Impact and benefits of early hearing screening

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THE EARLIER THE BETTER? DEVELOPMENTAL OUTCOME AFTER EARLY VERSUS LATER HEARING SCREENING IN THE NATIONAL DECIBEL-STUDY

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ABSTRACT

Context

Newborn Hearing Screening (NHS) programmes were implemented in many countries under the assumption that the earlier permanent childhood hearing impairment (PCHI) is detected the less developmentally disadvantaged children would become. To date, however no strong evidence exists for universal introduction of NHS.

Objective

Study the effect of NHS versus the previously used distraction hearing screening (DHS) on developmental outcome and quality of life.

Design, setting and participants:

From 2002 onwards all 65 regions in the Netherlands replaced DHS by NHS. Consequently the type of hearing screening offered was based on availability at the place and date of birth and was independent of developmental prognosis of the individual child. This created a unique study design in which all children born in the Netherlands between 2003 and 2005 were included.

Main outcome measures

At the age of 3-5 years all children with PCHI in the 2003-05 study cohort were identified. Performance measures (education and mode of communication), development (general and language development) and quality of life were assessed.

Results

335.560 children were born in a NHS and 234.826 children in a DHS region. At follow up 0.78 (NHS) and 0.73 (DHS) per 1000 children had been diagnosed with PCHI. The proportion of children with PCHI in regular education was comparable in both groups. Children in NHS had better language development (mean diff. spoken vocabulary: 11.5 95%CI-1.0; 24.1, mean diff. expressive language: 7.6 95%CI-1.1; 16.3), better social development (mean diff.8.7 95%CI 0.6; 16.7) and quality of life (mean diff.6.0 95%CI 2.4; 9.6) at the age of 3-5 years compared to children in DHS. In sensitivity-analysis (excluding children with congenital cytomegalovirus infection) children in NHS had statistically significant better outcomes.

Conclusion

This study is the first to demonstrate in a nationwide, naturally randomized design that children with PCHI have a better developmental outcome at the age of 3-5 years when they are screened by NHS than by DHS.

INTRODUCTION

Permanent Childhood Hearing Impairment (PCHI) is a serious, relatively common condition.[2;3;5] Auditory input is considered to be essential for development and social functioning and it seems important to be aware of the child's hearing abilities early in life to create opportunities for early amplification and habilitation when necessary.

Until some years ago distraction methods (DHS) were used for hearing screening around the age of 9 months. Under the assumption that the earlier PCHI is detected, the less developmentally disadvantaged children would become, Newborn Hearing Screening (NHS, within 2 weeks of birth) became implemented in many developed countries when objective screening instruments became available. However, to date no strong evidence exists for universal implementation of NHS. Earlier studies on developmental effects of NHS are descriptive in nature and based on convenience samples.[21;31;37;87;88;90;91] Beside the methodological difficulties of earlier studies, it is also unclear what proportion of children with progressive or delayed onset hearing loss, is unidentified by NHS.

Ideally a randomized trial would be preferred to determine the true effect of type and moment of hearing screening on developmental outcome in children with PCHI. In such a trial live born infants would be randomly assigned to DHS or NHS (individually randomized or clustered by region of birth) and development would be assessed at a fixed age in all children diagnosed with PCHI. The age at developmental evaluation should be carefully chosen, since assessment alone may influence the habilitation program and thereby the developmental outcome during follow-up. However, apart from practical difficulties (including expense and duration) the initiation of a randomized trial is not considered ethically feasible.[21;37]

To overcome these difficulties, we used the regional differences in the assignment of type of hearing screening created by national policy, as an instrumental variable in the present study. In the Netherlands NHS was gradually introduced from 2002 onwards, replacing DHS region by region (n=65). In June 2006 NHS had totally replaced DHS. This policy created regional differences in the assignment of type of hearing screening to children based solely on the availability of a certain type of hearing screening at the place and date of birth (the 'instrumental variable'). Since the type of hearing screening offered was independent of the prognosis of hearing of the individual child, this study, with its 'naturally' randomized design, is expected to be as credible as a randomized trial.[38-41]

By using the regional differences in hearing screening, we studied the developmental effects of NHS compared with DHS in 3-5 year old children with PCHI. We hypothesize that in children with PCHI screening with NHS will lead to better development compared to screening with DHS.

METHODS

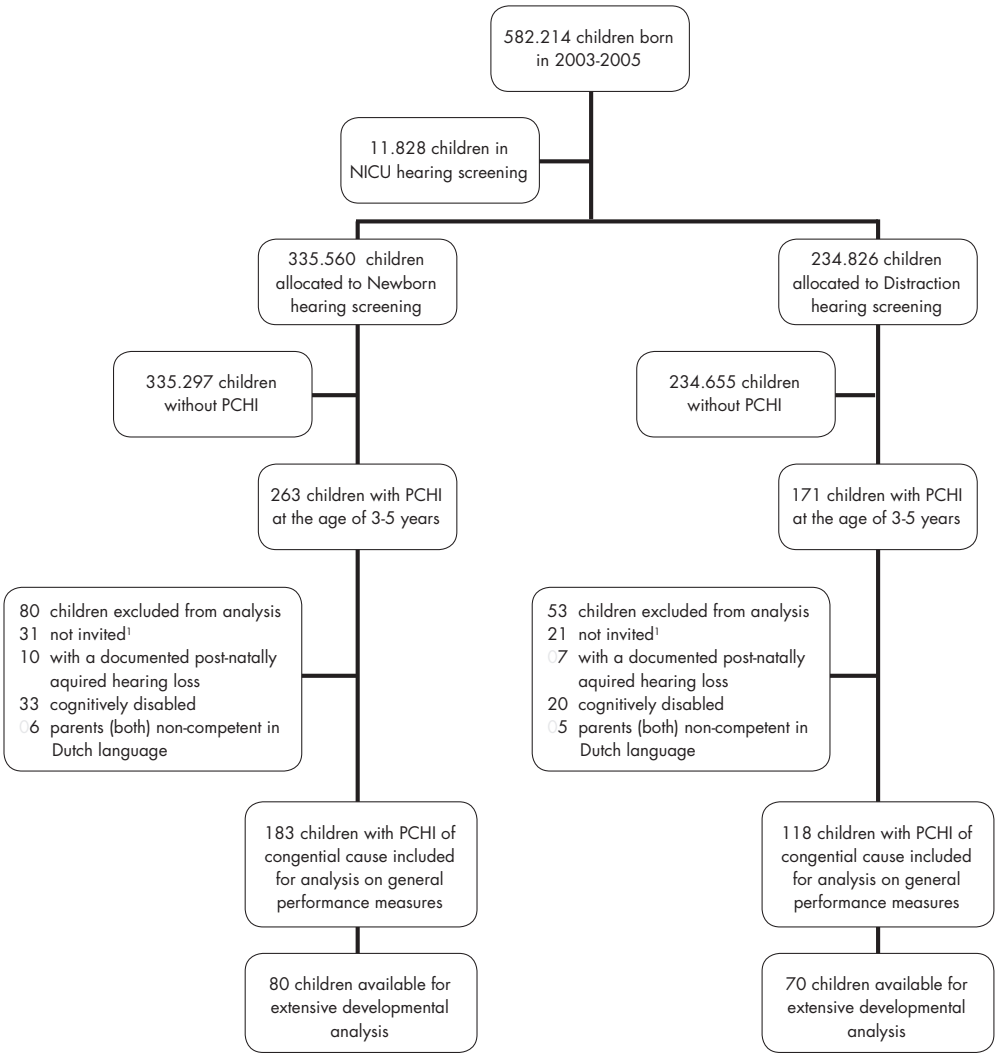
STUDY POPULATION

All children born in the Netherlands between January 1st, 2003 and December 31st, 2005 were included in the 2003-05 study cohort. Following ethical approval by the Medical Ethics Committee of the Leiden University Medical Center, all Audiology Centers (AC, n=22) agreed to collaborate in the follow-up of children from this 2003-05 study cohort. In the Netherlands the AC is the designated organisation for children with PCHI for diagnostic evaluation and amplification. Professionals at the AC conscientiously examined, with assistance of two of the researchers (AK and SK), all records of children from the 2003-05 study cohort who were known to the AC with PCHI at the age of 3-5 years, to ascertain in- or exclusion for this study. PCHI was defined as bilateral permanent conductive or sensorineural hearing loss of ≥40dB in the better ear and was classified on the basis of the most recent hearing test (measured unaided and computed using 500, 1000 en 2000 Hz). Hearing loss was categorized as moderate (40-60dB), severe (61-90dB) or profound (>90dB). Since the identification of children at an AC was performed cross-sectionally, the identification was unbiased with respect to type or result of hearing screening and type or degree of hearing loss.

Of all live born infants in the 2003-05 study cohort 11.828 children were admitted to a neonatal intensive care unit (NICU). Since NICU graduates are not the target population of universal hearing screening programs, these children were excluded from the study. 335.560 children were born in a region where NHS was offered at date and place of birth, 234.826 children were born in a region where DHS was offered. At follow-up 434 children were known to an AC with PCHI. Of these 133 children were excluded (see Figure 1.) and the remaining 301 children were included in the study on performance measures. Of these 150 children participated in extensive investigations on developmental outcome. Follow-up on developmental outcome ended in December 2009 (Figure 1.).

HEARING SCREENING PROGRAMS AND STUDY DESIGN

The place and date of birth of the child determined the type of hearing screening offered: DHS or NHS. The two programs differed in the age at screening and the method used. The DHS, carried out in our country since 1965 and offered at the age of 9 months, is a subjective three stage hearing screening using behavioural distraction methods. In our country the NHS for well babies is in accordance with NHS programs elsewhere and offered before the age of 2 weeks. The NHS is an objective three stage screening program, using transient evoked oto-acoustic emissions (OAE) for the first two stages and automated auditory brain stem response (A-ABR) in the third stage. A uni- or bilateral positive screen for hearing loss is followed by a



[1] Not invited: (1) one Audiology Center invited children not already participating in other research project and (2) one Audiology Center agreed to participate in the collaborative study group just before the end of developmental follow-up

Figure 1 Trial profile DECIBEL-study

repeat screening step and a positive screen in the third stage is followed by referral to an AC for diagnostic investigation and confirmation of hearing loss. The aim of NHS is to identify permanent conductive or sensorineural hearing loss early in life to allow early habilitation.[15] Unlike most developed countries in the Netherlands approximately one third of babies are born

at home and another third leave hospital within a few hours of birth. For that reason NHS is organized by the Youth Health Care organization (YHC) and is performed either during home-visits, together with newborn bloodspot screening, or at a well baby clinic. Since 2006 NHS is offered to all well babies born or living in our country before the age of 6 weeks (Figure 2.)

Situation at:	31-12-2003	31-12-2004	31-12-2005
Regions with NHS:	n= 17	n=45	n=65
Population covered:	21%	60%	97%

Black ● : NHS implemented in that region (n=65)

Figure 2 Implementation of newborn hearing screening in the Netherlands

We verified whether the hearing screening the child was allocated to on the basis of the regional hearing screening program at the time of birth ('intention to screen') corresponded with the hearing screening the child had received, as reported by parents and noted in the audiology records ('per protocol').

Parents were invited to participate in the DECIBEL-study by mail by the AC. Medical records as well as parental questionnaires provided information on characteristics and performance measures (see below). Characteristics included maternal education level (representing socio-economic status, SES), parental hearing status, type and result of hearing screening, age at confirmation of PCHI (usually age at the first visit to an AC), age at start of amplification, degree of hearing loss and aetiology (if available).

Parents who agreed to participate in extensive developmental investigations were sent three standardized questionnaires measuring developmental outcome by mail or e-mail.

ASSESSMENT OF DEVELOPMENT

Performance measures included the primary mode of communication (oral language only or oral and sign language) and the type of education (regular education, education for hearing

impaired children or education for children with developmental disabilities) as reported by parents or audiology records.

General and language developmental outcome was measured using the Child Development Inventory, expressive language development using the MacArthur Communicative Development Inventory and Quality of Life (QoL) using the PedsQL™ 4.0. Development was assessed on the basis of parental reporting. This was inherent to the age of the study cohort.

The Child Development Inventory (CDI), former Minnesota Child Development Inventory (MCDI) is a standardized instrument designed to assess the development of children from 15 months to 6 years and is often used in research on this topic.[102] The 1992 version of the CDI was translated into the Dutch language (CDI-NL) according to the rules formulated by Guillemin et al. and was also adjusted for use in children whose primary language is sign-language.[103] Parents completed the questionnaire by indicating which of the listed 270 behavioural items they observed in their child. The items are grouped to form scales including social development, motor development and expressive language and language comprehension (combined in a total language scale). The general development score was a summary score that provided an overall index of development by including 10 of the most age discriminating items from each of the scales. The scores were recalculated by the use of the original norm-data into developmental ages and these generated developmental quotients (DQ), when divided by chronological age and multiplied by 100. A DQ >80 represents normal development. A quotient between 70 and 80 is regarded as borderline development.

The short-form version of the MacArthur Communicative Development Inventory, (N-CDI 3 further referred to as MacArthur), was used to assess 3 aspects of expressive language.[104] Active vocabulary (number of spoken words/signs, total 100), sentence complexity (ranging from 1=least complex to 3=most complex for 9 sentences, total 27) and mean length of 3 longest utterances (MLU) were evaluated. With regard to active vocabulary: parents were asked to indicate which words of the spoken vocabulary inventory were spoken, signed or both (permission for adjusting for signs was received). Crude scores were used in analysis, eliminating any ceiling or floor effects caused by children chronologically or developmentally older than the population for whom the scale was designed.

The PedsQL™ 4.0 was used to assess QoL.[105;106] The PedsQL™4.0 encompasses both physical functioning and psychosocial functioning. Each item is scored on a 5-point Likert scale. To create scale scores, the mean crude was computed as the sum of the items divided by the number of items answered (which corrects for missing data). The total QoL score is the sum of the mean crude score on all scales. Higher PedsQL™ 4.0 scores indicate better QoL.

STATISTICAL ANALYSIS

Baseline characteristics of children allocated to NHS and DHS were compared. An 'intention to screen' analysis was performed to compare the performance measures. It was investigated whether children participating in extensive developmental outcome measures were comparable to all children included in study. Additionally, in those participating in the extensive outcome study, children in NHS and DHS were compared on those variables believed to affect the outcome in children with PCHI (SES, degree of hearing loss, parental hearing status, mode of communication and age at start of amplification). Linear regression was used to compare developmental outcome. Adjustment for residual confounding was done for SES and chronological age at developmental evaluation (when applicable). The difference in chronological age at developmental evaluation between the two groups was considered a consequence of the gradual introduction of NHS, with more children in NHS being younger. Two assumptions are embedded in the study design: (1) in both types of hearing screening the proportion of children with PCHI is similar and (2) all children with PCHI are identified by the age of 5 years. These assumptions were tested.

It is known that in children with congenital cytomegalovirus (CMV) infection hearing loss may be progressive over time and not yet detectable by NHS and that development may be abnormal. The presence of this infection could possibly be confirmed prior to hearing screening when appropriate methods are used. For these reasons a sensitivity analysis was performed excluding the children with known congenital CMV infection.[45]

A 'per protocol' analysis was also performed. Differences between this analysis and the 'intention to screen' analysis will be acknowledged.

The significance level was set at $p < 0.05$. All statistical tests were carried out using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

In the 2003-05 study cohort 335.560 children were offered NHS and 234.826 were offered DHS (Figure 1 and Table 1). At follow-up 0.78 per 1000 children in NHS and 0.73 per 1000 in DHS were known with PCHI to an Audiology Center (Figure 1).

In the study on performance measures the two groups (NHS 183, DHS 118) were comparable with respect to the degree of hearing loss, primary mode of communication and type of education (Table 2). Extensive developmental outcome measures were complete for 75 children in NHS and 64 children in DHS. The children available for extensive developmental assessment had a lesser degree of hearing loss than those not-participating (data not shown). Children in

		NHS	DHS
Year of birth	2003	42.166	152.900
	2004	114.374	76.200
	2005	179.020	5526
	Total	335.560	234.626
Prevalence of PCHI of congenital cause per 1000 children screened	2003	0.76	0.77
	2004	0.82	0.63
	2005	0.77	0.90
	Total	0.78	0.73

Table 1 Number of children allocated to a certain hearing screening program and prevalence of PCHI per year.

CHARACTERISTICS	NHS N=183	DHS N=118	P-VALUE
Degree of hearing loss- N (%) (n=179;118)			.898
Moderate (40-60 dB)	88 (49.2)	58 (49.2)	
Severe (60-90 dB)	49 (27.4)	30 (25.4)	
Profound (>90 dB)	42 (23.5)	30 (21.7)	
Primary mode of communication–N (%) (n=97;80)			.601
Oral language only	28 (28.9)	26 (32.5)	
Oral and sign language	69 (71.1)	54 (67.5)	
Type of education (in children > 48months)- N (%) (n=71;89)			.131
Regular education	18 (25.4)	23 (25.8)	
Regular education with counselling for hearing impairment	1 (1.4)	5 (5.6)	
Education for children with hearing impairment	49 (69.0)	61 (68.5)	
Education for children with developmental disabilities	3 (4.2)	0 (0.0)	

Table 2 Performance measures in children with PCHI at 3-5 years.

NHS and DHS participating in extensive outcome measures were comparable on all baseline characteristics except for a difference in age at amplification (13.1 months, p-value<0.00) and age at evaluation of development, language and QoL (13.2 months, p-value<0.00), with children in NHS being younger. The mean age at amplification in children in NHS was 15.9 months (SD 14.1) (Table 3.).

CHARACTERISTICS AT BIRTH	NHS N=75	DHS N= 64	P-VALUE
Male- N (%)	44 (58.7)	36 (56.3)	.774
Caucasian- N (%)	61 (81.3)	60(93.8)	.030
Higher education mother – N (%)	36 (48.0)	34 (53.1)	.547
Both parents normal hearing- N (%)	61 (81.3)	56 (87.5)	.568
Refer at hearing screening- N(%)	61 (81.3)	36 (69.2)#	.114
Degree of hearing loss at first evaluation- N (%)			.437
Lower than moderate (<40)	9 (12.2)	6 (9.4)	
Moderate (40-60 dB)	43 (57.3)	30 (46.9)	
Severe (61-90 dB)	11 (14.9)	15 (23.4)	
Profound (>90 dB)	12 (16.2)	13 (20.3)	
CHARACTERISTICS AT 3-5 YEARS			
Mean age at amplification in months (SD)	15.9 (14.1)	29.0(14.6)	.000
Type of amplification-N (%)			
Hearing aid	54 (72.0)	48 (75.0)	.554
Bone anchored hearing aid	5 (6.7)	2 (3.1)	
Cochlear Implant	16 (21.3)	13 (20.3)	
Hearing aid previously but not at present	0 (0)	1 (1.6)	
Mode of communication –N (%)			
Oral language only	30 (40.0)	26 (40.6)	.940
Oral and sign language	45 (60.0)	38 (59.4)	
Additional handicaps – N (%)	3 (4.0)	8(12.7)	.528
Mean chronological age at developmental evaluation CDI_NL in months (SD)	47.9 (10.0)	60.7 (6.9)	.000
Mean chronological age at language and QoL evaluation in months (SD)	45.8 (9.8)	59.0 (7.3)	.000

In the DHS group no hearing screening result was available for 12 children as they had not been screened (per protocol analysis).

Table 3 Characteristics at birth and at extensive developmental evaluation – Intention to screen analysis

The development of children in NHS was better (reflected by a higher mean quotient) on all scales of the CDI-NL than children in DHS (Table 4). Following adjustment for SES, (slightly higher in the DHS group) the mean developmental difference increased on all scales, resulting in a significant difference in social development and gross motor development. Additional adjustment for the degree of hearing loss, ethnicity or parental hearing status did not contribute to the model.

A larger spoken vocabulary was found using the MacArthur in children in the NHS group, when adjustment was made for SES and age at developmental evaluation. Children in the NHS group used fewer signed words compared to children in the DHS group. The level of sentence

DEVELOPMENT QUOTIENT CDI-NL (MEAN (SD))	NHS N= 68	DHS N= 57	MEAN DIFFERENCE (95% CI) ADJUSTED FOR SES
General development	81.8 (16.6)	79.5(16.1)	2.8 (-2.8;8.5)
Self Help	87.9 (24.0)	82.1(20.3)	6.3 (-1.6;14.2)
Expressive language	82.8 (25.3)	76.1 (24.8)	7.6 (-1.1;16.3)
Language comprehension	76.1 (19.1)	72.8 (19.0)	4.1 (-2.5;10.6)
Total language	79.5 (21.3)	74.5 (20.3)	5.8 (-1.3;13.0)
Social development	80.2 (24.3)	72.3 (22.0)	8.7 (0.6;16.7)[a]
Fine motor development	90.0 (19.2)	86.1 (15.6)	4.5 (-1.5; 10.6)
Gross motor development	86.1 (24.4)	77.5 (20.5)	9.0 (1.0;17.0)[a]
CRUDE MEAN SCORE MACARTHUR (MEAN (SD))	NHS N=72	DHS N=60	MEAN DIFFERENCE (95% CI) ADJUSTED FOR SES AND AGE
Total words (spoken)	55.3 (33.8)	66.7(31.9)	11.5 (-1.0;24.1)
Total words (signed)	11.3 (17.5)	18.4 (24.9)	-12.0 (-21.0;-2.9)[a]
Sentence structure spoken (n=67;57)	16.7 (7.8)	20.5(7.0)	0.6 (-2.3;3.5)
Mean length of longest utterance (n=61;52)	5.5 (2.4)	6.7 (3.1)	-0.2 (-1.4;1.0)
MEAN SCORE PEDSQL™ 4.0. (MEAN (SD))	NHS N= 75	DHS N= 64	MEAN DIFFERENCE (95% CI) ADJUSTED FOR SES
Physical	91.3 (10.8)	86.3 (17.7)	5.1 (0.2;10.0)[a]
Emotional	76.7 (15.1)	71.7 (14.8)	5.0 (-0.1;10.1)
Social	86.4 (14.6)	77.4 (15.5)	9.8 (4.6;14.9)[a]
Psychosocial	82.8 (10.9)	76.8 (11.4)	6.4 (2.6;10.2)[a]
Total score	86.1 (8.8)	80.4 (12.1)	6.0 (2.4;9.6)[a]

[a] p<0.05. The values represent differences between NHS and DHS.
Note: Higher mean scores indicate better results.

Table 4 Developmental outcome in NHS and DHS- intention to screen analysis

complexity and the mean length of longest spoken utterance were comparable in both groups after adjustment.
Quality of life was statistically significantly higher in children in the NHS group, except for the mean crude score on the emotion scale. Adjustment for SES did not influence the results (Table 4.).

In sensitivity analysis 10 children with congenital CMV infection were excluded (5 in each group). In addition to social development, gross motor development and QoL, language developmental outcome (expressive language and spoken vocabulary) of children in NHS was statistically significantly better compared to children in DHS (data not shown).
One AC selected only those children not already participating in other research projects for

participation in this study. A sensitivity analysis, excluding all children from that AC to rule out possible selection-bias, revealed similar results (data not shown).
Verification of the type of hearing screening showed that 12 children underwent no hearing screening, 8 children had undergone direct diagnostic evaluation, 8 children were screened by NHS but were in the 'intention to screen' DHS and 1 child was screened by DHS instead of the 'intention to screen' NHS. This resulted in 119 children in the per protocol analysis (78 in NHS, 41 in DHS). The outcome results were comparable to the results found in the intention-to-screen analysis (data not shown).

COMMENT

We found that children with PCHI have better general developmental outcome, language developmental outcome and QoL at the age of 3-5 years when screened by NHS compared with DHS.
This is the first time outcome following hearing screening in children with PCHI has been studied in a unique, pseudo-randomized design. Ethical and practical considerations which usually preclude a randomized trial were bypassed by a 'natural' phenomenon occurring at the time of study in our country. Gradual replacement of type of hearing screening lead to allocation to one or the other hearing screening program, based on the type of hearing screening offered at the place and date of birth, resulting at birth in 2 groups each with an equal prognosis of developmental outcome.
Our study has certain limitations. First, there could be a response bias, since it is unknown if parents of children with abnormal development were more eager to participate. However, it is not likely that this bias affected children unequally in the two types of hearing screening. Secondly, as a result of the relatively small sample size we were only able to detect large differences between the two groups. The results of our study however, are promising.
Verification of the assumptions embedded in the study design revealed that the proportion of children with PCHI is comparable in both types of hearing screening program and that, of all children with known PCHI at 3-5 years and a negative screen for hearing loss, only two children (with hearing loss of moderate degree) presented when older than school-age (48 months).[107] We therefore conclude that it is unlikely that children with more severe hearing loss of congenital cause will present later than school-age since a certain level of communication skill is required to start school, but moreover there is an extensive network of youth health care organizations monitoring the (language) development of all children during childhood.
To put the results of the present study in context: Our results strengthen the results of previous

studies (most of which were performed in convenience samples) that report that NHS leads to advantages in language developmental outcome in childhood for children with PCHI, when compared to children with PCHI with no screening or only targeted screening of high risk infants.[21;31;34;108-110] Our study also replicates the finding that children later identified with PCHI are at risk in areas such as behaviour, emotion and quality of life.[111] Moreover, in this study better outcome following early hearing screening is demonstrated in the strongest design possible to date, with an instrumental variable facilitating this naturally randomized study.

We found better general and language development and significantly better QoL in children in NHS. It is not unlikely that QoL is not only correlated with language development or general development (leading to e.g. more effective communication strategies) but also with other factors such as early parental awareness of the hearing loss due to early hearing screening by NHS.

We found that the aetiology of PCHI is an important factor when evaluating developmental outcome. Careful attention should be paid to the habilitation of children with congenital CMV infection and future studies presenting developmental outcome in children should take aetiology into account.

It has been suggested that it would be unlikely that large developmental differences could occur simply by identifying hearing loss early. Improved outcomes are to be expected only when early identification is followed by early intervention.[21] The Joint Committee on Infant Hearing (JCIH) recommends that intervention following a positive screen for hearing loss at hearing screening and confirmation of PCHI, should start no later than at the age of 6 months.[15] In our study, however, this recommendation was not always achieved, possibly (at least in part) due to the fact that in the study period NHS was still in its implementation phase. If anything, the delay between identification and amplification might have resulted in a reduction of the developmental differences between NHS and DHS in this study.

Finally, it is important to realize that despite early hearing screening the development of children with PCHI at 3-5 years following NHS, is still not comparable to that of normally developing children with normal hearing.

CONCLUSION

We believe that the results of our study, due to its design and its nationwide character provide clear evidence for the importance of early hearing screening programs. We found that early hearing screening by NHS is advantageous for general and language development and QoL in children with PCHI at school-age.

ACKNOWLEDGEMENTS

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