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Evaluation of Digits-in-Noise Test and Hearing Handicap Inventory for Adults Screening in Patients with Occupational Noise-Induced Hearing Loss

Zongzhi Shao*

Lianyungang Xuwei New District People's Hospital, Lianyungang 222000, Jiangsu Province, China

***Corresponding author:** Zongzhi Shao, 373384911szz@sina.com

Abstract: *Objective:* To explore the clinical evaluation role of the Digits-in-Noise (DIN) test and Hearing Handicap Inventory for Adults Screening (HHIA-S) for patients with occupational noise-induced hearing loss and to observe and analyze their application values. *Methods:* Fifty patients with suspected occupational noise-induced hearing loss were randomly selected from the Department of Otolaryngology at the hospital as the research target. The collection period for the research cases spanned from January 2022 to November 2023, and all patients had a history of noise exposure. The DIN test and HHIA-S were used for hearing examinations, with clinical, comprehensive diagnosis serving as the gold standard to study their diagnostic performance. *Results:* The compliance rate of the DIN test was 88.00%, the HHIA-S's compliance rate was 80.00%, and the combined compliance rate was 94.00%. The compliance rate of the DIN test and the combined compliance rates of the patients were statistically significant compared to the clinical gold standard data ($P < 0.05$), while there was no difference between the compliance rate of the HHIA-S and the gold standard ($P > 0.05$). The data shows that the sensitivity of the combined diagnosis is significantly higher than the sensitivity data of the DIN test and HHIA-S examination alone ($P < 0.05$). Its specificity is 100.00%, and the accuracy data of the joint diagnosis in the degree were higher than those of the DIN test alone ($P > 0.05$) and the HHIA-S alone ($P < 0.05$). *Conclusion:* For patients with occupational noise-induced hearing loss, the joint evaluation of the DIN test and HHIA-S can significantly improve their diagnostic value with high sensitivity and accuracy.

Keywords: Occupational noise-induced hearing loss; Digital speech in noise test; Hearing impairment screening scale; Application

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1. Introduction

Occupational noise-induced hearing loss is a reduction in hearing function resulting from prolonged exposure to high-intensity noise environments [1]. The Digits-in-Noise (DIN) test and the Hearing Handicap Inventory for

Adults Screening (HHIA-S) are utilized to assess and screen for this type of hearing impairment.

The DIN test evaluates the patient's listening comprehension of speech within a noisy background. During the test, the patient listens to a sequence of numbers played through speakers or headphones and repeats them as accurately as possible [2]. Hearing levels are assessed by comparing results between a group with normal hearing and a group with impaired hearing.

The HHIA-S serves as a simple and effective tool for initially screening patients for potential hearing problems. Typically, these scales include questions or tasks designed to evaluate a patient's response to various audio stimuli or the degree of hearing difficulty [3]. Based on the patient's responses or performance, an initial determination can be made regarding the presence of a hearing problem, prompting further professional hearing assessment.

Combining both the DIN test and the HHIA-S as auxiliary tools aids in diagnosing occupational noise-induced hearing loss, offering high sensitivity and significant clinical value. Building on these considerations, this study selects patients diagnosed with occupational noise-induced hearing loss to observe and analyze the application values of the DIN test and HHIA-S.

2. Materials and methods

2.1. General information

Fifty cases of patients with suspected occupational noise-induced hearing loss were randomly selected from the Department of Otolaryngology at the hospital as the research targets. The research case collection period is indicated from January 2022 to November 2023. Among them, there are 28 male patients and 22 female patients. The age range is 20–58 years old, with an average age of 29.91 ± 4.08 years. Body mass was measured within the range of 48–75 kg, with an average value of 53.88 ± 4.69 kg.

2.2. Inclusion and exclusion criteria

Inclusion criteria: (1) Patients with prolonged or intense exposure to occupational noise, such as factory workers, construction workers, military personnel, etc.; (2) Patients predominantly complain of hearing loss or symptoms of hearing difficulty; (3) Patients of all age groups, as occupational noise-induced hearing loss is not limited to the elderly; (4) Patients and their family members must provide informed consent.

Exclusion criteria: (1) Patients with hearing loss caused by factors such as hereditary hearing impairment, middle ear diseases, ear infections, etc.; (2) Patients with severe external auditory canal stenosis, tympanic membrane perforation, or other significant ear structural abnormalities; (3) Patients with hearing loss where local surgery may interfere with the test results; (4) Patients with missing or incomplete clinical data; (5) Patients with intellectual disability or other physical conditions preventing cooperation with the study.

2.3. Methods

(1) Test environment and equipment: The test environment requires background noise to be less than 30 dB(A) during testing. A standard soundproof room meeting this criterion was utilized. Pure tone audiometry and acoustic impedance testing were conducted to confirm the acoustic resistance characteristics of the speakers. Otometrics Conera pure tone audiometer and TDH39 in-ear headphones were used for pure tone audiometry. The acoustic resistance characteristics of the speaker were tested in the soundproof room. The speaker was placed 25 cm away from the test position, and the volume was adjusted to 0 dB(A). Ambient noise was measured at 25 dB(A), with both plus and minus signs for ambient noise recorded as -60 dB spi. The GSI TympStar Pro middle ear function

analyzer was used for acoustic impedance testing, and the DIN test was conducted using a MacBook Air laptop and Sony MDRZX110AP ZX series over-ear headphones.

(2) Test patient preparation: Before testing, a dedicated person provided detailed explanations to familiarize subjects with the test methods and procedures. The sequences included pure tone audiometry, acoustic immittance test, and completion of the HHIA-S. The DIN test was performed at the optimal listening intensity.

(3) DIN test: The DIN test involves testing in a standard soundproof room with a background noise below 30 dB(A). The DIN test utilized speech material – digits 0 to 9 – arranged in triplets, meeting equalization requirements. The recorded three consecutive digits were averaged over a long period and played against a background of spectral noise. To ensure result reliability, recording and playback signals were windowed before playing. After windowing, the recording signal underwent a 2-octave fast Fourier transform (FFT), followed by spectrum analysis on the frequency domain signal, reduced to auditory notation. An adaptive program dynamically adjusted the signal-to-noise ratio (SNR) to match environmental noise. Subjects recited numbers they heard, with SNR decreasing or increasing in 2 dB steps after correct or incorrect answers. After completing 23 sets of recognition, the system automatically calculated the average SNR of the 4th to 23rd groups as the final test result, also known as the speech recognition threshold (SRT). A lower SRT indicates better speech recognition ability in noise.

(4) HHIA-S: The HHIA-S scale comprises 5 emotional items and 5 social items, each with scores ranging from 0 to 10. Emotional categories include fear, happiness, anger, and sadness, while social categories encompass like, dislike, worry, and suspicion. Following the "International Diagnostic Criteria for Communication Disorders in Hearing Impaired Patients" (GB/T17623-2014), the total score ranges from 0 to 40, with higher scores indicating more severe hearing communication impairment. Researchers asked subjects questions such as "Can you hear others clearly?" based on the questionnaire, and scores were calculated based on subjects' answer sheets.

2.4. Observation indicators

(1) The statistical detection rate of the DIN test, HHIA-S, and combined diagnosis, with clinical comprehensive diagnosis as the gold standard. When the DIN test results in SRT > -16.1 dB, it is considered positive. When the total score of HHIA-S > 8, it is considered positive.

(2) The sensitivity, specificity, and accuracy of the DIN test, HHIA-S, and combined diagnosis.

2.5. Statistical analysis

SPSS 22.0 was used for statistical analyses. Measurement data were expressed as mean ± standard deviation (SD), and an independent sample *t*-test was used. Count data were expressed as *n* and %, and the χ^2 test was implemented. A P value of < 0.05 indicated a statistically significant difference between the compared data.

3. Results

3.1. Statistical detection rate

The compliance rate of the DIN test appeared to be 88.00% (**Table 1**), whereas HHIA-S's compliance rate was 80.00% (**Table 2**). The combined diagnosis had a compliance rate of 94.00% (**Table 3**). There were statistically significant differences when comparing the DIN test's compliance rate and the combined diagnosis's compliance rate with the clinical gold standard data ($P < 0.05$).

Table 1. The statistical detection rate of the DIN test

Plan		Gold standard		Total [*n* (%)]
		Positive (*n*)	**Negative (*n*)**	
DIN	Positive (*n*)	44	0	44 (88.0)
	Negative (*n*)	4	2	6 (12.0)
	Total [*n* (%)]	48	2	50 (100.0)

Table 2. The statistical detection rate of HHIA-S

Plan		Gold standard		Total [*n* (%)]
		Positive (*n*)	**Negative (*n*)**	
HHIA-S	Positive (*n*)	40	0	40 (80.0)
	Negative (*n*)	8	2	10 (20.0)
	Total [*n* (%)]	48	2	50 (100.0)

Table 3. The statistical detection rate of combined diagnosis

Plan		Gold standard		Total [*n* (%)]
		Positive (*n*)	**Negative (*n*)**	
DIN + HHIA-S	Positive (*n*)	47	0	47 (94.0)
	Negative (*n*)	1	2	3 (6.0)
	Total [*n* (%)]	48	2	50 (100.0)

3.2. Sensitivity, specificity, and accuracy

Table 4 shows that the sensitivity of the combined diagnosis is significantly higher than the sensitivity of the DIN test and the HHIA-S alone ($P < 0.05$). The combined diagnosis has a specificity of 100.00%, and its accuracy is higher than the DIN test alone ($P > 0.05$) and the HHIA-S alone ($P < 0.05$).

Table 4. Sensitivity, specificity, accuracy [% (*n*)]

Group	Sensitivity	Specificity	Accuracy
DIN	91.67 (44/48)	100.00 (2/2)	92.00 (46/50)
HHIA-S	83.33 (40/48)	100.00 (2/2)	84.00 (42/50)
DIN + HHIA-S	97.92 (47/48)	100.00 (2/2)	98.00 (49/50)
χ^2/P of DIN vs. HHIA-S	3.180/0.075	-	3.030/0.082
χ^2/P of DIN vs. combined diagnosis	3.958/0.047	-	3.790/0.052
χ^2/P of HHIA-S vs. combined diagnosis	12.527/0.000	-	11.966/0.001

4. Discussion

Occupational noise-induced hearing loss results from prolonged exposure to high-noise environments. The auditory cells in the inner ear can be damaged due to this exposure, leading to hearing loss, particularly in the high-frequency range. Early signs may include decreased sensitivity to specific frequencies and difficulty recognizing speech. If left untreated, hearing loss can progressively worsen, impacting not only auditory function but also affecting an individual's mental health, social abilities, and overall quality of life negatively [4]. Hearing aids, auditory training, and other interventions can help individuals partially restore their hearing function and enhance their quality of life. However, an accurate diagnosis before treatment initiation is crucial for precise interventions. Clinical assessment typically involves audiometric testing, including pure tone audiometry, acoustic impedance, and speech testing, to determine the degree and type of hearing loss [5].

In this study, there was statistical significance ($P < 0.05$) when comparing the compliance rate with the clinical gold standard data. The sensitivity of the combined diagnosis surpassed the sensitivity data of the DIN test and HHIA-S alone ($P < 0.05$). This suggests that combining the DIN test and the HHIA-S enhances the diagnostic accuracy and sensitivity of occupational noise-induced hearing loss. The synergy between the two assessment tools is attributed to the advantages they bring. The DIN test offers realistic hearing level information, while the HHIA-S helps doctors understand patients' subjective hearing distress and symptoms. Combining the results of both assessments provides a more comprehensive and accurate hearing evaluation, thereby improving sensitivity and diagnostic accuracy. In conclusion, the joint assessment, by considering objective hearing levels and subjective hearing problems, yields more comprehensive and accurate results for occupational noise-induced hearing loss, guiding effective treatment and rehabilitation plans [6].

In summary, for clinical patients with occupational noise-induced hearing loss, the joint evaluation of the DIN test and HHIA-S significantly enhances their diagnostic values with high sensitivity and accuracy.

Disclosure statement

The author declares no conflict of interest.

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