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RESEARCH ARTICLE **Open Access**

DIAGNOSTIC ACCURACY OF THE ETDQ-7 IN ADULTS AT UNIVERSITY OF BENIN TEACHING HOSPITAL

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Abstract

Background: Diagnoses of Eustachian tube dysfunction in Benin City are typically made clinically or with tympanometry. The Eustachian Tube Dysfunction Questionnaire-7 (ETDQ-7) is a scoring system with potential as an alternative tool, particularly useful in resource-challenged settings. This novel tool may not have been previously investigated in this environment for its accuracy.

Objective: The study aimed to compare the diagnostic accuracy of the Eustachian Tube Dysfunction Questionnaire-7 (ETDQ-7) to tympanometry (used as the reference standard) in identifying adult patients with Eustachian tube dysfunction at the ENT clinic of the University of Benin Teaching Hospital.

Methodology: This was a hospital-based, prospective diagnostic accuracy study using a case-control design. A total of 150 study participants were recruited, including 75 case participants and 75 controls. The ETDQ-7 instrument was administered to all participants, followed by tympanometry for each. Data were analyzed using the IBM Statistical Package for the Social Sciences (IBM SPSS) version 26.

Results: The diagnostic accuracy of the ETDQ-7 in the study group was found to be 68%, while in the control group, it was 85.4%. The Area Under the Curve (AUC) for the study group was approximately 0.75, and for the control group, it was approximately 0.80.

Conclusion: The ETDQ-7 demonstrates moderate accuracy for the diagnosis of Eustachian tube dysfunction, making it a useful tool for adoption as a screening method. Its ease of administration, noninvasive nature, and reproducibility make it particularly advantageous in settings where resources are limited. However, due to its moderate specificity, it is best utilized as a preliminary screening tool rather than a definitive diagnostic method.

Keywords Eustachian tube dysfunction, ETDQ-7, tympanometry, adults, diagnostic accuracy.

INTRODUCTION

Bluestone defined Eustachian tube dysfunction (ETD) as the abnormal function of the Eustachian tube, a component of the tubotympanic system of the ear that includes the middle ear cleft and mastoid air cells, without reference to its aetiopathogenesis, which may involve structural or functional factors.1 Disruption in Eustachian tube function results in middle ear effusion and its sequelae or worsens the prognosis of pre-existing middle ear disease.

As ETD progresses, fluid collects in the middle ear cleft, causing otitis media with effusion or secretory otitis media, potentially leading to other middle ear pathologies and sequelae.1 Secretory otitis media and other middle ear diseases significantly contribute to the global burden of ear diseases, with substantial economic and social impacts.2 It is more prevalent in children under five and those with craniofacial abnormalities. Musa reported in 2014 that 8.1% of children with cleft anomalies had ETD compared to 2.5% in the control group, as well as in Aboriginal groups from Australia and the Americas.3,4 Akpalaba and Ogisi reported ETD in 57.6% of children with cerebral palsy, compared to 14.3% in the control population.5

Globally, over 80% of children under three have experienced at least one middle ear infection, and more than 40% have had three or more episodes of acute otitis media.1,2 Shan et al. estimated ETD prevalence in adults in the United States at 4.6%, compared to <1% in the UK.6,7 Somefun et al. reported a 2.6% prevalence of otitis media with effusion in a hospital-based survey of adult patients.8

In developing nations like Nigeria, all forms of otitis media, including otitis media with effusion, are significant causes of hearing loss.9 These conditions impair speech development in children and negatively impact social interaction and

earning potential in adults. Tympanostomy and similar interventions can improve speech development in children and sustain socio-economic activities in adults, as shown in Alabi et al.'s study.10

Bartolomeus Eustachio (1510–1574) discovered the Eustachian tube in 1553.11 Anatomists refer to it as the auditory or pharyngotympanic tube. Its functions include ventilation, secretion clearance, and pressure equalisation between the middle ear and the pharynx.

In 2015, Schilder et al. classified ETD into:

1. Dilatory ETD
2. Patulous ETD
3. Baro-challenged ETD12

The dilatory type was further subdivided into:

1. Functional obstruction
2. Dynamic subtype (muscular failure)
3. Anatomic obstruction

Bluestone categorised ETD based on impairments in pressure regulation, protective function, and clearance.13 Impaired pressure regulation stems from anatomical or functional obstructions, while loss of protective function involves anomalies like abnormally short or patent tubes. Clearance failures result from impaired mucociliary action or muscle activity.

These factors promote negative pressure build-up in the middle ear, particularly during infections or allergic inflammation, leading to fluid accumulation. Diagnosing ETD relies on patient-reported symptoms like ear fullness, autophony, blockage, tinnitus, otalgia, and hearing loss, often combined with physical examination findings.1,2 Risk factors include weight loss, chronic illnesses, anxiety, and allergies, as noted by Ward et al.14 Pneumatic otoscopic findings may reveal increased or decreased tympanic membrane mobility, retraction, and prominent malleolar folds.1

Assessment of Eustachian tube function includes visual inspection of the nasopharyngeal opening using indirect mirrors in adults or video endoscopy (nasopharyngoscopy). Locally, immittance tympanometry is the standard investigation, estimating middle ear pressure, volume, and eardrum compliance to infer tube function. A negative tympanogram curve suggests ETD.

Subjectivity in diagnosing ETD from history-taking can lead to variability among clinicians. The disease-specific Eustachian tube dysfunction questionnaire-7 (ETDQ-7), introduced by McCoul et al. in 2012, offers a reproducible and validated tool with 100% sensitivity and specificity.15 It assesses symptoms like aural fullness, tinnitus, and an “underwater” sensation, providing a standardised diagnostic approach.16

There is limited evidence on the ETDQ-7’s validation in large African populations. However, it has been translated and tested in several languages, mostly within Caucasian populations, yielding varied outcomes.17-21

Bartolomeo Eustachio first described the Eustachian tube in 1553. Valsalva elaborated on its anatomy in 1717.1 It originates embryologically from the tubotympanic recess of the first pharyngeal cleft and measures 36–44 mm in adults.22,23 The tube begins in the anterior tympanic recess of the petrous temporal bone (Protympanum) and follows a pyriform course, narrowing at the junction between its bony posterior third and cartilaginous anterior two-thirds (tubal isthmus). The tube opens into the nasopharynx anterior to the Fossa of Rosenmuller and remains closed at rest.23-25

The cartilaginous portion is lined by pseudostratified ciliated epithelium, interspersed

with mucus glands, resembling the respiratory tract. A wavy basement membrane underneath serves as a mucosa reservoir, particularly near the pharyngeal end. The shorter bony portion has ciliated cuboidal epithelium with fewer mucus glands and a thinner basement membrane.26

Dornhoffer et al. noted a fibrocartilaginous mass linking bone and hyaline cartilage, while Bluestone observed higher elastin content in adult cartilage, aiding recoil to resting position after swallowing or yawning.1,22 As shown in the diagram below, a 2-dimensional frontal view of the Eustachian tube lumen shows it divided into two compartments. The medial, smaller compartment, known as "Rudinger's safety canal," is usually patent and contains gas and mucus. Below this canal is a larger auxiliary gap with folds on its posteromedial wall, called micro-turbinates, which play a role in clearance.26

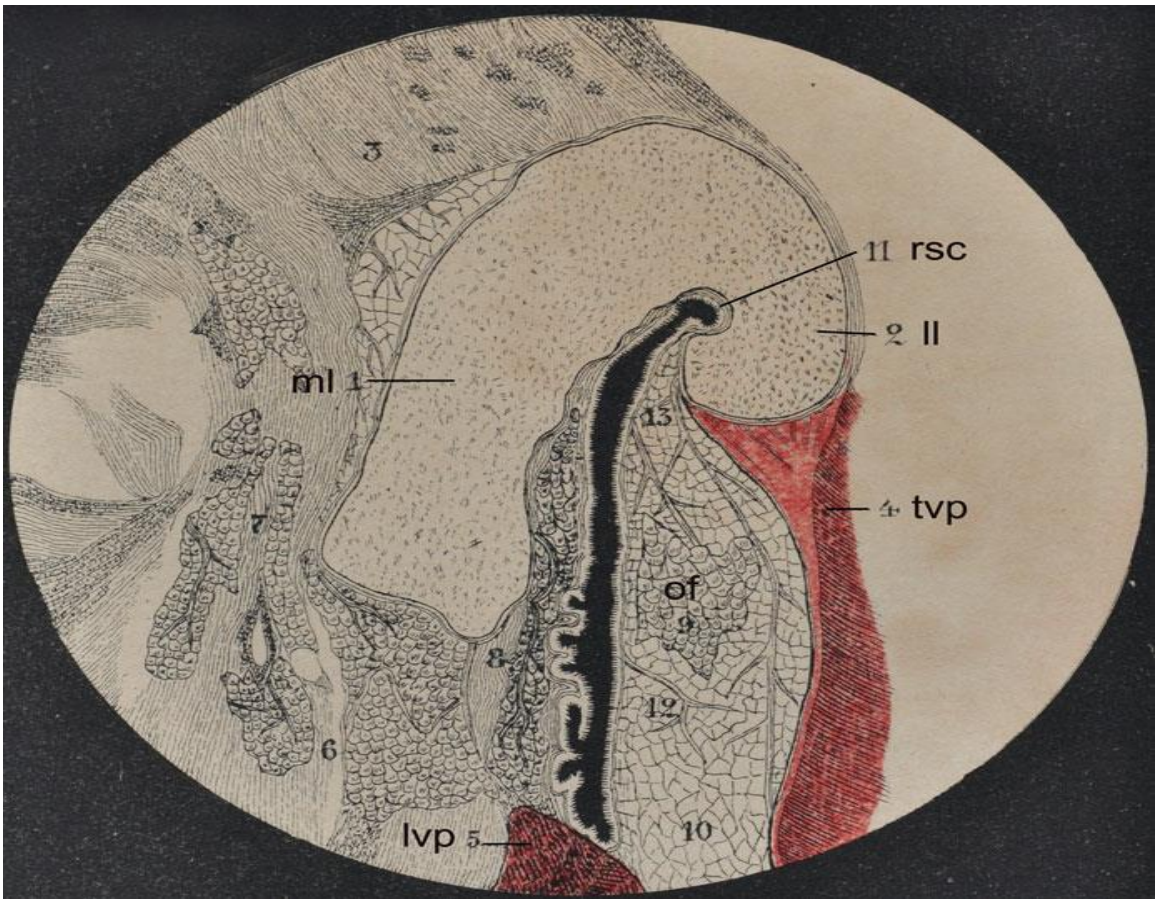

Fig. 1: Illustration of the Eustachian tube ultrastructure from Dornhoffer JL, Leuwer R, Schwager K, Wenzel S, Pahnke J. A practical guide to the eustachian tube. Berlin: Springer; 2014., showing Rüdinger's safety canal in humans. (Rsc) Rüdinger's safety canal, (ll) lateral lamina of the tubal cartilage, (ml) medial lamina of the tubal cartilage, (tvp) tensor veli palatini muscle, of (lateral) Ostmann's fat pad, (lvp) levator veli palatini muscle.

Three muscles surround the Eustachian tube:

1. Tensor veli palatini (dilator tubae)
2. Levator veli palatini (pump clearance function)
3. Salpingopharyngeus (no functional role in

ETD)26

Neuronal control involves reflex arcs responding to stimuli like pressure changes, with afferent input via the glossopharyngeal and otic ganglia and motor innervation from trigeminal and vagus nerves. Blood supply comes from the internal maxillary artery and its branches, while venous drainage occurs via the pharyngeal plexus. Lymphatics drain into retropharyngeal and deep cervical nodes.

The Eustachian tube has three primary functions:

1. Maintenance of ventilation/pressure gradient
2. Protection from nasopharyngeal sound pressure and secretions
3. Clearance of middle ear secretions

Optimal hearing requires equalised middle ear and atmospheric pressures. The Hypomocholia model describes a pivot mechanism enabling this.22 Doyle highlighted the role of mastoid air cells and mucociliary mechanisms in preventing negative pressure build-up.29

ETD arises from multiple factors, including genetic, immunologic, environmental, and social influences.2 Pathophysiological mechanisms include:

1. Anatomic obstruction: Causes include inflammation, stenosis, or mass lesions.30

2. Impaired pressure regulation: Often due to functional obstruction from neurologic or traumatic etiologies.31–35

3. Loss of protective function: Results in autophony and affects populations with Down's syndrome or after bariatric surgery.36

4. Impaired clearance: Factors include ciliary dysfunction due to smoking or inflammation.37–39

Limited research exists on ETD in African settings, especially for adults. The ETDQ-7's validation in Nigeria or Africa is sparse. Kirfi et al. reported a 1.5% ETD prevalence in a Kano prison population,40 while Somefun et al. found a 2.6% prevalence of otitis media with effusion in adults.8 Tympanometry studies are limited to tertiary institutions, restricting population-based prevalence data.41–45

Affordable diagnostic tools like ETDQ-7 could benefit resource-limited settings where tympanometry is inaccessible. This study aims to assess ETDQ-7's utility as a diagnostic tool for ETD in Nigeria.

This research aims to compare the accuracy of the ETDQ-7 with that of tympanometry in identifying Eustachian tube dysfunction in adults with an intact tympanic membrane. Specifically, it seeks to determine the sensitivity and specificity of the ETDQ-7 in the adult population presenting to UBTH, Benin City.

METHODOLOGY

STUDY POPULATION

The study population included all adult patients aged 18 years and above who presented to the ENT, Head and Neck Surgery Clinics at the University of Benin Teaching Hospital (UBTH), Benin City, during the study period, along with volunteering staff and students.

ELIGIBILITY CRITERIA

Inclusion Criteria (Study Group)

All adult patients attending the ENT Clinic at UBTH were recruited if they met the following criteria:

1. At least 18 years of age.
2. Had at least two of the following complaints in one or both ears over one month:15
   - Aural fullness.
   - Sensation of clogged or muffled hearing.
   - Features of persistent or recurrent middle

ear effusion, evidenced by tympanic membrane retraction or an air-fluid level observed one month apart.

o Symptoms exacerbated by changes in ambient pressure, such as descending stairs, driving on a slope, or diving into a swimming pool.

Inclusion Criteria (Control Group)

The control group included healthy volunteers or patients without otologic complaints or abnormal otoscopic findings. Participants could present with unrelated complaints (e.g., voice disturbances or intraoral lesions) and were matched with the study group for age and sex.

Exclusion Criteria

Participants were excluded if they met any of the following criteria:

1. Age below 18 years.
2. Active ear discharge.
3. Persistent tympanic membrane perforation, foreign bodies, or wax in the ear canal impeding tympanometry recording.
4. Lack of consent to participate in the study.
5. History of rhinosinusitis within the last month or nasal/nasopharyngeal obstructive pathology mimicking eustachian tube dysfunction.

STUDY DESIGN AND DURATION

This was a prospective diagnostic accuracy study of the ETDQ-7 in detecting eustachian tube dysfunction, using tympanometry as the reference standard. The study followed the Standards for Reporting Diagnostic Accuracy Studies (STARD) 2015 guidelines46 and spanned nine months, from December 2022 to August 2023.

SAMPLE SIZE DETERMINATION

Sample size was calculated using Cochran's formula for a diagnostic test with a binary outcome and a reference standard47-49:

$n = v^2p(1-p)/E^2$

Where n=desired sample size

Z = desired confidence level, 1.96 corresponds to 95% confidence interval.

p=anticipated sensitivity/specificity of the test, which is set to 80% as desired to be able to adequately power the study.[48]

p=1 –p

E= acceptable margin of error set at 10%

$N= (1.96)^2 \times (0.8) \times (1-0.8) / (0.1)^2$

$= (3.8416) \times (0.8) \times (0.2) / (0.01)$

= ~62 persons

Accounting for a 10% attrition rate, the final sample size was adjusted to 75 per group, for a total of 150 participants.

SAMPLING TECHNIQUE

Participants were recruited consecutively from the ENT, Head and Neck Surgery Clinic at UBTH. They were assigned to either the study or control group based on inclusion criteria.

METHOD OF DATA COLLECTION

Initial Clinical Assessment

Participants were briefed about the study and its voluntary nature. Informed written consent was obtained before recruitment. Detailed history and ENT examinations were performed to determine eligibility, including otoscopic examination for mobile tympanic membranes, tympanic membrane retraction, or fluid levels for the study group, and normal findings for the control group (see Appendix I).

Administration of ETDQ-7

Participants were assigned to study or control groups, and the ETDQ-7 questionnaire (see Appendix II) was administered to ensure consistency and minimize observer bias. The participants who did not understand English were interviewed using a pidgin English version (see Appendix III). Scores ≥14.5 indicated eustachian

tube dysfunction, while scores <14.5 did not.

Tympanometric Measurements

Tympanometry was conducted after ensuring an intact tympanic membrane and selecting an appropriate ear tip size. The test involved altering ear canal pressure from +200 daPa to -400 daPa while recording middle ear pressure, ear canal volume, and static admittance (see Appendix IV). Tympanograms with middle ear pressure < -100 daPa were diagnostic for eustachian tube dysfunction.

DATA ANALYSIS

Data were analysed using IBM-SPSS version 26. Descriptive statistics, sensitivity, specificity, predictive values, and likelihood ratios were computed. Receiver Operating Characteristics (ROC) curves were used to estimate the area under the curve (AUC). A p-value <0.05 was considered statistically significant.

ETHICAL CONSIDERATION

Ethical clearance was obtained from the UBTH Ethical Review Committee. Written informed consent was collected from all participants. Study procedures adhered to the Helsinki Declaration on ethical principles for medical research involving human subjects, as well as UBTH COVID-19 safety measures50.

RESULTS

The sociodemographic characteristics of participants are illustrated in Table I below. The mean age of study participants is 43.52 ± 14.16 years, while the control group had a mean age of 42.51 ± 16.27 years. There is no statistical difference between the two groups (P-value = 0.685). Most participants in both the study and control groups are within the age range of 38-47 years, accounting for 29.4% of each group. This is followed by those aged 38-57 years, with 20.0% in each group. Participants aged 18-27 years, 28-37 years, 58-67 years, and 68 years and above accounted for 17.3%, 13.3%, 17.3%, and 2.7% respectively in each group. No statistically significant differences were observed between the two groups (P-value = 1.000).

Table I: Sociodemographic characteristics of study participants.

Parameter		Study group (n =75)	Control group (n =75)	Statistics	P value
Age	18-27	13 (17.3)	13 (17.3)	0.000[a]	1.000
	28-37	10 (13.3)	10 (13.3)		
	38-47	22 (29.4)	22 (29.4)		
	48-57	15 (20.0)	15 (20.0)		
	58-67	13 (17.3)	13 (17.3)		
	68 and above	2 (2.7)	2 (2.7)		
	MEAN±SD	43.52 ± 14.16	42.51 ± 16.27	0.165[b]	0.685
Sex	Male	32 (42.7)	32 (42.7)	0.000[a]	1.000
	Female	43 (57.3)	43 (57.3)		

Religion	Christian	74 (98.7)	73 (97.4)	1.183[a]	1.000
	Islam	1 (1.3)	1 (1.3)		
	African traditional religion	0 (0.0)	1 (13)		
Occupation				3.263[a]	0.804
	Artisan	8 (10.7)	12 (16.0)		
	Business	27 (36.0)	21 (28.0)		
	Public servant	20 (26.7)	20 (26.7)		
	Farmer	4 (5.2)	6 (8.0)		
	Retired	3 (4.0)	5 (6.7)		
	Students	11 (14.7)	10 (13.3)		
	Unemployed	2 (2.7)	1 (1.3)		
Ethnicity				2.726[a]	0.763
	Bini	29 (39.7)	33 (44.0)		
	Esan	9 (12.0)	10 (13.3)		
	Estako	3 (4.0)	2 (2.7)		
	Urhobo	7 (9.3)	7 (9.3)		
	Igbo	12 (16.0)	6 (8.0)		
	Others	15 (20.0)	17 (22.7)		

P-value < 0.05 is significant, a= chi-square, b= Student T-test

EUSTACHIAN TUBE DYSFUNCTION QUESTIONNAIRE-7 RESULTS

The prevalence of ETD, using an ETDQ-7 score greater than 14.5, is 53.3% in the study group and 22.7% in the control group. There are significant statistical differences between the two groups (p-value < 0.001). Tympanometry findings with middle ear pressure less than -100 daPa show a prevalence of 26.7% in the study group and 10.7% in the control group. This difference is statistically significant (p-value = 0.010), as shown in Table II below.

Table II: Prevalence of Eustachian tube dysfunction using ETDQ-7 and Tympanometry

Parameter	Study group (n =75)	Control group (n =75)	Statistics	P value

EDQ-7 (Total)			**13.153[F]**	**<0.001***
7-14.4	35 (46.7)	58 (71.0)		
14.5-21.4	21 (28.0)	17 (17.0)		
21.5-28.4	16 (21.3)	6 (6.0)		
28.5 and above	3 (4.0)	6 (6.0)		
EDTQ-7			**14.969[a]**	**<0.001***
Normal	35 (46.7)	58 (77.3)		
Abnormal	40 (53.3)	17 (22.7)		
Tympanometry			**6.323[a]**	**0.010***
Normal	55 (73.3)	67 (89.3)		
Abnormal	20 (26.7)	8 (10.7)		

P-value < 0.05 is significant, a= chi-square, F= Fisher's exacts

TYMPANOMETRY RESULTS

The mean right ear canal volume was 1.37 ± 0.46 for the study group and 1.36 ± 0.38 for the control group (p-value = 0.888). The mean right middle ear pressure was -40.73 ± 60.41 for the study group and -45.33 ± 55.28 for the control group (p-value = 0.639). Right ear static admittance/maximum compliance was 0.85 ± 0.65 for the study group and 0.77 ± 0.62 for the control group (p-value = 0.468).

The mean left ear canal volume was 1.39 ± 0.41 for the study group and 1.32 ± 0.38 for the control group (p-value = 0.285). The mean left middle ear pressure was -52.68 ± 67.64 for the study group and -35.78 ± 34.98 for the control group (p-value = 0.066). Left ear static admittance/maximum compliance was 0.71 ± 0.69 for the study group and 0.79 ± 0.49 for the control group (p-value = 0.440). The tympanometry readings showed no significant differences between the findings in both groups (p-values > 0.05). These findings are represented in Table III.

Table III: Mean and standard deviations of findings of ETDQ7 and tympanometry readings

S/N	Items	Study group (n =75)	Control group (n =75)	Statistics	P value
ETDQ 7 Questions					
1	Pressure in the ears?	1.88 ± 1.41	1.49 ± 1.30	3.043[b]	0.083

2	Pain in the ears?	2.20 ± 1.73	1.63 ± 1.64	4.328[b]	0.039
3	A feeling that your ears are clogged or "under water"?	2.63 ± 1.75	1.56 ± 1.34	17.637[b]	<0.001*
4	Ear symptoms when you have a cold or sinusitis?	2.03 ± 1.46	1.44 ± 1.22	7.116[b]	0.008*
5	Crackling or popping sounds in the ears?	1.91 ± 1.47	1.35 ± 1.08	7.037[b]	0.009*
6	Ringing in the ears?	2.92 ± 1.99	2.25 ± 1.83	4.537[b]	0.008*
7	A feeling that your hearing is muffled?	2.91 ± 1.74	1.95 ± 1.75	11.363[b]	0.001*
	ETDQ7 TOTAL	16.47 ± 7.53	11.68 ± 7.99	14.330[b]	<0.001*
Tympanometry findings					
	Right ear				
	Ear canal volume	1.37 ± 0.46	1.36 ± 0.38	0.020[b]	0.888
	Middle ear pressure	-40.73 ± 60.41	-45.33 ± 55.28	0.221[b]	0.639
	Static Admittance/Maximum Compliance	0.85 ± 0.65	0.77 ± 0.62	0.530[b]	0.468
	Left ear				
	Ear canal volume	1.39 ± 0.41	1.32 ± 0.38	1.153[b]	0.285
	Middle ear pressure	-52.68 ± 67.64	-35.78 ± 34.98	3.424[b]	0.066
	Static Admittance/Maximum Compliance	0.71 ± 0.69	0.79 ± 0.49	0.600[b]	0.440

P-value < 0.05 is significant, b= Student T-test

The total questionnaire item score from the study population was 16.47 ± 7.53, compared to 11.68 ± 7.99 in the control group. Only items 1 and 2 were found to be statistically not significant.

The diagnostic accuracy of the ETDQ-7, compared to tympanometry as the standard in the study group, showed a sensitivity of 90% and a specificity of 60%. The positive predictive value was calculated to be 45.0%, while the negative predictive value was as high as 94.0%. The positive likelihood ratio was 2.2,

and the negative likelihood ratio was 0.17. These findings are represented in Tables IV and V below.

Table IV: 2 x 2 table of ETDQ 7 compared to Tympanometry as standard in study group

Parameters	Tympanometry			Total
		Detected	Not detected	
ETDQ 7	Detected	18 (24.0)	22 (29.3)	40 (53.3)
	Not detected	2 (2.7)	33 (44.0)	35 (46.7)
Total		20 (26.7)	55 (73.3)	100 (100.0)

KEY: TP (true positives) = 24.0, FN (false negatives) = 2.7, TN (true negatives) = 44.0, FP (false positives) = 29.3
Sensitivity = TP/TP+FN 24.0/ (24.0 + 2.7) = 0.90= 90%
Specificity = TN/TN+FP 44.0 / (44.0 + 29.3) = 0.60= 60%
Positive predictive value = TP/TP+FP = 24.0/ (24.0 + 29.3) = 0.45 = 45%
Negative predictive value = TN/TN+FN 44.0 / (44.0 + 2.7) = 0.94= 94%
Positive likelihood ratio = [TP/(TP+FN)]/[FP/(FP+TN)] = [24.0 / (24.0+2.7)] / [29.3 / (29.3+44.0)] = 2.2
Negative likelihood ratio = [FN/(TP+FN)]/[TN/(FP+TN)] = [2.7 / (24.0+2.7)] / [44.0 / (29.3+44.0)] = 0.17
Diagnostic accuracy = TP + TN/TP +FP + FN +TN = 24 + 44 / 24 + 2.7 +44 +29.3 = 68/100 = 68%
The ETDQ-7 when compared to tympanometry as standard in the control group had Sensitivity of 87% and Specificity of 85%. The Positive predictive value was calculated to be 41% while the Negative predictive was as high as 98%. Positive likelihood ratio of 5.9 and Negative likelihood ratio of 0.14. These findings are represented in Table VI below.

Table V: 2 x 2 Table of ETDQ 7 compared to Tympanometry as standard in control group

Parameters	Tympanometry			Total
		Detected	Not detected	
ETDQ 7	Detected	7 (9.4)	10 (13.3)	17 (22.7)
	Not detected	1 (1.3)	57 (76.0)	58 (77.3)
Total		8 (10.7)	67 (89.3)	100 (100.0)

KEY: TP true positives = 9.4, FN false negatives = 1.3, TN true negatives = 76.0, FP false positives = 13.3
Sensitivity = TP/TP+FN 9.4/ (9.4 + 1.3) = 0.87= 87%

Specificity = TN/TN+FP 76.0/ (76.0 + 13.3) = 0.85= 85%
Positive predictive value = TP/TP+FP = 9.4/ (9.4 + 13.3) = 0.41 = 41%
Negative predictive value = TN/TN+FN 76.0/ (76.0 + 1.3) = 0.98= 98%
Positive likelihood ratio = [TP/(TP+FN)]/[FP/(FP+TN)] = [9.4/(9.4+1.3)]/[13.3/(13.3+76.0)]= 5.9
Negative likelihood ratio = [FN/(TP+FN)]/[TN/(FP+TN)] = [1.3/(9.4+1.3)]/[76.0/(13.3+76.0)]= 0.14
Diagnostic accuracy = TP + TN/TP +FP + FN +TN = 9.4 + 76 / 9.4 + 1.3 +76 +13.3 = 85.4/100 = 85.4%

Receiver Operating Characteristics Curves

The Receiver Operating Characteristics Curves were generated for the control and the study group using the SPSS program from the diagnostic accuracy data, the information gleaned from the ROC curves were used to calculate the Area Under the Curve (AUC) their corresponding p-values and the confidence intervals, and are as follows:

ROC for study group

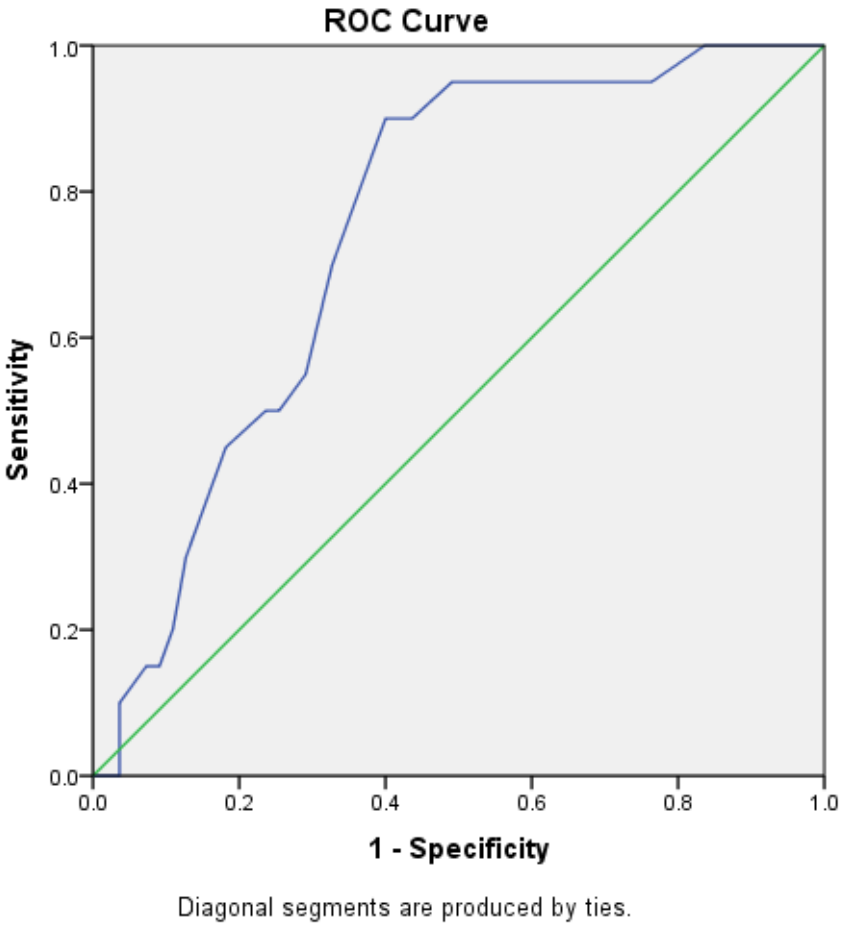

Table VI: AUC for study group

Area	Standard error	P value	Confidence interval	
			Upper	Lower
0.747	0.058	0.001	0.634	0.861

ROC for control group

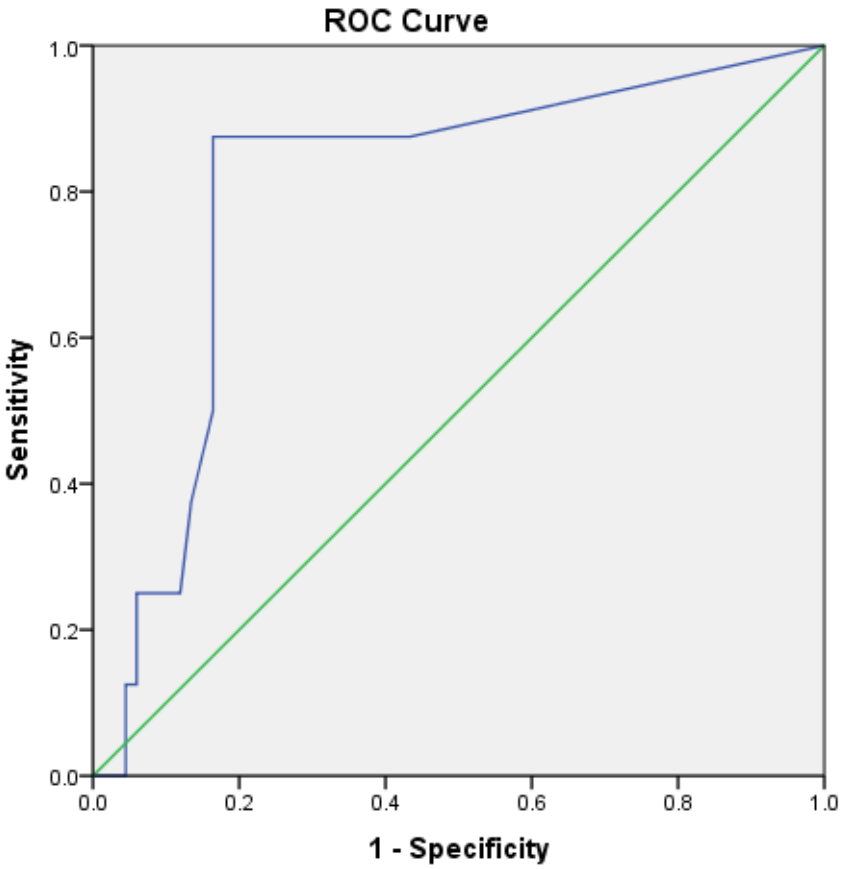

Table VII: AUC for control group

Area	Standard error	P value	Confidence interval	
			Upper	Lower
0.801	0.081	0.006	0.642	0.961

DISCUSSION

SOCIODEMOGRAPHICS

The mean age for the study group was 43.52 years ± 14.16, while the control group had a mean age of 42.51 ± 16.27. Both groups were matched appropriately with no statistically significant difference (P-value = 0.685). Nearly half (49.4%) of the participants were in the 38–57 age bracket. This finding aligns with studies conducted in other populations, including McCoul et al. (mean ages 49.8 ± 13.9 for the study group and 53.4 ± 11.2 for controls) and van Roeyen et al., who reported mean ages of 45 years and 36 years for obstructive and patulous Eustachian Tube Dysfunction (ETD), respectively. Herrera et al. also reported a mean study group age of 43 years, while Al Kholawi et al. documented a younger group with a mean age of 31 years.[51-54]

Combined, 80% of participants in the current study were aged 18–57 years, reflecting the general population, as corroborated by the 2006 Nigerian census, which reported 59.3% of the population in the 16–64 age bracket. These findings suggest that the study sample mirrors the broader demographic distribution in the region.

The prevalence of ETD based on ETDQ-7 scores greater than 14.5 was 53.3% in the study group and 22.7% in the control group, highlighting the tool's utility in detecting the condition. This result aligns with Tangbumrungtham et al., who reported 48.5% prevalence.[55] Newman et al. documented a higher prevalence of 66.7% in patients with coexisting temporomandibular joint disease (TMJD), while Wu et al. and Marino et al. reported lower prevalences of 47.6% and 43.92%, respectively, in patients with chronic rhinosinusitis and ETD symptoms.[56-58] These disparities may be due to differences in methodology, sample size, or the potential causal relationships between chronic rhinosinusitis and ETD, as well as overlapping symptoms between ETD and TMJD.

EUSTACHIAN TUBE DYSFUNCTION QUESTIONNAIRE-7

The mean total item score for the study group was 16.47 ± 7.53, compared to 11.68 ± 7.99 for the control group. McCoul et al. reported significantly higher scores of 29.3 ± 11.7 in cases and 9.1 ± 4.0 in controls. Similarly, Danish and Brazilian versions yielded scores of 30.83 ± 13.1 and 48.0 ± 11.0 for cases and 13.5 ± 9.52 and 22.0 ± 3.2 for controls, respectively.[15,16,20] Variations in scores may stem from differences in translation, patient comprehension, sample sizes, or study designs. Unlike the current study, many previous studies employed cohort or cross-sectional designs rather than dividing participants into case and control groups.

In this study, "muffled hearing" had the highest score among cases (2.91 ± 1.74), while "pressure" was the lowest (1.88 ± 1.41). Herrera et al. similarly found "muffled hearing" to be the highest-scored item (4.4 ± 2.7) and "ear pain" the lowest (2.0 ± 1.7). Menezes et al. also observed

"muffled hearing" as the highest and "pain" as the lowest. Conversely, the Danish and original studies by McCoul et al. reported "ear symptoms during colds or sinusitis" as the highest and "pain" as the lowest.[21,51,59]

Interestingly, the Saudi Arabian version of ETDQ-7 reported "muffled hearing" as the lowest-scored item, with no statistically significant difference from controls (P = 0.356), a result attributed to age differences in the study population.[53] In the current study, most p-values for mean item scores between the study and control groups were statistically significant, except for "pressure" and "pain" (P = 0.083 and 0.039, respectively). Herrera et al. similarly noted overlap between ETDQ-7 symptoms and conditions such as TMJD, Ménière's disease, and superior semicircular canal dehiscence. Teixeira et al. suggested that items like "muffled sounds" and "clogged hearing" may introduce redundancy.[51,59]

DIAGNOSTIC PERFORMANCE

In the study group, ETDQ-7 demonstrated a sensitivity of 90%, higher than the 87% achieved with tympanometry, suggesting the tool's utility in detecting ETD. However, its specificity was 60%, lower than McCoul et al.'s findings of 100% sensitivity and specificity.[15] Smith et al. reported 80.7% sensitivity and 24.6% specificity, while Herrera et al. documented 73% sensitivity and 43% specificity. Lin et al. observed near-perfect values (100% sensitivity and 99.9% specificity).[17] Differences across studies may arise from methodological variations, such as whether objective tests preceded the questionnaire. McCoul et al. noted that larger populations might yield different accuracy rates.[15]

Smith et al. recommended administering objective tests after the questionnaire to minimize selection bias, a methodology also applied in this study.[60,61] Despite ETDQ-7's moderate diagnostic accuracy, caution is necessary when interpreting results, as a low positive predictive value (PPV) of 45% in the study group indicates a high false-positive rate. Conversely, the negative predictive value (NPV) of 94% suggests strong reliability in ruling out ETD.

LIKELIHOOD RATIOS

In the study group, the positive likelihood ratio (LR+) of 2.2 implies that individuals with a positive test are 2.2 times more likely to have ETD than those with a negative test. Although not conclusive, this provides some evidence supporting positive results. The negative likelihood ratio (LR−) of 0.17 indicates that participants with a negative test are 83% less likely to have ETD, bolstering confidence in negative results.

In the control group, sensitivity was 87%, with a specificity of 80%. The NPV was 98%, reinforcing the test's utility in ruling out ETD. However, the PPV was 41%, highlighting a substantial risk of false positives. The LR+ of 5.9 and LR− of 0.14 support the test's classification ability, but the prevalence of ETD in this group (22.7%) necessitates caution. These findings align with STARD guidelines, which emphasize context-specific interpretations of diagnostic metrics.[46]

DIAGNOSTIC ACCURACY

The overall diagnostic accuracy was 68% for the study group and 85.4% for the control group, reflecting ETDQ-7's limitations in distinguishing ETD subtypes and ruling out differentials such as TMJD. The receiver operating characteristic (ROC) curve analysis showed an area under the curve (AUC) of ~0.75 (CI = 0.63–0.86) for cases and ~0.80 (CI = 0.64–0.96) for controls. This indicates moderate diagnostic accuracy, comparable to Herrera et al.'s AUC of 0.57 and Teixeira et al.'s AUC of <0.68 (CI = 0.53–0.83).55,100 In contrast, McCoul et al. reported an AUC of 1, while van Roeyen et al. and Lin et al. documented AUC values of ~0.95 and ~0.98, respectively.[17,18,52]

These results suggest that ETDQ-7 performs better in ruling out ETD than diagnosing it, especially in symptomatic populations. Smith et al. recommended using ETDQ-7 as a supplementary tool rather than a standalone diagnostic method.[61]

LIMITATIONS

Several factors may influence ETDQ-7's accuracy in local settings. These include sample size, potential machine error, symptom variability over time, and inter-operator variability. While participant comprehension appeared sufficient, administering the questionnaire in local dialects or pidgin English may yield different results. Further research is needed to explore test-retest reliability and alternative study designs. Additionally, incorporating objective tests such as tympanometry remains critical to confirm ETDQ-7 findings, as suggested by Teixeira et al. and Smith et al.[59,60]

RECOMMENDATIONS

1. The Eustachian Tube Dysfunction Questionnaire-7 (ETDQ-7) should be utilized as a primary screening tool within community settings to identify individuals who may need further evaluation at specialized reference facilities.
2. In settings with limited resources, the ETDQ-7 can be used to manage patients empirically, serving as an alternative to more costly and less accessible objective tests.
3. The ETDQ-7 can also be adapted as a cost-effective follow-up tool for patients who have undergone interventions, helping to assess the efficacy of these treatments over time.
4. Conducting a population-based study could provide valuable insights into the diagnostic yield of the ETDQ-7 when used in conjunction with objective tests, potentially enhancing its overall utility.

CONCLUSION

The study demonstrated a statistically significant improvement in the accuracy of the Eustachian Tube Dysfunction Questionnaire-7 (ETDQ-7), with its sensitivity surpassing that of tympanometry. This finding underscores the ETDQ-7's effectiveness in identifying individuals with Eustachian tube dysfunction. The questionnaire's ease of administration, non-invasive nature, and reproducibility further enhance its practicality for widespread use in various settings.

Moreover, the ETDQ-7's simplicity makes it accessible for both healthcare providers and patients, facilitating early detection and management of Eustachian tube dysfunction without the need for complex equipment or procedures. This is particularly beneficial in community and resource-limited settings where advanced diagnostic tools may not be readily available.

However, the study also revealed that the ETDQ-7 has lower specificity within the study group. This limitation indicates that while the ETDQ-7 is highly effective as a screening tool to identify potential cases of Eustachian tube dysfunction, it may not be as reliable for definitive diagnosis. Therefore, it is recommended to use the ETDQ-7 primarily for initial screening purposes, with positive cases being referred for further evaluation using more specific diagnostic methods.

CONFLICTS OF INTEREST

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SUPPLEMENTARY MATERIALS

APPENDIX I: DATA COLLECTION SHEET

SECTION I

1. Age in years: (as at last birthday) _____
2. Sex M [ ] F[ ]
3. Ethnicity: Bini [ ] Esan[ ] Etsako[ ] Igbo[ ] Yoruba[ ] Hausa[ ] Urhobo[ ]
4. Isoko [ ] Ijaw[ ] Itsekiri[ ] Others[ ]
5. Occupation: _____
6. Religion: Christianity [ ] Islam[ ] African traditional religion[ ]
7. Others _____

SECTION II

1. Do you have Ear Discharge? Yes [ ] No [ ]
2. If yes, for how long?
3. Have you had surgery of the Head and Neck done? Yes [ ] No [ ]
4. Does the participant snore while sleeping? Yes [ ] No [ ]
5. If yes, for how long?
6. How loud is it? Loud [ ] Very loud[ ] Embarrassing[ ]

7. Does the participant toss excessively in bed while asleep? Yes [ ] No [ ]
8. Does he/she sometimes stop breathing while asleep? Yes [ ] No [ ]
9. Does the participant mouth breathe during the day? Yes[ ] No [ ]
10. Does the participant have recurrent nasal discharge? Yes [ ] No [ ]
11. Does the participant have a history of Epistaxis? Yes [ ] No[ ]
12. Does the participant have a history of Nasal blockage? Yes [ ] No[ ]

APPENDIX II: ENGLISH VERSION OF ETDQ-7

Over the past 1 month, how much has each of the following been a problem for you?	No Problem			Moderate Problem		Severe Problem	
1. Pressure in the ears?	1	2	3	4	5	6	7
2. Pain in the ears?	1	2	3	4	5	6	7
3. A feeling that your ears are clogged or ‘‘under water’’?	1	2	3	4	5	6	7
4. Ear symptoms when you have a cold or sinusitis?	1	2	3	4	5	6	7
5. Crackling or popping sounds in the ears?	1	2	3	4	5	6	7
6. Ringing in the ears?	1	2	3	4	5	6	7
7. A feeling that your hearing is muffled?	1	2	3	4	5	6	7

Total ETDQ-7 Score =