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Original Article

What Is the Audiological Evaluation Time for those Aged 0-5 Years and Older?

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OBJECTIVE: The purpose of this study was to determine the time taken to perform audiological evaluation under routine clinical test conditions. We also aimed to investigate relevant variables and reasons for increases in test time.

MATERIALS and METHODS: The total test times of 300 patients were recorded and calculated using an "Audiological Evaluation Time Calculation Form." Behavioral and objective test times were determined and calculated separately. The patients were divided into groups on the basis of age, educational status, cooperation, and coordination in order to determine the effects of these factors on the test time.

RESULTS: The mean time for behavioral tests was 41.85 min for children below the age of 6 years and 36.2 min for those above that age. The times for transient evoked otoacoustic emission, distortion product otoacoustic emission, automated auditory brainstem response, and auditory brainstem response tests were 6.4/4.3 min, 4.8/6.9 min, 14.4 min, and 48.0/47.5 min, respectively, for the two age groups. The shortest total test times were obtained from the 15-29 age group, high school/university levels, and patients who cooperated. Conversely, the longest total test times were found in 6-14 age group, those with no literacy, and who hardly cooperated.

CONCLUSION: Although audiological evaluation methods have well-defined international standards, numerous factors, including patient conditions, clinician experience, and equipment, may have an adverse effect on test times. Determining the optimum patient number in one working day can help reduce workload and work stress and prevent possible errors of diagnosis/treatment. It will also help determine staff numbers needed in audiology clinics.

KEYWORDS: Audiological evaluation, hearing tests, test time

INTRODUCTION

Audiological measurements are of great important for ear, nose, and throat (ENT) clinicians because they assist in diagnosis and treatment. Incomplete or incorrect audiological results can lead to in unnecessary medical or surgical treatments, prolonged rehabilitation time, or legal liability because of misinformation.

Measurement techniques in audiology are categorized as subjective (behavioral) and objective (electrophysiological). Subjective test protocols include behavioral responses of a person to acoustic stimuli. An audiologist evaluates the voluntary/involuntary motor response of a person with acoustic stimulus (e.g., pure tone, speech, or noise). Test methods must be changed according to age. Sucking is the most definite response of infants against to acoustic stimuli. Visual reinforcement audiometry is used for 4-30 month babies, whereas play audiometry is used for those above 3 years. Children throw a toy into the basket when they hear the sound in play audiometry. "If you hear the sound, press the button" is a classic response method that is used for all people after the age of 5 years. Classic responses may change to "lift your hand or shake your head" according to personal specialities. Auditory system responses to acoustic stimuli are fundamental for the objective test methods. Immittancemetric measurement evaluates the external and middle ear region, and the otoacoustic emission test evaluates the outer hair cell function. The auditory nerve and brainstem are evaluated by an auditory brainstem response device [1].

Both techniques must be used for all patients depending to their age, and measurements must be separately performed for each ear. These are preconditions for audiological diagnosis and rehabilitation. The "*cross-check*" principle should therefore be adopted in all audiology clinics. Originally described by Jerger and Hayes [2], the cross-check principle suggests that several appropriate behavioral and electrophysiological tests should be used to determine the extent of the patient's auditory function [2].

Patient's age, cooperation, and sociocultural level can affect the test type and sequence at the audiological evaluation, and these variables are known to affect working time in clinics. As testing times increase, the number of patients seen also decreases.

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Audiology is closely associated with specialities such as ENT, pediatrics, and geriatrics. Therefore, the age range in audiology patients is quite wide. Patient numbers also increase by the long-term follow-up evaluations of patients with hearing disabilities. A negative correlation between clinical circulation and patient numbers can create difficulties in multidisciplinary team relations. Clinicians may request incomplete test procedures from audiology clinics because of time constraints. This affects the reliability of test results and may result in irreversible consequences.

The history of audiology in Turkey goes back to the 1960s [3]. Audiology is performed in almost all healthcare institutions in the form of newborn hearing screening programs and/or cochlear implantation applications. Audiological input is essential for success in all these programs. The determination of audiological evaluation test time is important to calculate the number of patients that an audiologist can assess in one day. It is also a significant factor in the determination of the number of audiologists employed in healthcare institutions.

The primary aim of this study was to determine the mean evaluation time for one patient in a university audiology clinic. Subsidiary aims included the calculation of objective and subjective test times, determination of factors that increase test times, and effects of age, sociocultural level, cooperation, and coordination on the test time.

MATERIALS and METHODS

The study comprised 300 patients examined in the Ondokuz Mayis University Medical Faculty Hospital ENT department and who were referred to the audiology unit for hearing tests between February and April of 2014. Clinical diagnosis, gender, and differences in socioeconomic levels were not taken into consideration. A written consent was taken from all the patients or from their legal guardians. The study was conducted according to the principles of the Helsinki Declaration [4], and approval was granted by the Institutional Ethics Committee (2014/ 671).

A "Time Calculation Form for Audiological Evaluation" (Table 1) to determine test times was prepared with the help of the public health department. Pre-testing preliminary validation of the form was performed with a small group.

Time Calculation

The time taken for the test was calculated with a stopwatch by three audiometric technicians under the supervision of an experienced audiologist. Information about time calculation was given to the technicians by an audiologist before the study for standardization and for avoiding personal differences before. The patient files were carefully examined by the technicians. The time counter was started once the patient was seated in a suitable position in the test room and was stopped when the results were delivered to the patient. The times between the s*tart* and *end* of tests were calculated for all the patients. The time for each test was separately determined.

Grouping

Age, educational level, cooperation, and coordination were evaluated as the factors that increase test time. The patients were divided into groups on the basis of these factors (Table 2).

Audiological Evaluation

Calibrated clinical audiometers (GSI 61, Grason-Stadler INC.; Eden Prairie, MN, USA and AC30; Interacoustics, Assens, Denmark) were used with MX41AR headphones and a B71 bone vibrator. All audiometric measurements were performed in soundproof rooms. Age-appropriate test methods were used in behavioral tests. Air and bone conduction thresholds were determined in accordance with the standard audiometric frequencies. Children under the age of 14 years were tested in the presence of a family member. Behavioral observation audiometry, visual reinforcement audiometry, play audiometry, and behavioral audiometry with standard responses were used depending on the age groups. Word recognition scores were measured with a phonetically balanced 50-word list with live voice at a comfortable volume level. Uncomfortable volume levels were defined using the ascending method, and lateralization tests were performed between 500 and 4000 Hz. Child anamnesis forms were completed with information given by the mother only.

Immittancemetric evaluations were performed using a middle ear analyzer (GSI Typstar V2, Grason-Stadler INC.; Eden Prairie, MN, USA). An 85 decibel (dB) intensity level and 226 Hertz (Hz) probe tone were used in the +200/−400 pressure range for tympanometric measurements. Acoustic reflex thresholds were determined between the 500 and 4000 Hz frequencies, both ipsilaterally and contralaterally. We waited for spontaneous sleep to occur in children. Otherwise, chloral hydrate dissolved in liquid to 0.5 mg/kg was administered under the supervision of a physician. Waiting time was added to the total test time.

Otoacoustic emissions (OAE; transient evoked OAE, TEOAE and distortion-product OAE, DPOAE) were measured using AccuScreen Pro (GN Otometrics; Taastrup, Denmark). Probe tips were selected on the basis of the size of the patient's ear canal. Click stimuli (80 dB sound pressure level and between 500 and 4000 Hz) were used for TEOAE, and 45 and 55 dB stimuli were used at 1.5,2,3 and 4 kHz for DPOAE. Automated results in the form of "PASS" or "REFER" were obtained for both tests and were read from the screen. Measurements were conducted in soundproof rooms. We waited till spontaneous sleep or a sedative was applied in the case of babies and children. Adults were instructed to relax.

Auditory brainstem responses (ABRs) were measured using an automated ABR (AccuScreen; GN Otometrics, Taastrup, Denmark) and clinical ABR (GSI Audera, Grason-Stadler INC.; Eden Prairie, MN, USA). Measurements were performed in soundproof rooms when patients were asleep, sedated, or calm. Stimulus intensity levels for automated ABRs were 45, 40 and 35 dB. Electrode placement was performed on the basis of the equipment with the active electrode below the eyes, negative electrode on the mastoid, and common electrode on the neck. Electrode impedances were automatically controlled by the system before measurement. Intensity levels in clinical ABR measurements were initiated above the behavioral thresholds. All ABR waves were repeated twice. Clinical ABR electrode placement was different to automated electrode placement; the active electrode was placed between the eyebrows, negative electrode on the mastoid of the tested ear, and earth electrode on the upper part of the forehead. Electrode impedances were below 5 kilo ohm (kΩ). The OAE and ABR tests were only applied to patients who required an objective audiological evaluation.

Table 1. Time calculation form for audiological evaluation

Start time	End Time			Patient file #	
Subject characteristics					
1. Age (years):	0-5 ( )	6-14 ( )	15-29 ( )	30-64 ( )	65-85 ( )
2. Gender:	female ( )	male ( )			
3. Diagnosis:					
4. Education level:	Illiterate ( )	primary school ( )	high school ( )	university ( )	
5. Cooperation:	good ( )	moderate ( )	poor ( )		
6. Coordination:	calm ( )	active ( )	curious ( )	on a gurney ( )	mental retardation ( )
A. Test characteristics					
Completion of child anamnesis form (min)		Start ( )	End ( )		
Factors that increased test time;					
Behavioral tests (min)		Start ( )	End ( )		
Air conduction thresholds					
Right ear..					
Left ear...					
Bone conduction thresholds					
Right ear..					
Left ear...					
Speech reception threshold					
Right ear..					
Left ear..					
Speech discrimination					
Right ear..					
Left ear...					
Uncomfortable loudness level..............................					
Weber test					
Free field test...					
Factors that increased test time:					
Immittancemetric evaluation (min/both ears)		Start ( )	End ( )		
Factors that increased test time:					
Otoacoustic emissions (min/both ears)					
Transient evoked otoacoustic emission test		Start ( )	End ( )		
Distortion product otoacoustic emission test		Start ( )	End ( )		
Factors that increased the test time:					
5- Automated auditory brainstem response (min/both ears)		Start ( )	End ( )		
Factors that increased test time:					
6- Auditory brainstem response (min/both ears)		Start ( )	End ( )		
Factors that increased test time:					
7- Reporting (min)					
Factors that increased test time:					

Table 2. Patient groups and numbers based on factors that increased test times

Groups and Numbers							
Age (years)		**Educational status**		**Cooperation**		**Coordination**	
0-5	n=80	Illiterate	n=28	Good	n=147	Calm	n=168
6-14	n=44	Primary school	n=130	Moderate	n=91	Active	n=27
15-29	n=43	High school	n=35	Poor	n=20	Curious	n=10
30-64	n=101	University	n=23	Asleep for screening test	n=42	Mental retardation	n=29
65-85	n=32	Not school age	n=84			on a gurney	n=3
						Active+curious	n=21
						Asleep for screening test	n=42

Table 3. Behavioral (subjective) test times

	Age<6 Years (Pediatric Age)		Age≥6 years	
TEST TYPE	Mean±SD (min)	Median (Min-Max)	Mean±SD (min)	Median (Min-Max)
Right AC	7.0±2.1	7.0 (3.0-12.0)	3.8±2.7	3.0 (1.0-16.0)
Left AC	6.3±2.1	6.0 (2.0-15.0)	3.7±2.5	3.0 (1.0-14.0)
Right BC	3.4±1.8	3.0 (2.0-8.0)	2.8±1.8	2.0 (1.0-12.0)
Left BC	3.8±2.9	3.0 (2.0-12.0)	2.8±1.7	2.0 (1.0-9.0)
Right SRT	3.0±1.1	3.0 (2.0-9.0)	2.4±1.1	2.0 (1.0-10.0)
Left SRT	2.7±0.9	3.0 (2.0-6.0)	2.3±1.1	2.0 (1.0-10.0)
Right SD	4.5±2.4	4.5 (2.0-7.0)	2.7±1.5	2.0 (1.0-10.0)
Left SD	4.7±2.3	6.0 (2.0-6.0)	2.6±1.4	2.0 (1.0-10.0)
UCL	2.0±0.0	2.0 (2.0-2.0)	1.6±0.6	2.0 (1.0-4.0)
WEBER test	5.5±3.5	5.5 (3.0-8.0)	1.6±0.7	1.0 (1.0-5.0)
Free field test	9.8±4.4	9.0 (2.0-20.0)	8.8±8.1	7.5 (1.0-35.0)
TOTAL TIME	41.8±25.6	36.5 (10.0-150.0)	36.2±16.1	32.5 (15.0-140.0)

AC: air conduction; BC: bone conduction; SRT: speech reception threshold; SD: speech discrimination; UCL: uncomfortable loudness level; SD: standard deviation

Table 4. Objective test times

	Age<6 Years (Pediatric Age)		Age≥6 years	
TEST TYPE	Mean±SD (min)	Median (Min-Max)	Mean±SD (min)	Median (Min-Max)
Immittancemetry	6.4±8.0	5.0 (3.0-60.0)	4.3±1.4	4.0 (2.0-10.0)
TEOAE	4.8±3.2	4.0 (3.0-25.0)	6.9±12.9	4.0 (2.0-64.0)
DPOAE	3.0±0.0	3.0 (3.0-3.0)	7.0±2.6	6.0 (4.0-11.0)
A-ABR	14.4±7.6	12.0 (4.0-35.0)	not applied	
ABR	48.0±12.5	55.0 (30.0-60.0)	47.5±8.5	47.5 (35.0-65.0)

TEOAE: transient evoked otoacoustic emission; DPOAE: distortion-product otoacoustic emission; A-ABR: automized auditory evoked responses; ABR: auditory evoked responses; SD: standard deviation

Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) version 21 (SPSS Inc.; Chicago, IL, USA). All data were expressed as mean±standard deviation and median (minimum-maximum). Total test time measurement was not normally distributed; the Kruskal-Wallis test was conducted to compare this parameter. The Mann-Whitney U test was performed to test the significance of pairwise differences using Bonferroni correction to adjust for multiple corrections. An overall 5% type-I error level was used to infer statistical significance.

RESULTS

Total audiological test times for 300 patients were determined in this study. All patients underwent ENT examination and received a preliminary diagnosis before the audiological evaluation. Hearing loss was the most common preliminary diagnosis (154/300).

The behavioral and objective test times were separately calculated. Children below the age of 6 years were considered as the child group because test protocols are different above and below that age. The results are shown in Tables 3 and 4.

Increased subjective test times were attributed to failure to understand the instructions (33/101), masking difficulties (31/101), and lack of cooperation from the patients (21/101).

The most significant causes of increased test times were probe cleaning (80.3%) for immittancemetric evaluation, probe cleaning and changing (40.9%) for OAE tests, and electrode placement and impedance problems (88.2%) for ABR testing.

The time for completion of the child anamnesis form was 9.4±1.8 min. The time taken to explain the test results to the patients was also evaluated. The mean time was found to be 5.63±2.40 min. The greatest amount of time was required for providing information to patients/parents about hearing loss and hearing aids.

Age and Test Time

The patients were divided into 5 age groups to evaluate the effect of age on the total test time. The results are shown in Table 5.

Statistically significant differences were determined between the 6-14 and 15-29/30-59 year age groups (p=0.00). With the exception of the 0-5 and 60-85 year age groups, the 6-14 year age group differed significantly from all the other groups. There was no significant difference between the youngest and oldest age groups.

Education Level and Test Time

Education levels among the patients and their relationship with total test durations were evaluated in all the age groups except the 0-5 year group. The test times are shown in Table 6.

Statistically significant differences were determined between the four education groups (p=0.00). The illiterate group test time was significantly longer than those of the other groups (p=0.002). Additionally, the elementary group was significantly different from the university group (p=0.000). The total test times shortened as the educational level increased.

Cooperation and Test Time

The relationship between the cooperation of the patient and total test time was also evaluated (Table 7). Differences in total test times were significant in all groups (p=0.00). The shortest total test time was observed in the patients with good cooperation.

Coordination and Test Time

The relationship between the patient's coordination and total test time was also evaluated. No comparison was performed between groups because of insufficient patient numbers. The shortest total test time was observed among calm patients. Mental retardation and physical limitations were observed to increase total test time (Table 8).

Table 5. Total test times in the various age groups

Age (year)	Number	Mean±SD (min)	Median (Min-Max)
(0-5)	80	41.7±25.6	36.5 (10.0-150.0)
(6-14)	44	44.9±22.5	40.5 (20.0-140.0)
(15-29)	43	30.1±11.1	26.0 (17.0-70.0)
(30-64)	101	33.7±11.6	33.0 (15.0-75.0)
(65-85)	32	39.5±17.9	35.5 (15.0-75.0)

SD: standard deviation

Table 6. Total test times according to educational status

Educational Status	Number	Mean±SD (min)	Median (Min-Max)
Illiterate	28	45.3±14.3	43.5 (25.0-70.0)
Elementary school	130	36.1±13.7	35.0(15.0-75.0)
High school	35	31.8±12.5	30.0(15.0-70.0)
University	23	24.4±5.0	23.0(20.0-37.0)

SD: standard deviation

Table 7. Total test times on the basis of cooperation

Test Cooperation	Number	Mean±SD (min)	Median (Min-Max)
Good	147	30.4±11.6	27.0 (15.0-87.0)
Moderate	91	45.8±20.1	42.0 (20.0-150.0)
Poor	20	59.6±28.4	51.0 (30.0-140.0)
Not recorded*	42		

*babies undergoing newborn hearing screening tests were not recorded (SD: standard deviation)

Table 8. Total test time on the basis of coordination

Coordination	Number	Mean±SD (min)	Median(Min-Max)
Calm	168	30.9±10.8	30.0(15.0-75.0)
Active	27	47.8±16.0	45.0(23.0-90.0)
Curious	10	44.6±18.7	42.5(23.0-87.0)
On a gurney	3	63.3±11.5	70.0(50.0-70.0)
Mental retardation	29	53.8±22.5	55.0(25.0-140.0)
Active+curious	21	55.1±34.8	41.0(20.0-150.0)
Not recorded*	42		

*babies undergoing newborn hearing screening tests were not recorded (SD: standard deviation)

DISCUSSION

Audiology is the science concerned with hearing, and *audiologists* are the primary healthcare professionals involved in the identification, prevention, and evaluation of auditory disorders [5]. Audiology is a combination of science and art. It has a scientific basis and starts with the physics of sound and anatomy as well as electrophysiology. It is supported by the artistic aspect of audiology. This requires the ability to work well with people and to make skillful use of professional procedures. Knowledge alone is not enough to make a skilled audiologist [6].

Hearing starts in the 29th gestational week, and maturation continues after birth [7]. The audiology patient age range thus includes all age groups. Even though test protocols and courses differ according to age, the aim of the tests is always the same: the acquisition of reliable data about a patient's hearing using objective and subjective tests [8, 9].

Subjective audiological evaluation consists of pure tone audiometry and speech tests and relies on the responses given by the patient. Test times may vary among patients, although different test protocols have been established for different age groups. The first step when evaluating the pediatric population is to establish the child's history [2]. Prior information about a child's hearing problem can reduce test time and also increase the reliability of the results. Both ears need to be separately examined in subjective tests to determine the degree and type of hearing loss. In the current study, the total mean subjective test time for the patients aged 0-5 years was 41.8±25.6 min; for other patients, it was 36.2±16.1 min; the time for the completion of the child anamnesis form (9.4±1.8 min) must also be added to the total time.

The most significant cause of increased test time was identified as misunderstanding the instructions, followed by masking. Transmission of the test stimulus across the skull to the non-test ear is referred to as cross-over. The solution to the problem of cross-over of the auditory stimulus is to ensure that the response comes from the ear being tested by eliminating the possibility of response from the non-test ear [10]. This is accomplished by presenting a masking noise to the non-test ear at a level of intensity sufficient to eliminate the effect. Known as masking, this can be used for threshold determination in both air and bone conduction tests at the necessary frequencies. Instructions and procedures for masking may be protracted in some patients, and extra time may therefore be needed for subjective tests. The masking procedure may be prolonged in patients with tinnitus or bilateral conductive/asymmetric hearing loss.

The results from objective tests depend on the responses of the auditory system to acoustic stimulation, but no objective test methods can be used as a hearing test alone because all objective tests have mechanical and physiological limitations. It is essential for patients to be calm and immobile in all objective tests. Sedation is therefore sometimes used for child or adult patients. The test environment must also be silent throughout the test. The mean immittancemetric evaluation test time was 6.4±8.0 min for the 0-5 age group and 4.3±1.4 min for the other groups in this study. The TEOAE and DPOAE test times were 4.8±3.2/6.9±12.9 and 3.0±0.0/7.0±2.6 min, respectively, for the 0-5 age group and the other groups. Probe placement and probe cleaning were determined as the most significant reasons for prolonged test times in both the test methods. The mean test times for clinical ABR were 48.0±12.5 and 47.5±8.5 min for the 0-5 age group and the other groups, respectively. ABR is computer extracted from ongoing bioelectric activity recorded from the surface of the scalp and related sites following the presentation of acoustic stimuli [11]. Electrode placement and patient silence have a significant effect on the suitability of recordings. In the current study, the most significant cause of increased test time in the ABR test was electrode placement.

Various steps, such as writing reports or explaining hearing status to patients/parents, need to be taken to complete the audiological evaluation. In particular, families of a child with hearing loss must be informed about the adverse effects of such a loss and about hearing aids and rehabilitation programs [12, 13]. Rehabilitation of hearing loss in children must be immediately applied to prevent negative effects on the patient, the family, and their community. The mean time for explaining test results to patients/families and writing reports in this study was 5.6 min.

The patient group in this study was evaluated in a university audiology clinic; therefore, the results must be considered in this perspective. In conclusion, the total test time for a pediatric audiological evaluation was found to be approximately 1 h. This included the audiological test battery (subjective and objective tests), taking the history, explaining the results to the parents, and providing other information. The equivalent time for adults was approximately 45 min. Therefore, an audiologist can evaluate 8-10 adults or 6-8 children in one working day. Our scan of literature revealed no prior information about audiological evaluation times. This study can be considered to offer a different and valuable perspective to audiologists and to other disciplines associated with audiology.

Ethics Committee Approval: Ethics committee approval was received for this study from Ondokuz Mayıs University Clinical Research Ethical Committe (2014/671).

Informed Consent: A written consent was taken from all the patients or from their legal guardians.

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