



## **Summary: Hearing Screening**

### **Luxembourg**

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## 1. Glossary of Terms: Hearing Screening

<b>Abnormal test result</b>	A test result where a normal “pass” response could not be detected under good conditions. The result on screening equipment may indicate “no response,” “fail,” or “refer.”
<b>Attendance rate</b>	<p>The proportion of all those <u>invited for screening</u> that are <u>tested and receive a result</u>,</p> <ul style="list-style-type: none"> <li>• <u>Invited for screening</u> includes all those that are offered the screening test.</li> <li>• <u>Tested and receive a result</u> could be a “pass” or “fail”.</li> </ul> <p>Attendance rate provides information on the willingness of families to participate in screening.</p>
<b>Attendance rate in first year of life</b>	<p>See definition of <b>Attendance rate</b>.</p> <p>The calculation cut-off is after <u>one year of life</u>.</p>
<b>Compliance with referral (percentage)</b>	<p>The percentage of those who are <u>referred from screening</u> to a diagnostic assessment that actually <u>attend</u> the first diagnostic assessment.</p> <p>Percentage of compliance provides information on the willingness of families to attend the diagnostic assessment after referral from screening.</p>
<b>Coverage</b>	<p>The proportion of those <u>eligible for screening</u> that are <u>tested and receive a result</u> within a <u>specific time</u>.</p> <ul style="list-style-type: none"> <li>• <u>Eligible for screening</u> includes those within the population that are covered under the screening or health care program.</li> <li>• <u>Tested and receive a result</u> could be a “pass” or “refer to diagnostic assessment”.</li> <li>• <u>Specific time</u> can be defined, such as 1 month after birth, 3 months after birth, etc.</li> </ul> <p>Coverage provides information on the overall effectiveness and timeliness of a complete screening programme.</p> <p>Factors such as being offered screening, willingness to participate, missed screening, ability to complete the screen, and ability to document the screening results will influence the coverage.</p>
<b>Coverage in first year of life</b>	<p>See definition of <b>Coverage</b>.</p> <p>The <u>specific time</u> is pre-defined as within the first year of life.</p> <p>In other words, the coverage is the proportion of those eligible for screening that complete the screening sequence to a final result within the first year of life.</p>
<b>False negatives</b>	The percentage of <u>infants/children with a hearing loss</u> (defined by the target condition) that <u>receive a result of “pass”</u> during screening.



	Example: If 100 infants with hearing loss are screened, and 1 infant passes the screening, the percentage of false negatives is 1%.
<b>False positives</b>	<p>The percentage of <u>infants/children with normal hearing</u> that <u>receive a result of “fail”</u> from the final screening test.</p> <p>Example: If 100 infants with normal hearing are screened, and 3 infants fail the screening and are referred for diagnostic assessment, the percentage of false positives is 3%.</p>
<b>Guidelines</b>	Recommendations or instructions provided by an authoritative body on the practice of screening in the country or region.
<b>Hearing screening professional</b>	A person qualified to perform hearing screening, according to the practice in your country or region.
<b>Inconclusive test result</b>	A test result where a normal “pass” response could not be detected due to poor test conditions.
<b>Invited for screening</b>	Offered screening.
<b>Outcome of hearing screening</b>	An indication of the effectiveness or performance of screening, such as a measurement of coverage rate, referral rate, number of infants detected, etc.
<b>Permanent hearing loss</b>	<p>A hearing impairment that is <i>not</i> due to a temporary or transient condition such as middle ear fluid.</p> <p>Permanent hearing loss can be either sensorineural or permanent conductive.</p>
<b>Positive predictive value</b>	<p>The percentage of infants/children referred from screening who have a confirmed <u>hearing loss</u>, as described by your protocol or guideline and indicated in the <b>Target Condition</b> (see definition).</p> <p>For example, if 100 babies are referred from screening for diagnostic assessment and 90 have normal hearing while 10 have a confirmed hearing loss, the positive predictive value would be 10%.</p>
<b>Preschool or (pre)school children</b>	All children between 3-6 years of age.
<b>Preschool or (pre)school screening</b>	<p>Screening that takes place during the time children are between 3-6 years of age.</p> <p>This refers to <i>any</i> hearing screening during this age. The location of the screening is irrelevant to the definition.</p>



<b>Prevalence</b>	The number or percentage of individuals with a specific disease or condition. Prevalence can either be expressed as a percentage, proportion, or as the value per 1000 individuals within the same demographic.
<b>Programme</b>	An organized system for screening, which could be based nationally, regionally or locally.
<b>Protocol</b>	Documented procedure or sequence for screening, which could include which tests are performed, when tests are performed, procedures for passing and referring, and so forth.
<b>Quality assurance</b>	A method for checking and ensuring that screening is functioning adequately and meeting set goals and benchmarks.
<b>Referral criteria</b>	A pre-determined cut-off boundary for when an infant/child should be re-tested or seen for a diagnostic assessment.  For example, referral criteria may be “no response” at 35 dB nHL.
<b>Risk babies / Babies at-risk</b>	All infants that are considered to be at-risk or have risk-factors for hearing loss according to the screening programme.  Two common risk factors are admission to the neonatal-intensive care unit (NICU) or born prematurely. However, other risk factors for hearing loss may also be indicated in the screening programme.
<b>Sensitivity</b>	The percentage of infants/children with hearing loss that are identified via the screening program.  For example, if 100 babies with hearing loss are tested, and 98 of these babies are referred for diagnostic assessment while 2 pass the screening, the sensitivity is 98%.
<b>Specificity</b>	The percentage of infants/children with normal hearing that pass the screening.  For example, if 100 babies with normal hearing are tested, and 10 of these babies are referred for diagnostic assessment and 90 pass the screening, the specificity is 90%.
<b>Target condition</b>	The hearing loss condition you are aiming to detect via your screening programme. This includes: <ul style="list-style-type: none"> <li>• The <u>laterality of the condition</u>, whether the program aims to detect both unilateral and bilateral hearing loss or just bilateral hearing loss.</li> <li>• The <u>severity of the condition</u>, whether the program aims to detect hearing loss <math>\geq 30</math> dB HL, <math>\geq 35</math> dB HL, <math>\geq 40</math> dB HL or <math>\geq 45</math> dB HL</li> </ul>
<b>Well, healthy babies</b>	Infants who are <i>not</i> admitted into the NICU or born prematurely.  Well, healthy babies may or may not have additional risk factors for hearing loss, according to the procedures indicated in the specific screening programme.



## **2. Abbreviations**

ABR – auditory brainstem response

aABR – automatic auditory brainstem response

ANSD – auditory neuropathy spectrum disorder

ASSR – auditory steady-state response

CI – cochlear implant

CMV – cytomegalovirus

dB HL – decibel hearing level

dB nHL – decibel normalized hearing level

dB SNR – decibel signal-to-noise ratio

DPOAE – distortion product otoacoustic emissions

HA – hearing aid

NICU – neonatal intensive care unit

OAE – otoacoustic emissions

TEOAE – transient-evoked otoacoustic emissions



### 3. Background

In Luxembourg, hearing screening is performed nationally and organized nationally. The following report contains information with regards to childhood hearing screening in the entire country of Luxembourg.

#### 3.1. General

Luxembourg has a total area of 2586 km<sup>2</sup> with a population of 590 700 in 2017 (STATEC, 2018).

In Luxembourg, all births are registered to the Ministry of Health. The number of live births in Luxembourg in 2017 was 7128 (Ministry of Health, 2018).

The World Bank income classification categorizes Luxembourg as a high-income country (The World Bank, 2018). The gross domestic product (GDP) in 2017 was €92 600 per capita in Luxembourg (STATEC, 2018).

From the World Health Organization (WHO) Global Health Expenditure Database, health expenditure for Luxembourg in 2015 was 6236 USD or €5470 per capita (World Health Organization (WHO), 2018).

An infant mortality rate of 4.13 per 1000 is reported for Luxembourg in 2016 (Ministry of Health, 2018). The United Nations Statistics Division does not report a mortality rate given the low number of infants born in Luxembourg each year; 17 infant deaths were reported in 2015 (United Nations Statistics Division, 2016).

#### 3.2. Neonatal hearing screening

In Luxembourg, neonatal hearing screening is conducted universally, with all babies in the country having access to hearing screening, though participation is not obligatory for parents. Hearing screening using behavioural measures started and was fully implemented in 1970 and moved from birth to 6-months of age around 1983. In 2000, screening using objective measures (TEOAE) was introduced and screening was moved to the neonatal period (2-3 days of age). Finally, screening using aABR was introduced in 2012 for at-risk babies.

Neonatal hearing screening is funded through the state, though it is not embedded in the Preventive Child Health Care screening system. Neonatal hearing screening is organized by the Ministry of Health and performed by the Service Audiophonologique.

National guidelines are available as is a screening protocol used across the country. Across Luxembourg, the same protocol is followed for performing hearing screening.

#### 3.3. Preschool hearing screening

Preschool hearing screening is conducted universally in Luxembourg. It is not embedded in the Preventive Child Health Care screening system though is funded by the state. Preschool hearing screening started and was fully implemented in 1974. It is organized by the Ministry of Health and performed by the Service Audiophonologique.



## **4. Guidelines & Quality Control**

There are national guidelines for hearing screening in Luxembourg.

The content of the general hearing screening programme was decided on by the Ministry of Health, and there have been some changes since its initiation. The most recent change was the implementation of aABR for at-risk babies in 2012.

Quality assurance of hearing screening programmes is not imposed by the government; however, information is collected directly by the government service doing the screening (neonatal and preschool). In Luxembourg, all neonatal hearing screening is performed by the Service Audiophonologique, and data are collected in their internal database. Annual reports are available, produced by the Ministry of Health (e.g., Ministry of Health, 2018); however, data are not separated for well and at-risk infants.

There have not been any studies on hearing screening programmes in Luxembourg, nor has there been research performed on the effectiveness of screening in Luxembourg.

## 5. Process: Screening, Diagnosis, Intervention

### 5.1. Neonatal hearing screening

Well babies and at-risk babies are screened in the hospital or NICU. The percentage of infants born in a maternity hospital in Luxembourg is 98%, but the average length of stay in the hospital after delivery is unknown. Parents/caregivers of well and at-risk babies are invited to participate in neonatal hearing screening directly in the maternity hospital or via a letter if missed in the hospital.

Neonatal hearing screening for well babies should be completed before 4 weeks of age if not completed in the maternity hospital, or before 3 months of age if born outside the maternity hospitals. For at-risk babies, screening should be completed before discharge from the hospital or by 3 months of age.

At-risk infants are defined as those with low birth weight, prematurity, family history of hearing loss, gestational infections such as CMV, toxoplasmosis, or measles, history of drug abuse, low APGAR score, craniofacial anomalies, admission to the NICU for more than 5 days, anoxia, meningitis, or the use of ototoxic medications. These infants are screened with a different protocol due to the increased risk of retrocochlear hearing loss.

Data on the prevalence of CMV or meningitis is not available in Luxembourg.

The target condition for screening for well babies is hearing loss of 35 dB HL or worse and for at-risk babies is a hearing loss of 40 dB HL or worse. The target condition is defined based on the device used for screening.

### 5.2. Neonatal diagnostic assessment

The diagnostic assessment after neonatal hearing screening referral should be completed by 6 months of age for well infants, and 4-6 months of age for at-risk infants.

### 5.3. Preschool hearing screening

Preschool hearing screening is performed in the kindergarten schools, and children are invited to participate directly by the Ministry of Health in the kindergartens. Testing is performed by a speech-language pathologist.

The target condition for preschool hearing screening is a hearing loss of 20 dB HL or worse.

### 5.4. Intervention approach

In Luxembourg, treatment options available include grommets, hearing aids, bone conductive devices, and cochlear implants. Infants are fitted with hearing aids and cochlear implants from less than 6 months of age or older.

The fitting criteria in Luxembourg for a hearing aid is hearing loss of at least 30 dB HL in two or more frequencies from 500 to 3000 Hz, or a 10 dB HL or 10% reduction in speech audiometry with the addition of noise.

## 6. Protocols

Hearing screening protocols are described for neonatal hearing screening (well and at-risk) as well as for preschool hearing screening when applicable.

- The Test performed is the screening technique used
- The Age of the child is indicated in hours, days, months or years
- Referral criteria may be the lack of an OAE response at specified frequencies, a response-waveform repeatability constant, the absence of an aABR response at a specified intensity, or an absent behavioural response at a specified intensity. Referral criteria may be defined within a protocol or limited based on the device used.
- The Device is the screening device used.
- Unilateral Referrals indicates whether children are referred if only one ear fails screening.
- The Location is where the screening takes place

### 6.1. Neonatal hearing screening (well)

The process for neonatal hearing screening for well babies is described in Table 1. A 2-step OAE protocol is in effect, whereby the first OAE is performed in the maternity hospital on the 2<sup>nd</sup> day of life. If the infant fails the first step, rescreening occurs either before discharge on day 3 or at 1 month of age if the infant is discharged from the hospital before day 3. Infants that miss screening in the maternity hospital are also referred directly to step 2 screening. A subsequent fail at step 2 screening would warrant a referral to the ENT department for a diagnostic assessment.

**Table 1:** Process for neonatal hearing screening for well, healthy infants in Luxembourg.

Test	Age	Referral criteria	Device	Unilateral Referrals?	Location
OAE1*	24-72 hours		Madsen	Yes	Maternity hospital
OAE2	3 days / 1 month		Accuscreen	Yes	Maternity hospital

\* Although OAE1 is performed in the maternity ward, all infants that *miss* screening in the maternity ward are automatically referred to step 2 (OAE2) of the screening protocol. Therefore, these infants that miss OAE1 are only screened once before a referral to a diagnostic assessment.

### 6.2. Neonatal hearing screening (at-risk)

The screening process for at-risk infants is described in Table 2. A two-step process is in effect where aABR is performed during both initial screening and rescreening. Similar to well babies, infants that miss screening in the hospital are referred directly to aABR2 for screening.

**Table 2:** Process for neonatal hearing screening for at-risk infants in Luxembourg.

Test	Age	Referral criteria	Unilateral Referrals?	Location
aABR1*	24-72 hours	35 dB nHL	Yes	Maternity hospital / NICU
aABR2	Before discharge / 1 month	35 dB nHL	Yes	Maternity hospital / NICU

\* Although aABR1 is performed in the maternity ward/NICU, all infants that *miss* initial screening are automatically referred to step 2 (aABR2) of the screening protocol. Therefore, these infants that miss aABR1 are only screened once before a referral to a diagnostic assessment



### 6.3. Preschool hearing screening

Hearing screening is performed in kindergartens at 5-6 years of age. Pure-tone audiometry with headphones is performed at 20 dB HL in the kindergartens. If thresholds are greater than 20 dB HL, a retest is performed. If thresholds are still greater than 20 dB HL, a referral is made to the ENT clinic.

**Table 3:** Process for preschool hearing screening in Luxembourg.

<b>Test</b>	<b>Age</b>	<b>Referral criteria</b>	<b>Location</b>
Pure-tone audiometry1	5-6 years	Threshold >20 dB HL	Kindergarten
Pure-tone audiometry2	5-6 years	Threshold >20 dB HL	Kindergarten



## **7. Professionals**

### **7.1. Neonatal hearing screening (well)**

Neonatal hearing screening is performed by speech-language pathologists and audiologists.

There is no specific training for hearing screening staff.

### **7.2. Neonatal hearing screening (at-risk)**

Screening for at-risk infants is also performed by speech-language pathologists and audiologists.

### **7.3. Preschool hearing screening**

Screening for preschool-age children is performed by speech-language pathologists.

## 8. Results: Neonatal Hearing Screening

### 8.1. Coverage and attendance rates

In Luxembourg, all neonatal hearing screening is performed by the Service Audiophonologique and outcome data of the screening programme presented here are derived from their internal database for the year 2017 (Ministry of Health, 2018).

In 2017, 100% of well babies born in Luxembourg were offered hearing screening, and 98.2% completed the screening process. In total, 81% are screened in the maternity hospital and the other 19% are called in for screening in the clinic along with the referrals from the initial screen performed in the maternity hospital (Service Audiophonologique, 2018). Attendance rates for step 1 and step 2 for well infants are described in Table 4. If including only those that were referred from step 1, the attendance rate was 91.6%. In other words, 8.4% of referrals to step 2 were lost to follow-up, which is 0.67% of all babies screened. Infants that are lost to follow-up are invited to an ENT assessment (Service Audiophonologique, 2018).

**Table 4:** Attendance rates for neonatal hearing screening (well babies) in Luxembourg (Service Audiophonologique, 2018).

Test	Attendance Rate (steps 1 and 2)	Attendance Rate (directly to step 2)	Attendance Rate (total)
OAE1	81%*	→ 19% directly referred to OAE2	
OAE2	91.6%	93.1%	92.7%

Attendance rate is the percentage of infants out of the total number offered screening at each step that attend.

\*Remaining 19% are referred to OAE2.

Attendance rates for at-risk babies is displayed in Table 5. In 2017, 100% of at-risk babies were offered hearing screening, and 89.9% were tested in the hospital / NICU. Again, infants not tested in the hospital/NICU are invited to be screened in the Service Audiophonologique office.

**Table 5:** Attendance rates for neonatal hearing screening (at-risk babies) in Luxembourg (Service Audiophonologique, 2018).

Test	Attendance Rate (steps 1 and 2)	Attendance Rate (directly to step 2)	Attendance Rate (total)
aABR1	89.9%*	→ 10.1% directly referred to aABR2	
aABR2	98.2%	83.1%	89.7%

Attendance rate is the percentage of infants out of the total number offered screening at each step that attend.

\*Remaining 10.1% are referred to OAE2.

### 8.2. Referral rates

The pass rates for neonatal hearing screening of well, healthy infants are presented below in Table 6. Referral data are collected by the Service Audiophonologique.

**Table 6:** Stepwise referral rates for neonatal hearing screening (well babies) in Luxembourg (Service Audiophonologique, 2018).

Test	Referral Rate
OAE1	7.9% total

	9.9% [day 2] to 5.5% [day 3]
OAE2	5.7%*

Referral rates assume a 100% attendance rate at each step. \*OAE2 includes infants referred from OAE1 and infants that missed OAE1. In total 19% of well infants born in 2017 missed OAE1 and were invited to OAE2 screening.

In total, the final referral rate to a diagnostic assessment for well, healthy babies were 3.1%.

Referral rates for neonatal hearing screening of at-risk infants are presented in Table 7.

**Table 7:** Stepwise referral rates for neonatal hearing screening (at-risk babies) in Luxembourg (Service Audiophonologique, 2018).

Test	Referral Rate
aABR1	8.7%
aABR2	40%

For at-risk infants, the final referral rate for at-risk infants after the 2-step aABR protocol was 6.17% (Service Audiophonologique, 2018).

### 8.3. Diagnostic assessment attendance

Out of the well infants referred from neonatal hearing screening, 71% completed a diagnostic assessment, and out of the at-risk infants referred from neonatal hearing screening, 64.3% completed a diagnostic assessment (Service Audiophonologique, 2018). There has been no feedback from the remaining referred infants; however, it is possible that an ENT assessment was completed and Service Audiophonologique was not provided this information from the ENT clinic.

### 8.4. Prevalence / Diagnosis

Data are unavailable regarding the prevalence of neonatal hearing loss in Luxembourg. Data are unavailable regarding the prevalence of auditory neuropathy in Luxembourg.

### 8.5. Treatment success

In Luxembourg, it is unknown how many children per year are fitted with hearing aids or cochlear implants.

### 8.6. Screening evaluation

Actual data on the sensitivity or specificity of neonatal hearing screening are not available, and neither are data on false positives, false negatives, or the positive predictive value.

However, estimations were provided. A positive predictive value of a refer result was estimated at 4% for well infants. For well infants, sensitivity was estimated to be 100% and specificity was estimated to be 97%. For at-risk infants, sensitivity was estimated to be 100% and specificity was estimated to be 94% (Service Audiophonologique, 2018).

## 9. Results: Preschool Hearing Screening

### 9.1. Coverage and attendance rates

In Luxembourg, all preschool hearing screening is performed by the Service Audiophonologique and outcome data of the screening programme presented here are derived from their internal database for the year 2017 (Service Audiophonologique, 2018). The report published the Ministry of Health shows data combining 2016 data with partial data from 2017.

Attendance rates for at-risk babies is displayed in Table 8. In 2017, 99% of preschool age children in Luxembourg were offered hearing screening, and 99.4% completed the two-step screening process (Service Audiophonologique, 2018).

**Table 8:** Attendance rates for pre-school hearing screening in Luxembourg (Service Audiophonologique, 2018).

Test	Attendance Rate (steps 1 and 2)
Pure-tone audiometry 1	95.6%*
Pure-tone audiometry 2	86.8%

### 9.2. Referral rates

**Table 9:** Stepwise referral rates for neonatal hearing screening (at-risk babies) in Luxembourg (Service Audiophonologique, 2018).

Test	Referral Rate
Pure-tone audiometry 1	10.1%
Pure-tone audiometry 2	32.2%

The final referral rate to a diagnostic assessment for preschool age children was 7.6% (Service Audiophonologique, 2018).

### 9.3. Diagnostic assessment attendance

In total, 57.9% of children that were referred from preschool hearing screening completed a diagnostic assessment (Service Audiophonologique, 2018). No feedback was received from the remaining children. Similar to neonatal hearing screening, it is possible that an ENT assessment was completed and Service Audiophonologique was not provided this information from the ENT clinic.

### 9.4. Screening evaluation

The positive predictive value of a refer result was estimated (via calculation) to be 66.3%. That is, out of the infants who were referred and completed an ENT assessment, 33.6% had normal hearing and treatment was recommended for 66.3% (Service Audiophonologique, 2018).

## 10. Costs: Neonatal Hearing Screening

Financing of neonatal hearing screening in Luxembourg is organized by the Ministry of Health. Screening is free of charge for parents. There is a financial reward when parents attend hearing screening. The reward is a one-time birth benefit. In order for parents receive the reward, they must participate in numerous health assessments between 0 and 2 years of age. Parents must participate in hearing screening before 6 months of age. There is no penalty, except for that parents who do not attend screening are not eligible for the reward.

A cost analysis of neonatal hearing screening in Luxembourg has not been completed.

### 10.1. Screening costs

The total screening costs for well babies are calculated to be an estimated €130 000 per year, or €18.20 per infant. For at-risk babies, screening is estimated to cost €16 500 per year, or €66 per infant.

### 10.2. Equipment costs

*(Information extracted to protect commercially sensitive data)*

Maintenance costs are roughly estimated to be €90 per year for an OAE or aABR device. Devices are often replaced every 10 years. The cost for disposables is roughly estimated to cost around €1200 per year (in total).

### 10.3. Staff costs

There are 33 professionals performing hearing screening in Luxembourg.

The average annual salary for a screening professional is roughly estimated to be €92 000 or €43 per hour. It may be useful to note that screening for the national neonatal hearing screening programme in Luxembourg takes approximately 50 hours per week.

The cost for training hearing screening professionals is unknown.

### 10.4. Diagnostic costs

The total cost of diagnostic confirmation is not indicated.

### 10.5. Amplification costs

In the Luxembourg, all children with hearing loss are treated, except for children of deaf parents who refuse cochlear implant for their children.

Data are unavailable regarding the yearly costs for hearing aid or cochlear implant treatment.

### 10.6. Social costs

There is 1 school in Luxembourg for deaf and hard-of-hearing students that runs from preschool to primary school. It is unknown how many children attend this school. In mainstream schools, extra support is not provided to children with hearing impairment. All costs for mainstream or special education schools are unknown.



## **11. Costs: Preschool Hearing Screening**

### **11.1. Screening costs**

The total costs for preschool hearing screening are calculated to be an estimated €35 000 per year, or €5.80 per child.

### **11.2. Equipment costs**

The cost a pure-tone screening audiometer is €1600. Maintenance costs are roughly estimated to be €70 per year, and devices are often replaced every 10 years. The cost for disposables is included in the total cost of €1200 per year (see section 10.2).

### **11.3. Staff costs**

See section 10.3 for the salary of a hearing screening professional.



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