC Status was the combination of FTN, PP and HC, which correctly predicted 66% of the cases, χ^2 (1, N = 330) = 29.99, $p < .001$. Sensitivity was .29 and specificity was .93. The positive predictive value was .76 and the negative predictive value was .64. Positive likelihood ratio and negative likelihood ratio were 4.28 and .76, respectively.

Table 3
Prediction of BAC status by four tests alone and in combination.

Test	Prevalence	% correct	Sensitivity	Specificity	PPV	NPV	LR+	LR−
1. HGN positive/negative	.43	84.8	.86	.84	.80	.89	5.27	.16
2. FTN positive/negative	.42	67.3	.49	.81	.65	.68	2.56	.63
3. PP positive/negative	.42	65.2	.76	.57	.57	.77	1.77	.41
4. HC positive/negative	.42	59.4	.62	.57	.52	.67	1.46	.66
1, 2	.43	74.5	.46	.96	.89	.70	10.80	.57
1,3	.43	81.5	.70	.90	.84	.80	6.96	.33
1, 4	.43	76.0	.56	.90	.81	.74	5.93	.48
2, 3	.42	68.5	.41	.89	.73	.67	3.68	.67
2, 4	.42	65.8	.34	.89	.70	.65	3.19	.74
3, 4	.42	66.1	.51	.77	.62	.68	2.22	.63
1, 2, 3	.43	72.0	.39	.97	.90	.68	12.15	.63
1, 2, 4	.43	69.0	.31	.97	.88	.66	9.95	.71
1, 3, 4	.43	74.5	.49	.93	.84	.71	7.17	.54
2, 3, 4	.42	66.1	.29	.93	.76	.64	4.28	.76
1, 2, 3, 4	.43	68.1	.28	.98	.91	.65	13.24	.74
1 and any other one test	.43	84.5	.81	.87	.82	.86	6.39	.22
1 and any other two tests	.43	79.3	.64	.91	.84	.77	7.10	.40
2 and any other one test	.43	69.7	.49	.85	.71	.69	3.30	.60
2 and any other two tests	.43	70.8	.44	.91	.78	.69	4.84	.62
3 and any other one test	.43	71.3	.73	.70	.65	.78	2.46	.39
3 and any other two tests	.43	76.3	.61	.87	.78	.75	4.84	.44
4 and any other one test	.43	66.3	.59	.71	.61	.70	2.08	.57
4 and any other two tests	.43	73.3	.54	.87	.76	.72	4.28	.52

Note. PPV = positive predictive value. NPV = negative predictive value. LR+ = positive likelihood ratio. LR− = negative likelihood ratio. HGN = horizontal gaze nystagmus, FTN = finger to nose. PP = palm pat. HC = hand coordination.

3.7. Reliability

When possible, the observers scored the FTN, PP, and HC tests while the officer administered the tests to the BUI suspects. HGN could not be scored because the eyes of the BUI suspects were not clearly visible from where the observers were standing on the patrol boat.

For FTN, the correlation between the total score of the officer and the total score of the observer was .84. Kappa was .73 ($N = 134$), indicating substantial agreement. For PP, the correlation between the total score of the officer and the total score of the observer was .84. Kappa was .87 ($N = 134$), indicating almost perfect agreement. For HC, the correlation between the total score of the officer and the total score of the observer was .82. Kappa was .84 ($N = 133$), indicating almost perfect agreement.

4. Discussion

The current project is the first to systematically examine the usefulness of four seated sobriety tests for use in the marine environment. Data were obtained by a team of four marine officers and two civilian observers.

Officers were extensively trained in administering the four tests. Only when the officers were proficient and comfortable administering and scoring the test did data collection begin.

The tests were administered at almost all hours of the day; with probable cause or at sobriety checkpoints; under clear or cloudy weather; with and without wind; at various water and air temperatures; on calm, choppy, or rough water surface; and under various lighting conditions.

The sample of boaters was relatively homogeneous, as it consisted predominantly of Caucasian males. Very few women, Latinos, African Americans, and Asians were stopped for the study. Ages ranged from 18 to 80 years.

Study BACs ranged from .00% to .32%. HGN was found to be the most useful test in predicting BACs of .08% and above, followed by FTN, PP, and HC. A positive HGN test indicates a .80 probability that the BUI suspect has a BAC ≥ .08%. Thus, HGN is a very good predictor of BAC Status not only at roadside, but also on the water. Alone, it can correctly identify 85% of BUI suspects as either BAC < .08% or BAC ≥ .08%. Officers who can properly administer it and score it may confidently rely on it to form their arrest/release decision.

FTN is a moderate predictor of BAC Status. Alone, it can correctly identify 67% of BUI suspects as either BAC < .08% or BAC ≥ .08%. A positive FTN test indicates a .65 probability that the BUI suspect has a BAC ≥ .08%.

The PP and HC tests are only fair predictors of BAC Status. Alone, they can correctly identify 65% and 59%, respectively, of BUI suspects as either BAC < .08% or BAC ≥ .08%. A positive PP test indicates a .57 probability that the BUI suspect has a BAC ≥ .08%. A positive HC test indicates a .52 probability that the BUI suspect has a BAC ≥ .08%.

HGN and any one of the FTN, PP, and HC correctly predicted BAC Status in 85% of the cases. The positive likelihood ratio of 6.36 and the negative likelihood ratio of .22 indicate that this combination is useful in detecting alcohol-related impairment.

Without HGN, the best predictor of BAC Status was the combination of FTN, PP, and HC, which correctly predicted 66% of the cases. The positive likelihood ratio of 4.28 and the negative likelihood ratio of .76 indicate that this combination is likely to be moderately useful in detecting alcohol-related impairment.

The overall correct percentages, sensitivity, and specificity of the tests were consistent with what is typically reported in literature on the roadside SFSTs. It should be noted that the prevalence of BACs at or above .08% was lower in the current field study (.43) than in the previous field studies on SFSTs (.79, .80, .73).

The tests' reliability was also consistent with what is typically reported in literature on the roadside SFSTs. Note, however, that HGN could not be included in the reliability analyses because it was impossible for the observers to clearly see the suspects' eyes from their position on the boat.

It is proposed that marine officers administer HGN, FTN, PP, and HC to all BUI suspects, and then, for each suspect, use the pattern of test results to estimate the probability of BAC ≥ .08% as shown in Table 3. The usefulness of this approach should be assessed periodically, including a systematic review of the performance of each test, alone and in combination. If necessary, changes in administration and scoring may be required from time to time to maximize the predictive power of the battery.

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Appendix A. Tests' scoring sheet and instructions

A.1. General instructions

To ensure that the subjects are stable, give the following instructions to all subjects before starting any of the tests.

- Please sit straight at the front edge of your seat.
- Put your arms down at your sides.
- Place your feet shoulder-width so that you are comfortable and stable.
- Are you comfortable and stable?
- Wait for response.
- Do not move your feet until the test is over. Stay in this position. Do not do anything else until I tell you to do so. Do you understand?
- Get acknowledgement of understanding.

A.2. Finger to nose

This test requires the subjects to bring the tip of the index finger to touch the tip of the nose. It is performed with eyes closed and head tilted slightly back. This test should be administered in an environment where the subject is stable and is able to tilt their head back with eyes closed without risking personal injury.

A.2.1. Administrative procedures

- Tell the subjects to make a fist with both hands, extend the index fingers, and turn the palms forward.
- Tell the subjects that when you say BEGIN, they should tilt their head back slightly and close their eyes.
- Demonstrate how head should be tilted back, but do not close your eyes.
- Inform the subjects that you will instruct them to bring the tip of the index finger to touch the tip of the nose.
- The arm is brought directly from the subjects' side in front of the body touching the tip of the nose with the tip of the index finger.
- Demonstrate how the subject is supposed to move the arm and how they are supposed to touch the tip of the nose with the tip of the finger.
- Tell the subjects that as soon as they touch their nose, they must return the arm to their side.
- Tell the subjects that when you say RIGHT they must move the right hand index finger to their nose; and when you say LEFT they must move the left hand finger to their nose.
- Get acknowledgement of understanding.
- Tell the subjects to BEGIN.
- Ensure they tilt their head back and close their eyes. Do not start to give the commands until the subjects are in compliance. If necessary, emphasize to the subjects that they must keep their eyes closed until you say to open them.
- Give the commands in exactly this order: LEFT, RIGHT, LEFT, RIGHT, RIGHT, LEFT.
- Make sure the subjects return the arms to their side immediately after each attempt. Pause about 2 or 3 s between commands.
- After the sixth attempt, tell the subjects to open their eyes and straighten their head.

A.2.2. Documenting the test

The test requires monitoring two sets of clues: compliance with instructions and finger-to-nose accuracy.

A.2.3. Criterion

Nine or more clues suggest that the individual being tested is impaired with BAC $\geq$ .08%.

A.3. Hand coordination

This test requires the subjects to perform a series of tasks with their hands. It is adapted from the Walk-And-Turn test performed on land.

A.3.1. Administrative procedures

- Tell the subjects to make fists with both hands, place the left fist thumb against the sternum, and the thumb side of the right fist against the fleshy side of the left fist.
- Demonstrate.
- Tell the subjects to stay in that position.
- Tell the subjects that when you say BEGIN they must perform four tasks. The first is to count aloud from one to four, placing one fist in front of the other, in step-like fashion, making sure the thumb side of one fist is touching the fleshy side of the other fist at each step.
- Demonstrate.
- The second task is to memorize the position of the fists after having counted to four, clap the hands three times (no aloud count required), and return the fists in the memorized position.
- Demonstrate.
- The third task is to move the fists in step-like fashion in reverse order counting aloud from five to eight, and return the left fist to the chest.
- Demonstrate.
- Finally, tell the subjects to return their hands, opened and palms down, to their laps.
- Get acknowledgement of understanding.
- Say BEGIN.

A.3.2. Documenting the test

The test requires monitoring for compliance with instructions.

A.3.3. Criterion

Three or more clues suggest that the individual being tested is impaired with BAC $\geq$ .08%.

A.4. Palm pat

The Hand Pat FST requires the subjects to place one hand extended, palm up, out in front of them. The other hand is placed on top of the first with the palm facing down. The top hand rotates 180° and pats the bottom hand, alternating between the back of the hand and the palm of the hand. The bottom hand remains stationary. The subject counts out loud, ONE-TWO, ONE-TWO, etc., in relation with each pat.

A.4.1. Administrative procedures

- Start by instructing the subjects to put one hand out in front of them with the open palm facing upward. The opposite hand is then placed on top of the first hand with the open palm facing downward.

- The hand with the palm facing upward is held in a stationary position. The hand on top with the palm facing downward will be the only hand moving.
- When told to begin, the subjects will rotate the top hand 180° and pat the back of the top hand to the palm of the bottom hand simultaneously counting out loud, "one". The top hand then rotates 180° so the palm of the top hand pats the palm of the bottom hand simultaneously counting out loud, "Two".
- Demonstrate.
- The process then repeats. The subjects should start at a slow speed, then gradually increase the speed until a relatively rapid pace is reached.
- If necessary, prompt the subject to increase the speed.
- The subject should perform this test for a minimum of 10 s but no more than 15 s.

A.4.2. Documenting the test

The test requires monitoring of compliance with instructions.

A.4.3. Criterion

Two or more clues suggest that the individual being tested is impaired with BAC ≥ .08%.

A.5. Horizontal gaze nystagmus

This test is made out of three separate checks, administered independently to each eye.

A.5.1. Administrative procedures

- Ask if the subject is wearing contact lenses and note the response. If the subject is wearing eyeglasses, have them removed.
  - "I am going to check your eyes."
  - "Keep your head still and follow this stimulus with your eyes only."
  - "Keep following the stimulus with your eyes until I tell you to stop."
  - "Do you understand?"
- Position the stimulus approximately 12–15 in. from the nose and slightly above eye level.
- Check to see that both pupils are equal in size and for the presence of resting nystagmus.
- Check the subject's eyes for the ability to track together.
  - Move the stimulus smoothly across the subject's entire field of vision. Check to see if the eyes track the stimulus together or one lags behind the other. If the eyes don't track together, it could indicate possible medical disorder, injury, or blindness.
- Check both eyes for lack of smooth pursuit.
  - Check the subject's left eye by moving the stimulus to the right. Move the stimulus smoothly, at a speed that requires approximately 2 s to bring the subject's eye as far to the side as it can go. Look at the subject's eye and determine whether it is able to pursue smoothly.
  - Move the stimulus all the way to the left, back across subject's face checking if the right eye pursues smoothly. Movement of the stimulus should take approximately 2 s out and 2 s back for each eye. Repeat the procedure.
- Check the eyes for distinct and sustained nystagmus at maximum deviation.
  - Move the stimulus to the subject's left side until the eye has moved as far to the side as possible. No white will be showing in the corner of the eye at maximum deviation.
  - Hold the eye at that position for a minimum of 4 s, then move the stimulus all the way across the subject's face to check the right eye, holding that position for a minimum of 4 s. Repeat the procedure.
- Check for onset of nystagmus prior to 45°.
  - Start moving the stimulus towards the right at a speed that would take approximately 4 s for the stimulus to reach the edge of the subject's shoulder. Watch the eye carefully for any sign of jerking. When observed, stop and verify that the jerking continues.
  - Move the stimulus to the left at a speed that would take approximately 4 s for the stimulus to reach the edge of the subject's shoulder. Again, when you see jerking, stop and verify that the jerking continues.
  - Repeat the procedure. If the subject's eyes start jerking before 45°, check to see that some white of the eye is still showing in the corner of the eye closest to the ear.
- Check for vertical nystagmus
  - Raise the stimulus upward until the subject's eyes are elevated as far as possible.
  - Hold for approximately 4 s and watch for evidence of jerking.

A.5.2. Documenting the test

The test requires monitoring of three sets of clues: lack of smooth pursuit for left and right eye, maximum deviation for left and right eye, and angle of onset for left and right eye.

A.5.3. Criterion

Four or more clues suggest that the individual being tested is impaired with BAC ≥ .08%.

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