

# NEONATAL HEARING SCREENING BY CHILD HEALTH SERVICES IN THE NETHERLANDS

The neonatal hearing screening consists of a three-round screening. The OAE (OtoAcoustic Emission) method is used in rounds 1 and 2, and the AABR (Automated Auditory Brainstem Response) method in round 3. When adequate hearing is not demonstrated in both ears after these three rounds of screening, referral to an audiological center (AC) follows. A small proportion of children follows a different screening protocol (e.g., AABR-AABR).

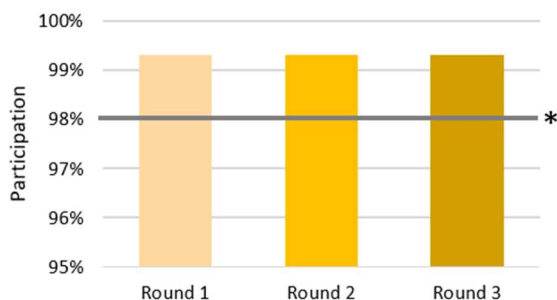
## SCREENING BY CHS

161,171 children eligible

## DIAGNOSIS AT THE AC

582 children referred

### Participation

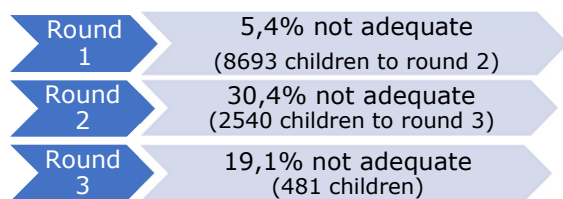


- Screening participation rates are high.

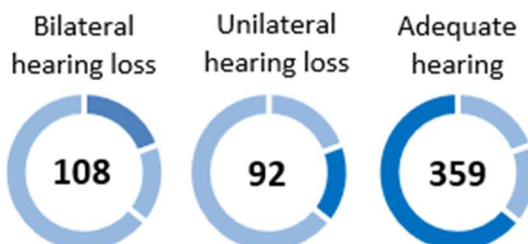


- Between 96.2% and 99.7% of the referred children received a diagnosis.

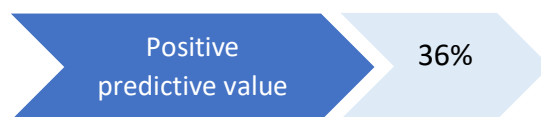
### Referral / findings



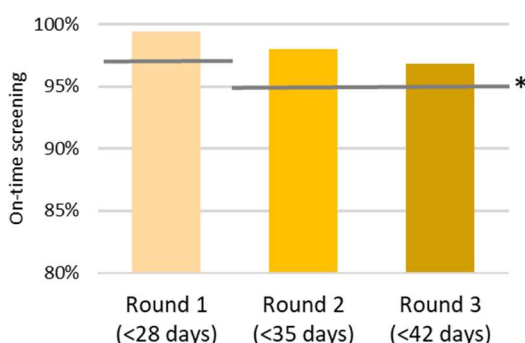
- The number of referrals to the AC by the standard three-round screening (i.e., OAE-OAE-AABR) is low (0.32%).
- Another 98 children were referred through other screening routes (mainly OAE-AABR).
- A total of 582 children were referred to the AC (0.36%).
- 10 CHS organizations did not meet quality norm of ≤7% refers in round 1.



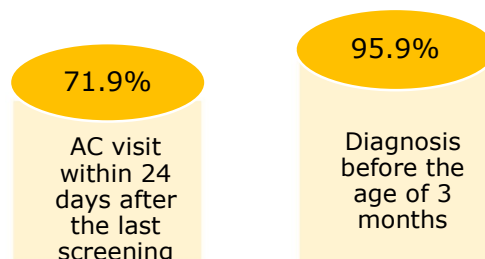
- 200 children with hearing loss ≥ 40 dB were identified.
- 36% of the 559 children with a known diagnosis have hearing loss (PPV):



### Timeliness



- The signal values for timely screening were met. Many WBC organizations did not achieve these.



- The diagnosis should be made within 3 months in ≥ 95%. This condition has been satisfied for the first time.

\*Signal value: minimum target value

Diagnosis refers to (not) having permanent hearing loss of at least 40dB in one or both ears.

## NEONATAL HEARING SCREENING

The neonatal hearing screening (NHS) is a nationwide population screening offered to every newborn in the Netherlands by Child Health Services (CHS). The NHS is financed by municipalities.

The aim of the NHS is on-time identification of children with permanent hearing loss of at least 40dB in one or both ears, so that suitable intervention can be started in children with bilateral hearing loss before the age of six months.

The Center for Population Screening of the Dutch National Institute for Public Health and the Environment (RIVM) coordinates a number of national tasks for the NHS, including the annual monitoring of implementation quality. The Centre for Population Screening commissions an independent party to do this. This monitor serves as its report.

Children who are admitted to a Neonatal Intensive Care Unit (NICU) receive the hearing screening as part of their care there. This is not covered by this monitor.

### THREE-ROUND SCREENING

The neonatal hearing screening consists of a three-round screening. The OAE (OtoAcoustic Emission) method is used in rounds 1 and 2, and the AABR (Automated Auditory Brainstem Response) method in round 3. When adequate hearing is not demonstrated in both ears after these three rounds of screening, referral to an audiological center (AC) follows. Children who are at risk for auditory neuropathy are exclusively screened with the AABR in two rounds. More information about this and the neonatal hearing screening program can be found in the neonatal hearing screening scripts of CHS (<https://www.pns.nl/draaiboek-gehoorscreening>).

### SCREENING AT HOME OR AT THE CONSULTATION OFFICE

Many children receive their first hearing screening during a home visit by the Child Health Services (CHS), during which the heel prick screening also takes place. The CHS organizations that offer the screening combined with the heel prick screening are referred to as heel prick organizations. In so-called CB organizations, the heel prick screening is performed by midwives or in the hospital, and the hearing screening is offered at the well-baby clinic (WBC) when the child is a few weeks old.

### MONITOR FOR 2023

This monitor reports the results of the neonatal hearing screening program of children born in 2023. The indicators established for this purpose were used (see [the set of indicators](#) of the neonatal hearing screening scripts of CHS).

### DIFFERENCE WITH THE PREVIOUS MONITOR

#### Changes at CHS organizations

In 2023, organization 71 ceased to exist: the children have been screened by organization 32 since mid-2022.

#### Changes at audiological centers (ACs)

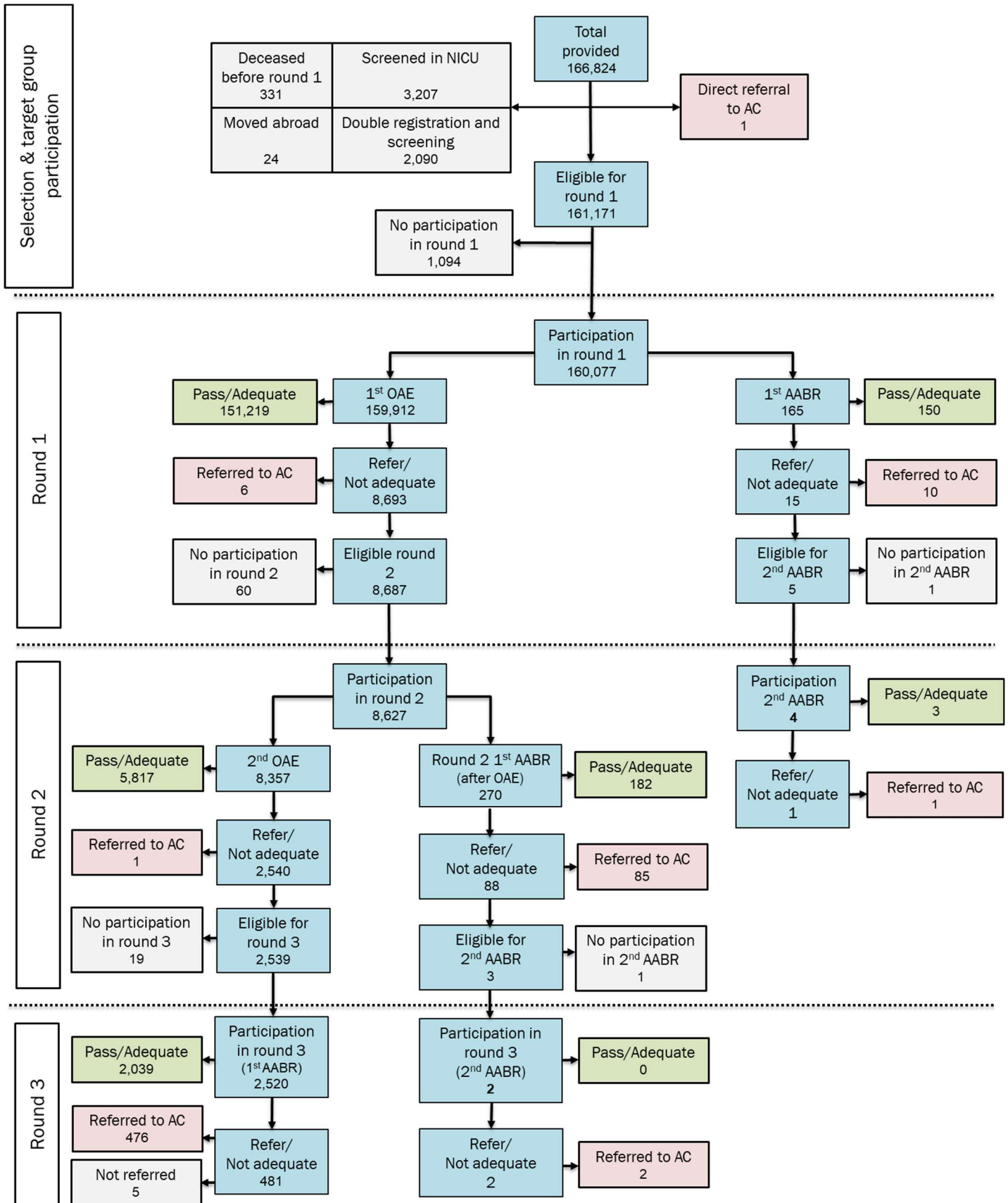
In 2023, data have been provided by 23 ACs, 2 less than last year. One AC stopped, and no children were referred to another AC in 2023. The number of referred children per AC can fluctuate strongly.

### METHOD

Screening and diagnostic data were obtained from the neonatal hearing screening information system (NIS). Using a reporting tool, the Dutch Foundation for the Deaf and Hard of Hearing Child (NSDSK) supplies the number of children per indicator of the screening and diagnostics, nationwide, per CHS organization and per AC. TNO compares the supplied totals with those of previous years and interprets the results.

# RESULTS OF THE SCREENING PROGRAM IN 2023

Figure 1: Flowchart neonatal hearing creening of 2023



# PARTICIPATION

## PARTICIPATION AT NATIONAL LEVEL

In 2023, 161.171 children were eligible for neonatal hearing screening by CHS (Figure 1). The percentage of children who were offered the hearing screening at home in combination with the heel prick screening (78.3%) is, just like in 2022, higher than in previous years (75 to 77%; see Figure 2a and 2b, and Appendix A).

Table 1 shows that the signal values for participation ( $\geq 98\%$  per round) were amply surpassed in all three rounds of screening. A total of 1,094 children did not participate in round 1, 60 in round 2, and 19 in round 3. For 631 of the 1,094 children who did not participate, the parents did not give consent for the screening. This equals 0.39% of the children who were eligible for the screening and is higher than in previous years (Figure 2c, see Appendix A for the numbers). *Due to the increasing number of parents who refuse the screening, investigation into the reasons for refusal of the screening could be considered.* Furthermore, 46 children did not participate because they could not be traced. This is comparable to 2022 (41), but higher than the previous years. Other reasons were screening outside of the Netherlands (202), too old (37), meningitis (13), double no-show without notification (132), and other (33). The reason for not participating in round 2 or 3 often was refusal by parents or no-show, or the reason 'other'. 70% (42/60) of the children who did not participate in round 2 obtained an adequate result in one ear. Among non-participants in round 3 this percentage was 58% (11/19). For the 26 children who have not yet obtained adequate results in both ears, participation in the follow-up process is especially important.

As in previous years, the participation rate in 2023 was lower among WBC organizations than among heel prick organizations for round 1 and especially round 2 of screening (Table 1, Appendix A).

Figure 2a: Number of children screened per performing organization

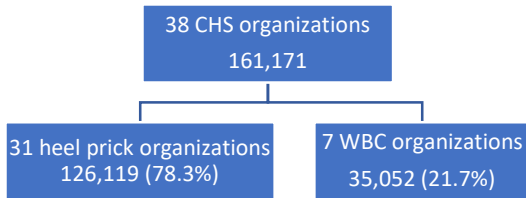


Table 1: Participation per round of screening by heel prick and WBC organizations in 2023

	Signal value	Heel prick org. number (denom.)	% participation 2023 (2022)	WBC org. number (denom.)	% participation 2022 (2021)	Total number (denom.)	% participation 2023 (2022)
Round 1 (OAE or AABR)	$\geq 98\%$	126,119	99.4% (99.5%)	35,052	99.0% (99.2%)	161,171	99.3% (99.4%)
Round 2 (OAE/AABR after OAE)	$\geq 98\%$	6,368	99.5% (99.6%)	2,319	98.7% (98.6%)	8,687	99.3% (99.3%)
Round 3 (AABR after 2xOAE)	$\geq 98\%$	1,685	99.3% (99.6%)	854	99.1% (99.9%)	2,539	99.3% (99.7%)
Multiplication of round 1-3			98.3% (98.6%)		96.8% (97.7%)		97.9% (98.4%)

Figure 2b: Percentage of children who are offered the hearing screening in combination with the heel prick screening

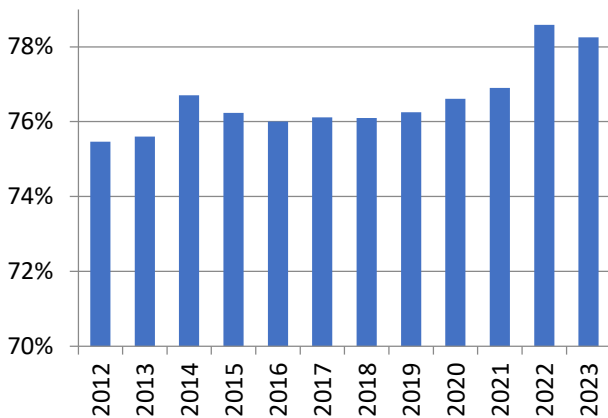
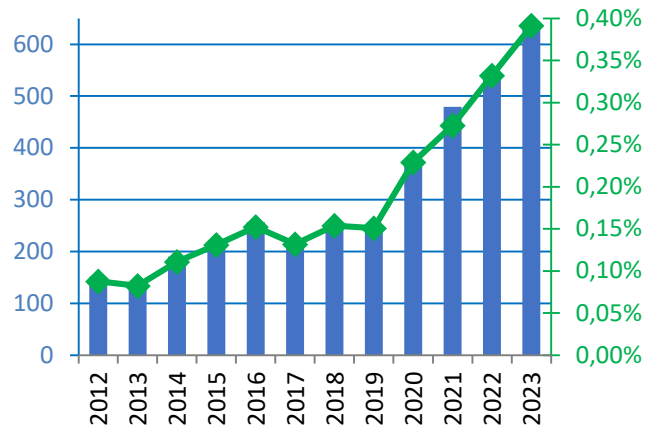


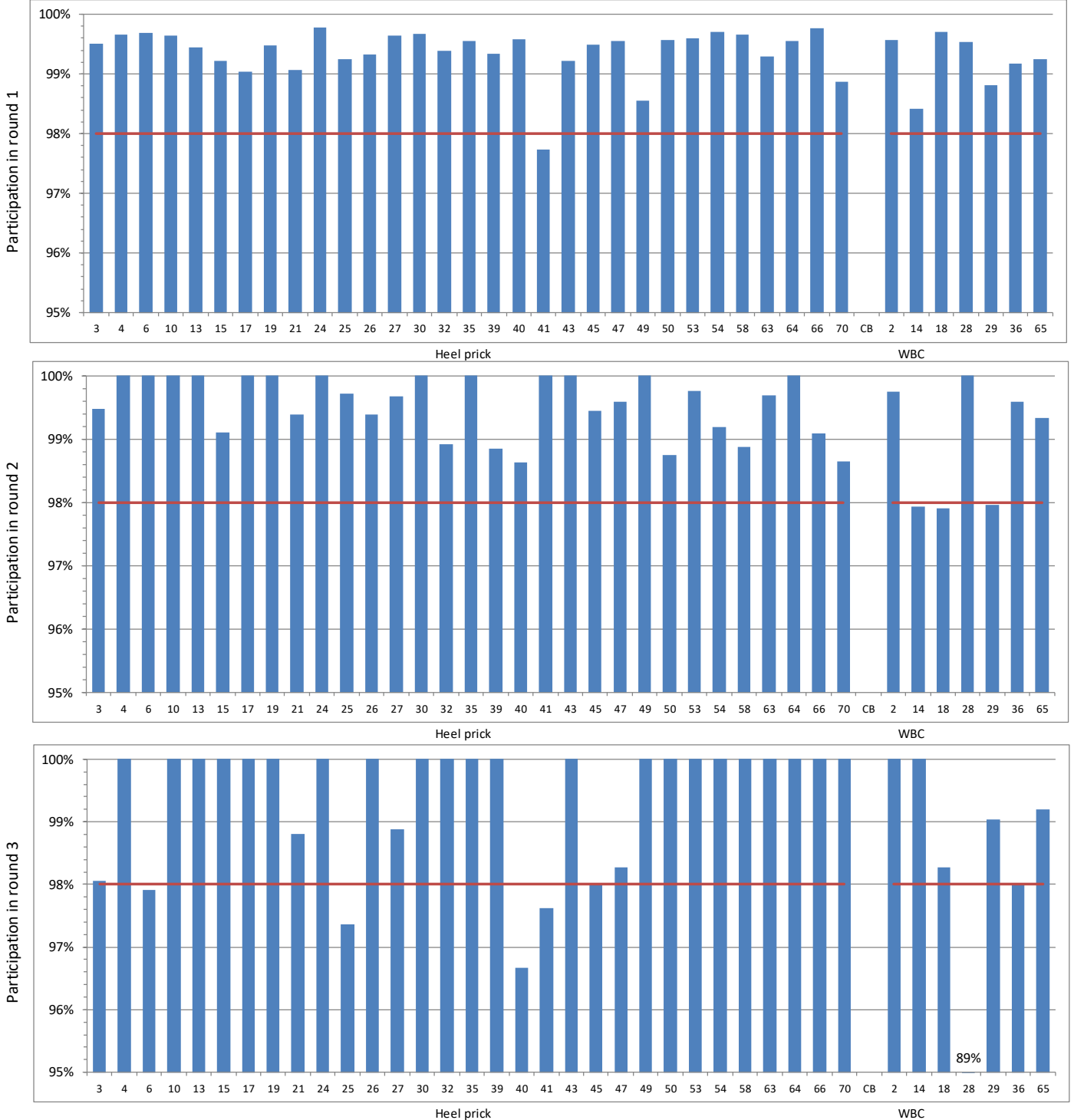
Figure 2c: Number of parents who did not consent with screening (blue) and percentage of number eligible (green).



**PARTICIPATION AT ORGANIZATIONAL LEVEL**

Figure 3 shows that almost all CHS organizations met the signal value of at least 98% for screening round 1 (only 41 did not). Three organizations (14, 18, and 29) failed to meet the signal value for screening round 2. Of these organizations, only organization 29 also failed to meet the signal value in 2021 and 2022. Five organizations (6, 25, 40, 41, and 28) failed to meet the signal value for round 3, but per organization only 1-2 children did not participate.

Figure 3: Participation per screening round by CHS organizations, plotted against the signal value (red line)



# TIMELINESS

## TIMELINESS AT NATIONAL LEVEL

The screening process should be completed within 6 weeks after birth for at least 95% of the children in the neonatal hearing screening program. When a child is born prematurely (i.e., after a pregnancy period of less than 37 weeks), this process is allowed to take longer: the due date is then used instead of the birth date.

Table 2 and Appendix A show that in 2023, all signal and target values were met both nationally and by the heel prick organizations. Only the timeliness of the screening by WBC organizations in round 2 and 3 fails to meet the signal value of 95%.

## TIMELINESS AT ORGANIZATIONAL LEVEL

Figure 4 shows which CHS organizations completed the screening on time for at least 97% (round 1) or 95% (rounds 2 and 3) of the children. In round 1, all CHS organizations screened the children on time. In round 2, WBC organizations 14, 29, 36, and 65 failed to meet the signal value of 95%, and in round 3, organizations 13, 14, 29, and 65 failed to meet the signal value of 95%. In total, 81 children did not receive the third screening on time. Of these, 30 came from organization 29.

At organization 65, less than 95% have been screened on time in the third round for years. Actions have already been directed towards this, and there is some improvement visible compared to previous years.

Table 2: Timeliness per screening round by heel prick and WBC organizations in 2023

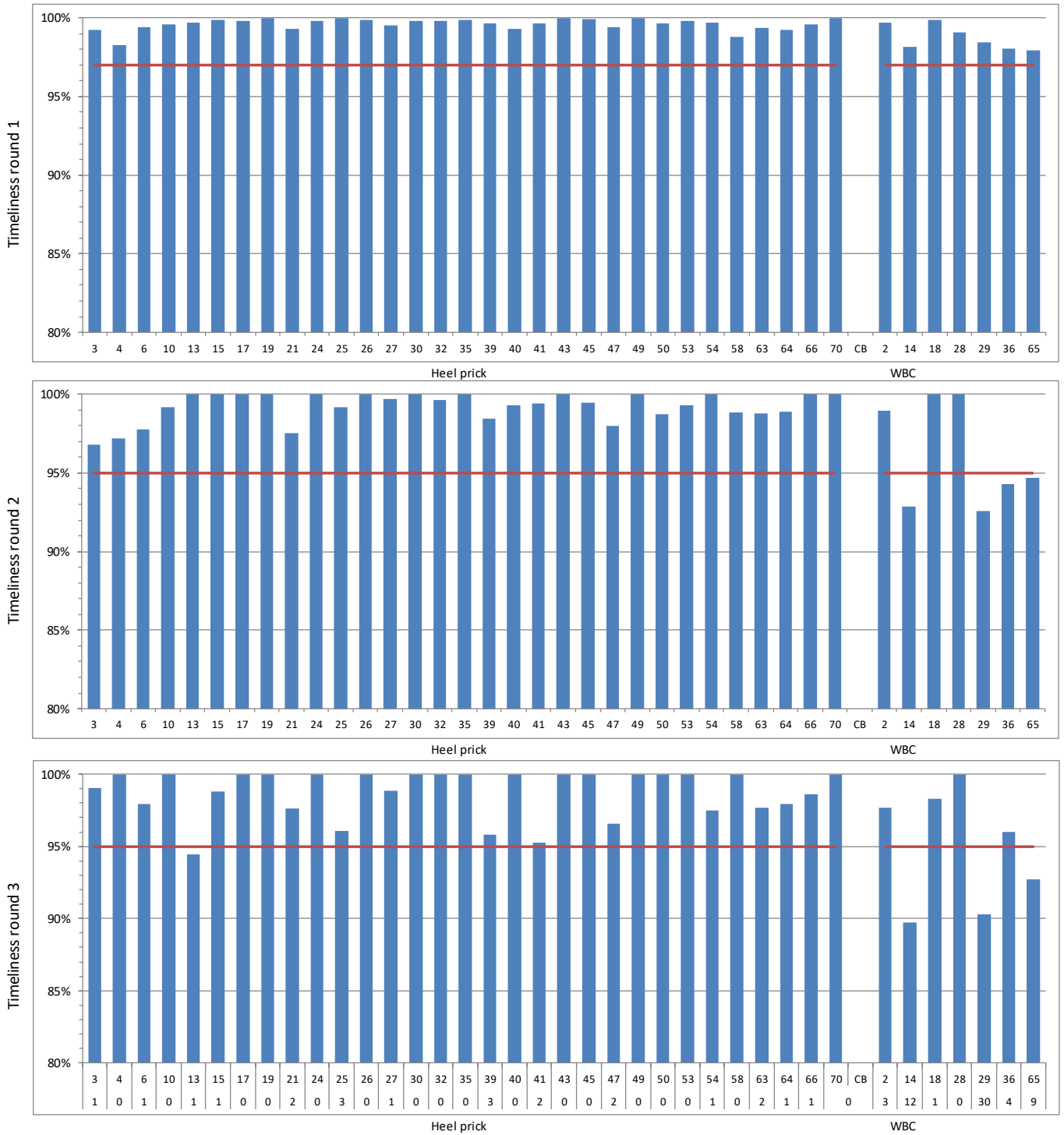
	Signal value	Heel prick org. number (denom.)	% timely screened 2023 (2022)	WBC org. number (denom.)	% timely screened 2023 (2022)	Total number (denom.)	% timely screened 2023 (2022)
Round 1 (OAE+AABR)	≥97% before day 28	125,361	99.6% (99.5%)	34,716	98.6% (98.8%)	160,077	99.4% (99.4%)
Round 2 (OAE+AABR*)	≥95% before day 35	6,339	99.1% (99.0%)	2,288	<b>94.8%</b> (95.6%)	8,627	98.0% (98.2%)
Round 3 (AABR*)	≥95% before day 42	1,674	98.7% (98.6%)	846	<b>93.0%</b> ( <b>94.4%</b> )	2,520	96.8% (97.2%)

Bold numbers indicate that the signal or target value was not met.

\* In the numbers for round 2, the 4 children with a second AABR after AABR in round 1 are not included. In the numbers for round 3, only the AABR screenings of the standard protocol (2x OAE and 1x AABR) were included.

Figure 4: Timeliness per screening round by CHS organizations, plotted against the signal value (red line).

Because of the small numbers, the number of children who were screened late is also shown below the graph for round 3.



## REFERS AND REFERRAL RATES

The word *refer* is used to indicate inadequate screening results in one or both ears. A refer in rounds 1 or 2 results in another screening round, and in round 3 this results in a referral. The word *referral* is used to indicate that a child is referred to an AC.

### REFER RATES AT NATIONAL LEVEL

At the national level, the refer rate in round 1 for screenings with OAE was increased again compared to 2022 and previous years (Table 3 and Appendix A). Therefore, more children need a second screening. More and more CHS organizations are using the Echoscreen III (ESIII), which gives a higher refer rate than the ESII (Van der Ploeg e.a. Stijging referpercentage bij 1<sup>e</sup> OAE-screening in 2023, okt 2024; about effect of type of device (ESI/II vs ESIII), age, experience with ESIII and type CHS (at home/WBC); in Dutch). The quality norm for round 1 ( $\leq 7\%$ ) is met nationally, although collectively the WBC organizations come close to the norm value with 6.7%. If the proportion of children with hearing loss is stable and the first round has a high referral rate, it is expected that the referral rate in the second round will be relatively low, because more children without hearing loss will undergo a second screening. This is also the case now.

Children screened at the WBC are several weeks older than children screened at home. This may contribute to the higher refer rates at rounds 1 and 2, and the higher referral rate at round 3: it is presumed that there are slightly more respiratory infections and the child is also awake more often (Van der Ploeg et al., 2007; Neonatale gehoorscreening: rol van de leeftijd op de testuitkomst. Tijdschrift JGZ 2007(2): 27-29; in Dutch).

A total of 582 children (including those with [alternative and hospital protocols](#)) were referred to the AC (0.36%, red boxes in Figure 1).

### SCREENING WITH AABR IN ROUND 1 OR 2

There were 165 children (0.10%) screened exclusively with the AABR method (the hospital protocol), because they had increased risk of auditory neuropathy or were hospitalized for a long period of time. This number is higher than 2021 and 2022 (154 and 146), and lower than in 2017-2020 (between 188 and 248). Children mainly follow this protocol because of meningitis (26x) or long hospital stay (17x), but in 98 cases the reason is unclear ('other reason'). Of these 165 children, 11 children ultimately received a referral (see Figure 1). The referral rate for this protocol is high (6.7%, Table 4). One child with a bilateral inadequate first AABR test did not participate in a second AABR test.

Exclusive screening with the AABR happened approximately equally frequent at WBC organizations as at heel prick organizations in 2023 (respectively 0.09% and 0.14%). At organization 41, the hospital protocol is used relatively frequently (0.69%, 23 children). Many of them (19 children) turned out to have been in an NICU.

A total of 270 children received a screening with OAE in round 1 and AABR in round 2. This number is comparable to 2016-2019 and 2021-2022 (253-288). Only in 2020, this number was much higher (357), presumably due to COVID-19. As in previous years, the referral rate in these children was high (32.2%, see Table 4 and Figure 1). This [alternative protocol](#) is applied sometimes, for example in case of schisis (71x), hearing loss in the family (73x), or a syndrome (52x). The reason is also sometimes 'other' (43x).

Table 3: Refer rates per screening round by heel prick and WBC organizations in 2023

	Norm or signal value	Heel prick org. number (denom.)	% refer 2023 (2022)	WBC org. number (denom.)	% refer 2023 (2022)	Total number (denom.)	% refer 2023 (2022)
Round 1 (OAE)	$\leq 7\%$	125,244	5.1% (4.9%)	34,668	6.7% (5.9%)	159,912	5.4% (5.1%)
Round 2 (OAE)	$\leq 40\%$	6,135	27.5% (28.3%)	2,222	38.4% ( <b>43.7%</b> )	8,357	30.4% (32.1%)
To round 3 (at 100% participation for rounds 1 and 2)			1.4% (1.4%)		2.6% (2.6%)		1.7% (1.6%)
Round 3 (AABR)	*	1,674	20.3% (23.4%)	846	16.7% (22.1%)	2,520	19.1% (23.0%)
Referral to AC (at 100% participation for rounds 1-3)	$< 0.5\%$		0.28% (0.32%)		0.43% ( <b>0.57%</b> )		0.32% (0.37%)

Bold numbers indicate that the quality norm or signal value was not met. For rounds 1 and 2 only the OAE results are reported, Table 4 shows the referrals for use of the AABR in rounds 1 and 2.

\* Because the results of rounds 1 and 2 affect the expectation for round 3, no signal value was set for round 3.



Table 4: Referrals to the AC after exclusive screening with the AABR method (hospital protocol) and in children screened first with the OAE and subsequently with the AABR

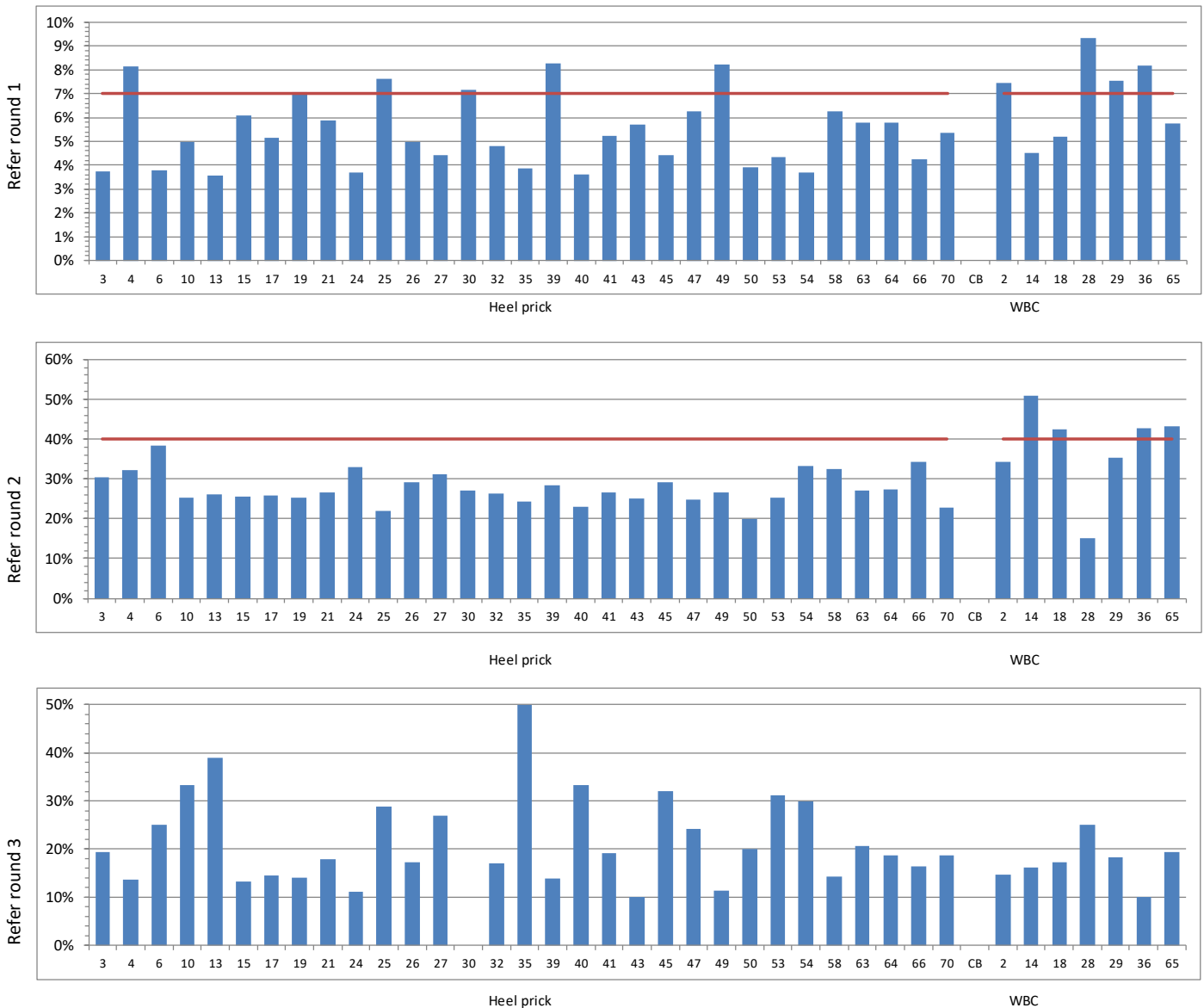
	Heel prick org. number	Referred number (%)	WBC org. number	Referred number (%)	Total number	Referred number (%)
Exclusive screening with AABR (in round 1 and possibly round 2)	117	6 (5.1%)	48	5 (10.4%)	165	11 (6.7%)
AABR in round 2 (following OAE)	204	60 (29.4%)	66	27 (40.9%)	270	87 (32.2%)

**REFER RATES AT ORGANIZATIONAL LEVEL**

Figure 5a shows that in screening round 1, 10 CHS organizations did not meet the quality norm of at most 7% refers in 2023 (CHS 4, 19, 25, 30, 39, 49, 2, 28, 29, and 36). CHS 29 and 36 also failed to meet the norm in 2022. At round 2, the signal value of ≤40% was met by all heel prick organizations, but 4 WBC organizations did not meet the signal value.

Heel prick organization 39 had a relatively high refer rate at round 1 for years, was below the norm in 2022 (6.6%), but now again has a too high value (8.3%).

Figure 5a: Refer rates per screening round per CHS organization, plotted against the norm value (red line)



## REFERRAL RATES

The quality norm for the referral rate after 3 rounds ( $\leq 0,5\%$ ) was in 2023 met by all CHS organizations (Figure 5b).

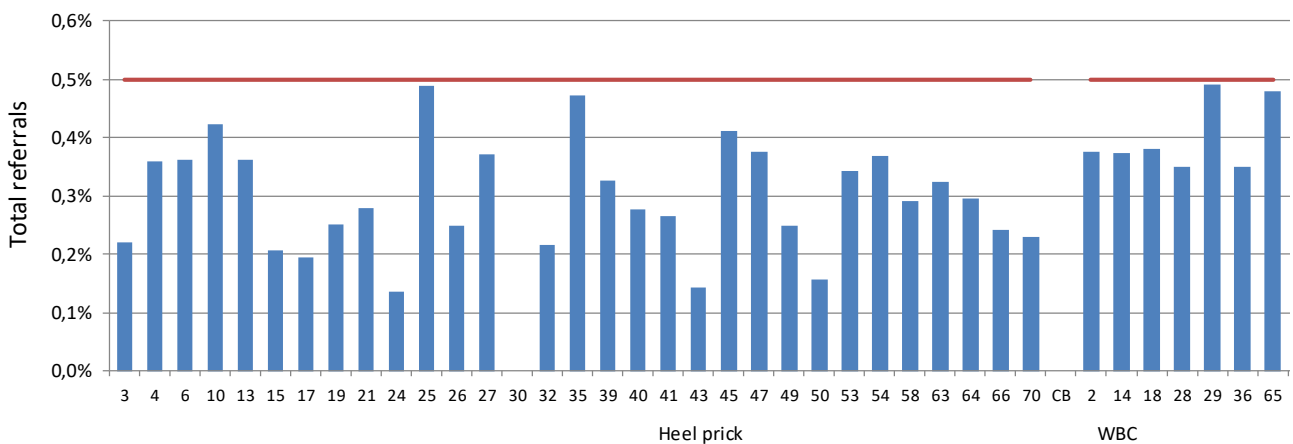
## NATIONAL LEVEL

Of the children born in 2023, 582 children were referred to an audiological center (Figure 1). One of them was referred before the screening. This sets the total referral rate to 0.36%. When we only look at children screened according to the standard protocol (i.e., three-round screening with 2x OAE and 1x ABRR), the referral rate after 3 rounds is 0.32%. Despite the increase of the referral rate in the first round, there is a decrease in the referral rate compared to 2022 (0.37%), and is comparable again to previous years (0.30-0.32%).

There are 476 referrals according to the standard protocol. Five children who followed the standard screening protocol received a refer at every round, but were nevertheless not referred and therefore are not counted. A potential reason for this can be that the parents refuse the referral.

Of the 435 children who followed a special protocol (270 with 1x OAE and 1x or 2x AABR, and 165 with 2x AABR), 98 (22.5%) received a referral. One child with an inadequate AABR at round 1 (the hospital protocol) was not screened further, and one child was not further screened despite an inadequate OAE and AABR. Both had a bilateral refer at the screening.

Figure 5b: Referral rate to the AC after three screening rounds per CHS organization, plotted against the norm value (red line)



## RESULTS DIAGNOSTIC PROCESS 2023

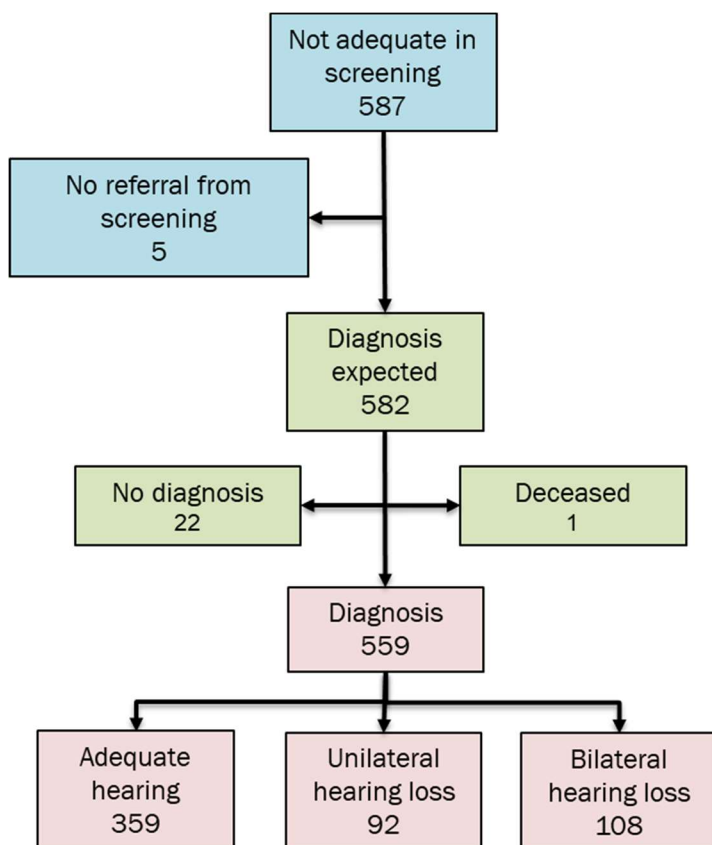
This section of the monitor deals with the execution of the diagnostic process after the neonatal hearing screening in 2023.

## PARTICIPATION

Of the 582 referred children (Figure 6), at least 560 children (96.2%) visited the AC at least once. For 559 of these 560 (99.8%), a diagnosis was provided. A diagnosis indicates: (no) permanent hearing loss of at least 40dB in one or both ears. The signal values of these quality indicators (100%) were not met.

For 23 of the referred children (4%) no diagnosis was provided. This limits the insight into the diagnostic outcomes. Reasons for the lack of diagnosis included no consent for reporting (18x), no participation in follow-up examination (2x), death (1x), or missing report (2x). When the deceased child is excluded, participation in diagnostics are at least 96.2% (559 with known diagnosis divided by 581). A maximum of 99.7% (579/581) received a diagnosis, since 2 children did not participate in (follow-up) examination with certainty.

Figure 6: Diagnostic examination of children of 2023



## TIMELINESS

### Referral interval

The aim is that at least 95% of the referred children visits the AC within 24 days following the final screening. This target value was not met in 2023: 71.9% of the 558 children of whom both dates are known visited the AC in time (Table 5). As in previous years, the target value was not met, but there is an upward trend (65.2% in 2021, 67.4% in 2022). In 2023, there is a big difference between heel prick and WBC organizations (79.0% versus 55.4%, see Appendix A), just like in previous years.

There is a difference between uni- and bilateral refer: children with a bilateral refer more often visit the AC within 24 days (Table 5).

### Timeliness completing diagnosis nationwide

For 558 children with a diagnosis it was possible to determine whether this diagnosis was made at the AC within the first three months of life (<92 days, after correction for premature birth). This condition was not achieved for 23 children, but it was for 95.9%: the target value of ≥95% was met for the first time. In 2023, children with a unilateral referral had a lower on-time diagnosis rate than children with a bilateral referral (Table 5), but whether the diagnosis is made more timely for uni- or bilateral referral varies over the years.

Since 2019, the percentage of children with an on-time diagnosis has improved compared with the years before 2019 (see Appendix A). This is likely due to the extra attention paid by the ACs to timely completion of diagnosis. In 2020, the result (82.6%) was poorer due to the temporary suspension of the screening due to COVID-19.

### Timeliness of completing diagnosis per AC

Figure 7 shows the percentage of children who visited the AC within 24 days after final screening per AC and the percentage of children for whom the diagnosis was known within 92 days per AC. The bottom rows with numbers indicate the number of children per AC for whom data are available.

Per AC, 91-100% of children received an on-time diagnosis in 2023, only for ACs 18 and 33 this was lower (resp. 86% and 80%). The target value of 95% was met by 17 ACs (and 6 ACs failed to meet it): 11 ACs show an improvement compared to 2022. In total, 23 children were diagnosed too late. Three ACs had more than one child too late (8 at AC 10, 6 at AC 18, and 2 at AC 33). ACs 10 en 18 therefore contribute strongly to the number of children with a diagnosis that was too late, but at AC 10 this is partly because it diagnoses a relatively large number of the referred children (8/101 too late, i.e., 92% on time; at AC 18 6/42 too late, i.e., 86% on time). AC 13 met the target value for the first time in 8 years.

Table 5: Timeliness of referral and known diagnosis nationwide and by type of referral. Target value is 95%. Bold: target value not met.

	Number of children	Data available	Visit AC within 24 days: number	Visit AC within 24 days: %	Diagnosis known within 92 days: number	Diagnosis known within 92 days: %
Total	559	558	401	<b>71.9</b>	535	95.9
Unilateral referral	390	389	270	<b>69.4</b>	372	95.6
Bilateral referral	169	169	131	<b>77.5</b>	163	96.4

Figure 7a: Percentage of children with a visit to the AC within 24 days following final screening, per AC, plotted against the target value (red line). Bottom rows: number of children per AC for whom data are available.

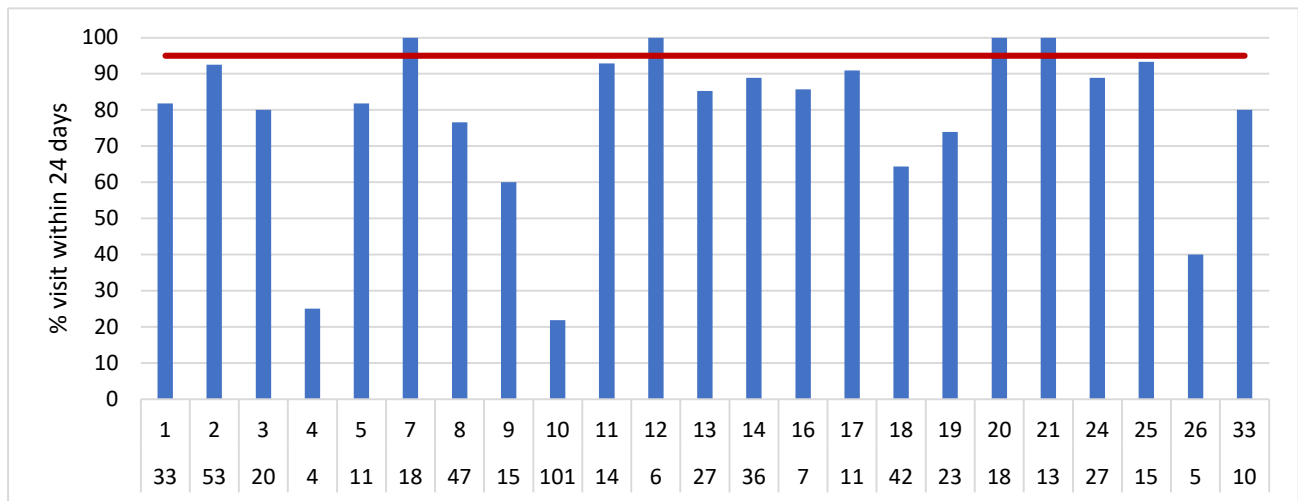
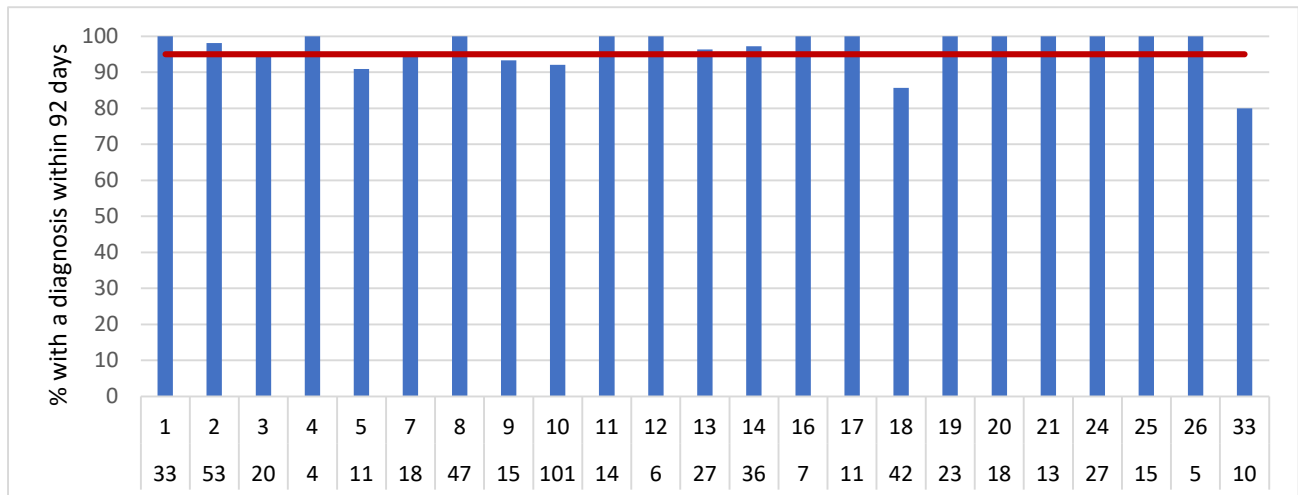


Figure 7b: Percentage of children for whom the diagnosis was made within 92 days after birth, per AC, plotted against the target value (red line). Bottom rows: number of children per AC for whom data are available.



## RESULTS

### Detected hearing impairment

The diagnosis is known for 559 children. Of them, 390 were referred due to an inadequate screening result in one ear (unilateral referral) and 169 due to inadequate screening results in both ears (bilateral referral).

An adequate hearing means that no permanent hearing loss of 40dB or more is detected in one or both ears (a smaller or temporary hearing loss may still be present). For 359 of the 559 referred children for whom the diagnosis is known (64%), an adequate hearing was detected. For the other 200 children (36%), a hearing loss of 40dB or more in one or both ears was detected (Figure 6). In 108 children, a bilateral hearing loss of at least 40dB was detected. Of them, 92 also had bilateral failure on the screening, however 16 were referred due to unilateral failure on the screening. Out of these 108 cases, 88 involved perceptible loss, 4 involved permanent conductive loss, and 14 permanent mixed loss, and 2 children had auditory neuropathy.

In 92 children, unilateral hearing loss of at least 40 dB was detected. Of them, 86 also had unilateral failure on the screening, but 6 had bilateral failure. 70 involved perceptive loss, 8 involved permanent conductive loss, and 14 involved permanent mixed loss.

### Detected number of children over the years

Table 6 shows the number of children detected via screening by CHS in combination with the number of screened children over the years. The numbers with unilateral and bilateral hearing loss fluctuate strongly over the years, but the sum of it and therefore the detection rate is quite stable. Approximately one-third of hearing-impaired children are additionally detected through neonatal hearing screening at the NICUs. The results of which can be found at [www.isala.nl/gehoorscreening](http://www.isala.nl/gehoorscreening).

Table 6: Number of children with hearing loss  $\geq 40$ dB detected through screening by CHS, per year and on average

	2023	2022	2021	2020	2019	2018	2017	2016	Average
Bilateral	108	142	135	125	129	146	119	128	129
Unilateral	92	65	86	81	77	85	74	68	79
Together	200	207	221	206	206	231	193	196	208
Number of children eligible for screening	161,171	164,415	175,649	164,981	166,367	165,149	166,101	168,790	166,578
Detection number uni- and bilateral hearing loss by CHS (per 1000 with participation)	1.25	1.27	1.26	1.26	1.24	1.40	1.17	1.16	1.25

### VALIDITY OF THE SCREENING PROGRAM IN 2023

#### Positive predictive value (PPV)

The likelihood that a child has permanent hearing loss in one or both ears of at least 40dB at the moment of referral to the AC was 36% in 2023. We call this the positive predictive value. The likelihood of bilateral hearing loss after bilateral failure at the screening is 54% (92/169). This is low compared to previous years, since the number of children with a bilateral hearing loss in 2023 was also low, while the number of referrals was comparable (Appendix A).

The difference in PPV between children coming from heel prick organizations and those coming from WBC organizations are reported below. The percentage is lower for WBC organizations due to the higher percentage of false positive referrals by these organizations.

PPV heel prick organizations:	40% (156/391)
PPV WBC organizations:	26% (44/168)
PPV together:	36% (200/559)

#### Sensitivity

The sensitivity of the program provides an answer to the question of which proportion of the total number of hearing-impaired children is detected through the neonatal hearing screening. This value cannot be reliably determined, as for children in whom a hearing impairment is discovered at a later age it is unknown whether their hearing loss was already present during the hearing screening or only emerged afterwards.

#### Specificity

The specificity of the program provides an answer to the question of which proportion of children without hearing loss correctly received an adequate screening result and, thus, was not referred. There were a total of 582 children referred, of whom at least 200 had a hearing loss and 359 did not. The remaining 23 children, for whom it is unknown whether they have a hearing loss, were divided over the two groups of with/without hearing loss in the same proportions. The specificity is calculated by dividing the number of children without hearing loss who were not referred by the total number of children without hearing loss. The estimated specificity is 99.8%.

## APPENDIX A: INDICATORS NEONATAL HEARING SCREENING BY CHS: OVERVIEW OF RESULTS PER YEAR

For each cell the nationwide result is reported first and is followed by those for heel prick and WBC organizations separately in parentheses. Bold numbers indicate that the quality norm or target value in the year in question was not met.

	2023	2022	2021	2020*	2019	2018	2017
Combination hearing and heel prick screening	78.3%	78.6%	76.9%	76.6%	76.3%	76.1%	76.1%
Participation screening round 1	99.3% (99.4%; 99.0%)	99.4% (99.5%; 99.2%)	99.5% (99.6%; 99.3%)	99.5% (99.6%; 99.2%)	99.6% (99.7%; 99.4%)	99.6% (99.7%; 99.5%)	99.7% (99.8%; 99.6%)
Participation screening round 2	99.3% (99.5%; 98.7%)	99.3% (99.6%; 98.6%)	99.5% (99.7%; 98.9%)	99.6% (99.6%; 99.4%)	99.6% (99.7%; 99.4%)	99.6% (99.6%; 99.6%)	99.6% (99.7%; 99.3%)
Participation screening round 3	99.3% (99.3%; 99.1%)	99.7% (99.6%; 99.9%)	99.6% (99.8%; 99.3%)	99.7% (99.7%; 99.7%)	99.6% (99.7%; 99.4%)	99.7% (99.7%; 99.8%)	99.7% (99.7%; 99.8%)
Participation rounds 1-3	97.9% (98.3%; 96.8%)	98.4% (98.6%; 97.7%)	98.6% (99.1%; 97.4%)	98.8% (98.9%; 98.3%)	98.8% (99.1%; 98.2%)	98.9% (98.9%; 98.9%)	99.0% (99.2%; 98.7%)
Absence of consent	0.39% (631 times)	0.33% (546 times)	0.27% (479 times)	0.23% (378 times)	0.15% (251 times)	0.15% (254 times)	0.13% (219 times)
Child not traced	0.029% (46 times)	0.025% (41 times)	0.018% (32 times)	0.025% (42 times)	0.015% (25 times)	0.013% (22 times)	0.012% (20 times)
Participation AC: diagnosis (all of referred through screening)	<b>96.2%-99.7%</b> Nationwide	<b>94.2%-98.5%</b> Nationwide	<b>94.3%-99.1%</b> Nationwide	<b>93.7%-98.7%</b> Nationwide	<b>91.6%-98.7%</b> Nationwide	<b>95.7%-99.3%</b> Nationwide	<b>94.5% - 96.7%</b> Nationwide
Referral advice followed (visit AC)	<b>96.4%</b>	<b>94.6%</b>	<b>94.7%</b>	<b>94.5%</b>	<b>92.7%</b>	<b>96.6%</b>	<b>96.1%</b>
Completion of diagnosis (% of 1 <sup>st</sup> visit to AC)	<b>99.8%</b> (i.e., 96.2% followed-up and completed)	<b>99.4%</b> (i.e., 94.0% followed-up and completed)	<b>99.5%</b> (i.e., 94.3% followed-up and completed)	<b>99.1%</b> (i.e., 93.7% followed-up and completed)	<b>98.6%</b> (i.e., 91.4% followed-up and completed)	<b>98.9%</b> (i.e., 95.5% followed-up and completed)	<b>98.0%</b> (i.e., 94.2% followed-up and completed)
Not adequate at round 1	5.4% (5.1%; 6.7%)	5.1% (4.9%; 5.9%)	4.6% (4.5%; 5.0%)	4.7% (4.7%; 4.8%)	4.4% (4.3%; 4.9%)	4.5% (4.4%; 4.9%)	4.8% (4.7%; 4.9%)
Not adequate at round 2	30.4% (27.5%; 38.4%)	32.1% (28.3%; <b>43.7%</b> )	31.3% (27.7%; <b>42.1%</b> )	31.7% (28.7%; <b>41.2%</b> )	32.8% (29.2%; <b>43.0%</b> )	32.8% (28.3%; <b>45.8%</b> )	32.9% (29.1%; <b>44.8%</b> )
Not adequate at round 3	19.1% (20.3%; 16.7%)	23.0% (23.4%; 22.1%)	22.4% (23.6%; 20.0%)	20.8% (21.0%; 20.3%)	21.4% (22.4%; 19.5%)	20.4% (22.3%; 16.8%)	20.1% (19.9%; 20.4%)
Referral to AC (after OAE-OAE-AABR), vs. number of participants in 1 <sup>st</sup> screening (at 100% participation)	0.32% (0.28%; 0.43%)	0.37% (0.32%; <b>0.57%</b> )	0.32% (0.29%; 0.42%)	0.31% (0.28%; 0.41%)	0.31% (0.28%; 0.41%)	0.30% (0.28%; 0.38%)	0.32% (0.27%; 0.45%)
Overall referral rate (incl. hospital protocol and OAE-AABR(-AABR))	0.36%	0.41%	0.38%	0.38%	0.37%	0.35%	0.35%
Timeliness screening round 1 (<28d)	99.4% (99.6%; 98.6%)	99.4% (99.5%; 98.8%)	99.2% (99.5%; 98.3%)	<b>89.4% (90.4%; 86.2%)*</b>	99.3% (99.3%; 99.0%)	99.4% (99.4%; 99.2%)	99.4% (99.5%; 99.3%)
Timeliness screening round 2 (<35d)	98.0% (99.1%; <b>94.8%</b> )	98.2% (99.0%; 95.6%)	97.8% (98.7%; 95.2%)	<b>85.8% (88.1%; 78.3%)*</b>	98.3% (98.4%; 97.8%)	98.3% (98.8%; 97.1%)	98.3% (98.9%; 96.5%)
Timeliness screening round 3 (<42d)	96.8% (98.7%; <b>93.0%</b> )	97.2% (98.6%; <b>94.4%</b> )	97.0% (98.1%; <b>94.8%</b> )	<b>81.7% (84.3%; 76.1%)*</b>	98.0% (98.1%; 97.7%)	97.6% (97.8%; 97.1%)	97.6% (98.1%; 96.7%)
Interval between final screening and 1 <sup>st</sup> diagnostic examination (<24d)	<b>71.9% (79.0%; 55.4%)</b>	<b>67.4% (74.7%; 50.8%)</b>	<b>65.2% (73.7%; 44.8%)</b>	<b>64.9% (72.9%; 46.3%)*</b>	<b>65.6% (68.3%; 59.4%)</b>	<b>68.2% (70.2%; 63.2%)</b>	<b>67.5% (74.7%; 51.2%)</b>
Timeliness diagnosis (<92 d after birth)	95.9% (96.4%; 95.9%)	<b>94.0% (95.3%; 91.3%)</b>	<b>92.6% (94.8%; 87.4%)</b>	<b>82.6% (86.9%; 72.6%)*</b>	<b>93.5% (95.6%; 88.8%)</b>	<b>86.4% (86.5%; 86.3%)</b>	<b>86.2% (89.3%; 79.2%)</b>
Birth records in NIS (<3 working days)	23% < 3 calendar days 43% < 4 calendar days	22% < 3 calendar days 40% < 4 calendar days	22% < 3 calendar days 40% < 4 calendar days	22% < 3 calendar days 39% < 4 calendar days	24% < 3 calendar days 43% < 4 calendar days	25% < 3 calendar days 44% < 4 calendar days	24% < 3 calendar days 44% < 4 calendar days
Number with unilateral hearing loss	92	65	86	81	77	85	74
Number with bilateral hearing loss	108	142	135	125	129	146	119
Detection number uni- and bilateral	1.25 (1.24; 1.27)	1.27 (1.18; 1.57)	1.26 (1.23; 1.39)	1.26 (1.22; 1.36)	1.24 (1.17; 1.48)	1.40 (1.41; 1.40)	1.17 (1.15; 1.22)

	2023	2022	2021	2020*	2019	2018	2017
hearing loss by CHS (per 1000)							
Positive Predictive Value (PPV) for uni- and bilateral hearing loss combined	36% (40%; 26%)	32% (34%; 28%)	35% (37%; 30%)	35% (38%; 30%)	37% (39%; 34%)	42% (44%; 36%)	35% (38%; 29%)
PPV for bilateral hearing loss after bilateral failure at screening	54%	64%	60%	60%	62%	63%	59%
False positive results	>62%	>64%	>61%	>61%	>57%	>56%	>61%
Specificity	99.8%	<b>99.7%</b>	99.8%	99.8%	99.8%	99.8%	99.8%
Sensitivity	Cannot be determined	Cannot be determined	Cannot be determined	Cannot be determined	Cannot be determined	Cannot be determined	Cannot be determined
Children screened with AABR	165	146	154	210	188	248	240

\*In 2020, the hearing screening was suspended for 6 weeks due to COVID-19. This had a strong impact on the average timeliness of execution in 2020.

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