
The impact of universal newborn hearing screening on long-term literacy outcomes: a prospective cohort study.


doi: 10.1136/archdischild-2014-307516

This version is available: [https://radar.brookes.ac.uk/radar/items/e43d98cb-5d93-4ebb-84cf-2e4265df49c6/1/](https://radar.brookes.ac.uk/radar/items/e43d98cb-5d93-4ebb-84cf-2e4265df49c6/1/)

Available on RADAR: January 2016

Copyright © and Moral Rights are retained by the author(s) and/ or other copyright owners. A copy can be downloaded for personal non-commercial research or study, without prior permission or charge. This item cannot be reproduced or quoted extensively from without first obtaining permission in writing from the copyright holder(s). The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the copyright holders.

This document is the published version of the journal article.
The impact of universal newborn hearing screening on long-term literacy outcomes: a prospective cohort study

Hannah Pimperton,1 Hazel Blythe,2 Jana Kreppner,2 Merle Mahon,3 Janet L Peacock,4 Jim Stevenson,2 Emmanouela Terlektsi,1 Sarah Worsfold,1 Ho Ming Yuen,1 Colin R Kennedy1,5

ABSTRACT
Objective To determine whether the benefits of universal newborn hearing screening (UNHS) seen at age 8 years persist through the second decade.
Design Prospective cohort study of a population sample of children with permanent childhood hearing impairment (PCHI) followed up for 17 years since birth in periods with (or without) UNHS.
Setting Birth cohort of 100,000 in southern England.
Participants 114 teenagers aged 13–19 years, 76 with PCHI and 38 with normal hearing. All had previously their reading assessed aged 6–10 years.
Interventions Birth in periods with and without UNHS; confirmation of PCHI before and after age 9 months.
Main outcome measure Reading comprehension ability. Regression modelling took account of severity of hearing loss, non-verbal ability, maternal education and main language.
Results Confirmation of PCHI by age 9 months was associated with significantly higher mean z-scores for reading comprehension (adjusted mean difference 1.17, 95% CI 0.36 to 1.97) although birth during periods with UNHS was not (adjusted mean difference 0.15, 95% CI −0.75 to 1.06). The gap between the reading comprehension z-scores of teenagers with early compared with late confirmed PCHI had widened at an adjusted mean rate of 0.06 per year (95% CI −0.02 to 0.13) during the 9.2-year mean interval since the previous assessment.
Conclusions The benefit to reading comprehension of confirmation of PCHI by age 9 months increases during the teenage years. This strengthens the case for UNHS programmes that lead to early confirmation of permanent hearing loss.
Trial registration number ISRCTN03307358.

INTRODUCTION
Bilateral permanent childhood hearing impairment (PCHI) of moderate, severe or profound severity is the commonest sensory disability affecting 1 in 750 children and is present at birth in more than 80% of affected children.1 PCHI of this degree has a detrimental impact on all aspects of oral language development and impacts significantly on skills that depend on language ability, such as reading and writing.4–7

Identification of PCHI in early childhood enables affected children to receive early intervention to optimise their language access during a ‘sensitive period’ for language development.8 More than half of babies born with PCHI do not have prospectively identifiable risk factors so that only universal newborn hearing screening (UNHS) programmes can identify the majority of those affected. UNHS, when first introduced in the UK, more than doubled the proportion confirmed by 9 months to three-quarters of all cases of bilateral PCHI ≥40 dB.9 10 We have previously reported that children with PCHI from that birth cohort had significant benefits to language and reading at age 6–10 years associated with birth in periods with UNHS and with confirmation of PCHI by age 9 months.11–13

Systematic reviews have been increasingly supportive of UNHS14–16 and both the UK National Screening Committee and the US Preventative Services Task Force have recommended in favour of it.17–19 During the calendar year of 2009, an estimated 5073 cases of PCHI were detected by UNHS in the USA, accounting for 43% of all detected cases of the 29 medical conditions for which newborn screening is recommended.20

Both the US Preventative Services Task Force15 17 and a 2009 WHO report on UNHS21 have,
however, drawn attention to the evidence gap regarding benefits beyond primary school age and benefits to functional outcomes. This study consequently aimed to provide novel evidence regarding the effects of UNHS and early confirmation of PCHI on functional outcomes in the teenage years. We report findings regarding the abilities of teenagers with PCHI at age 17 years whom we previously assessed at age 8 years.\(^9\)\(^11\) Reading is a skill that is dependent on underlying language ability\(^2^2\)\(^2^3\) that relates very closely to educational and employment outcomes, and as such is a key functional outcome.\(^2^4\) Reading comprehension was therefore prespecified as the primary outcome in this study.

**PATIENTS AND METHODS**

The children in this prospective follow-up study, 120 children with bilateral PCHI \(\geq 40\) decibels hearing level (dB HL) (not known to be postnatally acquired) and a comparison group of 63 normally hearing children, were drawn from a birth cohort of 157,000 children born in eight districts of southern England (see online supplementary appendix 1), of whom about half were born in periods with UNHS. We previously reported a number of details relating to this population in infancy and first decade, including the UNHS programmes for PCHI to which they were exposed; the service provision by district and regional audiology and by other services for confirmation and management of their PCHI; and the language and reading abilities of the children at 6–10 years.\(^9\)\(^–\)\(^1^3\)\(^2^5\)\(^–\)\(^3^1\) Nine years after their previous language and reading assessments at 6–10 years, 76 (63%) teenagers with PCHI and 38 (60%) of the normally hearing comparison group have now participated in the study we report here (figure 1). We estimate that 49% of all oral language users with PCHI from the birth cohort had their reading assessed at age 17.1 years (see online supplementary appendix 1).

---

**Figure 1** Numbers of teenagers with permanent childhood hearing impairment who were eligible for the study and assessed for reading ability at primary school and teenage. Greyed out section of the figure indicates the previous study at age 6–10 years. dB HL, decibels hearing level.
Procedure
Each participant was assessed by a trained researcher, unaware of their audiological history, using the York Assessment of Reading for Comprehension Secondary Edition,32 a standardised reading test that provides measures of accuracy, comprehension and summarisation skill (see online supplementary appendix 1). A 20 min timed version13 of Raven’s Standard Progressive Matrices Plus31 was used as a measure of non-verbal ability. The preplanned primary outcome of our study was reading comprehension score after adjustment in a multiple linear regression for severity of hearing loss, non-verbal ability and maternal education, which were recognised as potential confounders of the primary outcome.11 Adjusted reading accuracy and reading summarisation ability z-scores were preplanned secondary outcomes.

Severity of hearing impairment was categorised from the most recent audiological evaluation at audiology and cochlear implant clinics as moderate (40–69 dB HL), severe (70–94 dB HL) or profound (≥95 dB HL) according to four-frequency averaging of the pure-tone thresholds at 0.5, 1, 2 and 4 kHz. Maternal education was classified according to the 2001 census in the UK.

This study was approved by the Southampton and SW Hampshire Research Ethics Committee. Written informed consent for participation in the study was obtained from principal caregivers and from the teenage participants themselves.

Analysis strategies
The primary outcome (reading comprehension) and the analysis strategy were prespecified and the statistical analysis plan was written before examination of the data. The target sample size of 96 with half of the sample born in periods with (or without) UNHS, or, in a parallel set of analyses, exposed to early (or late) confirmation of PCHI, was sufficient to have 90% power to detect a standardised difference in the primary outcome of at least 0.67 SDs at a 5% significance level (two sided) using a univariate test. We prespecified the definition of ‘early’ confirmation of PCHI as confirmation by nine completed months of age, consistent with the definition used in our previous trial of UNHS9 and with the US Preventive Services Task Force benchmark for diagnosing and treating infants before 10 months of age.15,16

The group mean and SD reading scores in the normally hearing comparison group were used to derive z-scores for the teenagers with PCHI where the mean and SD in the normally hearing group was 0 and 1, respectively. The z-scores in the participants with PCHI were thus expressed in terms of the number of SDs from the mean in the normally hearing comparison group. Analyses were run both with and without British Sign Language users. This did not alter the pattern of results which are therefore presented for the combined group of oral and signing communicators. Where statistically significant inter-group differences were found, subgroup analysis was then undertaken in those who had and had not received cochlear implants. The method of adjusting reading z-scores appropriately to look at change in reading ability over time comparing current scores with those previously obtained at aged 6–10 years is described in online supplementary appendix 1.

We assessed in a linear regression model the relationships between birth during periods of UNHS or confirmation of PCHI by age 9 months and age-adjusted reading z-scores (using Stata/SE V12.1) in oral and signing communicators (see online supplementary appendix 1). The extent to which the effect of early confirmation made a significant additional contribution to model fit after screening was included in the model was tested with a likelihood ratio test. Normality and homogeneity of the residual variance were examined for all measures to ensure that the regression models were appropriate.

RESULTS
The 114 participating teenagers were similar to the 183 who had previously participated in the study of reading and language at 7.9 years with regard to sex, non-verbal ability and maternal educational level at the time of the previous study (table 1). The 76 participants with PCHI (figure 1) were similar to the 120

| Table 1 Demographic characteristics of participants and non-participants in the current study of reading ability in teenagers |
|------------------|------------------|------------------|------------------|------------------|
| Characteristic                                           | Children with bilateral PCHI | Normally hearing children |
|                                                          | Whole sample* (n=120) | Teenage sample participating in present study (n=76) | Whole sample* (n=63) | Teenage sample participating in present study (n=38) |
| Mean age (SD) (range) in years                          | 7.9 (1.3) | 7.9 (1.1) | 8.1 (1.0) | 8.0 (1.1) |
| At primary school assessment                           | (5.4 to 11.7) | (5.8 to 10.7) | (6.2 to 9.8) | (6.2 to 9.8) |
| Female sex n (%)                                     | 53 (44) | 37 (49) | 26 (41) | 13 (34) |
| Severity of hearing loss n (%)                        | Moderate | 62 (52) | 38 (50) | NA | NA |
|                                                  | Severe | 29 (24) | 16 (21) | NA | NA |
|                                                  | Profound | 29 (24) | 22 (29) | NA | NA |
| Born in periods with UNHS n (%)                      | 61 (51) | 37 (49) | NA | NA |
| PCHI confirmed ≤9 months n (%)                      | 57 (48) | 35 (46) | NA | NA |
| English as main language at home n (%)               | 99 (83) | 67 (88) | 60 (95) | 36 (95) |
| Maternal education n (%)                            | No qualifications or <5 O-levels† | 42 (36) | 24 (32) | 25 (40) | 11 (29) |
|                                                        | ≥5 O-levels or some A-level† | 62 (52) | 40 (53) | 25 (40) | 16 (42) |
|                                                        | University or higher degree | 14 (12) | 12 (16) | 13 (21) | 11 (29) |

*The ‘whole sample’ was a population-based sample of children with PCHI and a normally hearing comparison group that participated 9 years earlier in a study of language and reading at primary school age.
†O-level examinations (now replaced by general certificates of education) are usually taken at 16 years of age; A-level examinations (now replaced by A2s) are taken 2 years later as qualifications for entry to higher education.

NA, not applicable; PCHI, permanent childhood hearing impairment (see Patients and methods section for detailed definition of degree of PCHI); UNHS, universal newborn hearing screening.
who had previously participated with regard to severity of PCHI, exposure to UNHS and confirmation of PCHI prior to nine completed months from birth (table 1). These characteristics were also similar between those who had their PCHI confirmed by age 9 months (n=35) and those who had it confirmed later (n=41) (table 2) and between those who were born in periods with UNHS (n=37) and those who were not (n=39) (data not shown). The early and late confirmed PCHI groups were similar with respect to the percentages affected by cerebral palsy, visual disability or learning disability (table 2). These effects were working independently (see online supplementary table e1). The teenagers who had their hearing impairment confirmed by nine completed months of age had significantly higher adjusted mean z-scores than the later confirmed teenagers for both reading comprehension (1.17 SD) and reading summarisation (0.96 SD) (table 3). These effect sizes were larger in the 78% (51/65) who had not received cochlear implants (adjusted inter-group differences 1.29, 95% CI 0.52 to 2.07, p=0.002; 1.00, 95% CI 0.30 to 1.70, p=0.006, respectively). Adjusted inter-group z-score differences on the three reading outcome measures between all teenage participants who were or were not born in periods with UNHS at birth were smaller (0.09 to 0.22) and not statistically significant (table 3).

Change in the estimates of effect sizes and p values of early confirmation and of screening was minimal when they were modelled together rather than separately, suggesting that these effects were working independently (see online supplementary table e1). Adding the effect of early confirmation into the regression model after screening was included made a significant additional contribution to model fit (likelihood ratio test

Table 2 Characteristics of participating teenagers with hearing impairment and with normal hearing

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Children with bilateral PCHI (n=76)</th>
<th>Confirmation of PCHI at ≤9 months (n=35)</th>
<th>Confirmation of PCHI at &gt;9 months (n=41)</th>
<th>Normally hearing children (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD) age at assessment in years</td>
<td>16.8 (1.5) 17.3 (1.3) 16.3 (1.2)</td>
<td>21.5 (1.5) 21.5 (1.5) 13 (34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female sex n (%)</td>
<td>16 (46) 21 (51) 13 (34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Born in period with UNHS n (%)</td>
<td>23 (66) 14 (34) NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity n (%)</td>
<td>Moderate* 16 (45) 17 (41)</td>
<td>Severe 7 (20) 12 (29) NA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cochlear implants/</td>
<td>7 (20) 8 (19)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hearing aids/s</td>
<td>23 (66) 32 (78) NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No hearing device</td>
<td>5 (14)+ 1 (2)+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD) non-verbal ability z-score§</td>
<td>−0.3 (0.9) 0 (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aetiology n (%)</td>
<td>Syndromic 9 (26) 4 (10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other hereditary</td>
<td>6 (17) 10 (24) NA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Known non-genetic risk¶</td>
<td>2 (6) 3 (7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not known</td>
<td>18 (51) 24 (59)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other disabilities n (%)</td>
<td>Cerebral palsy 1 (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual disability</td>
<td>1 (3) 1 (2) 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning disability</td>
<td>6 (17) 8 (20) 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None of the above</td>
<td>28 (80) 33 (80) 38 (100)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English as main language at home n (%)</td>
<td>34 (97) 36 (88) 36 (95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal education n (%)</td>
<td>No qualifications/&lt;5 O-levels** 9 (26) 10 (24) 6 (16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥5 O-levels or some A-levels**</td>
<td>17 (49) 21 (51) 14 (37)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University or higher degree</td>
<td>9 (26) 10 (24) 18 (47)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| NA, not applicable; PCHI, permanent childhood hearing impairment; UNHS, universal newborn hearing screening

§Age-adjusted z-scores are listed for Ravens Progressive Matrices total score. The z-scores are the number of SDs of the scores in normally hearing children by which the age-adjusted score differed from the mean score in the normally hearing children.

†One with significant additional impairments (learning disability).

¶Prematurity or cerebral palsy.

**O-level examinations (now replaced by general certificates of education) are usually taken at 16 years of age; A-level examinations (now replaced by A2s) are taken 2 years later as qualifications for entry to higher education.

¶Six participants (two with confirmation of PCHI at ≤9 months, four with confirmation of PCHI >9 months) classified with PCHI of moderate severity when previously assessed at 6–10 years of age had shown improvements by the current study such that their better ear hearing thresholds now fell between 30 and 40 dB.

‡Other hereditary disorders include one with significant additional impairments (learning disability). Three with significant additional impairments (all had chromosomal disorders and learning disability), two with moderate PCHI who were not current hearing aid users.

©Preterm or cerebral palsy.

*One with significant additional impairments (learning disability).

*Six participants (two with confirmation of PCHI at ≤9 months, four with confirmation of PCHI >9 months) classified with PCHI of moderate severity when previously assessed at 6–10 years of age had shown improvements by the current study such that their better ear hearing thresholds now fell between 30 and 40 dB.
Table 3  Reading z-scores for children with bilateral PCHI by age of confirmation of PCHI and by birth in periods with and without UNHS

<table>
<thead>
<tr>
<th>Measure</th>
<th>Number of observations</th>
<th>Mean z-score (SD)</th>
<th>Unadjusted mean difference (95% CI)</th>
<th>Adjusted* mean difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PCHI confirmed at ≤9 months</td>
<td>PCHI confirmed at &gt;9 months</td>
<td>a—b</td>
<td>p Value</td>
</tr>
<tr>
<td>YARC reading comprehension</td>
<td>28</td>
<td>37</td>
<td>−0.63 (1.63)</td>
<td>−1.74 (1.50)</td>
</tr>
<tr>
<td>YARC reading summarisation</td>
<td>28</td>
<td>37</td>
<td>−0.56 (1.37)</td>
<td>−1.36 (1.44)</td>
</tr>
<tr>
<td>YARC reading accuracy</td>
<td>27</td>
<td>33</td>
<td>−1.12 (1.69)</td>
<td>−1.71 (1.44)</td>
</tr>
</tbody>
</table>

*Adjusted for severity of PCHI, maternal education level, non-verbal ability and English as main language at home.

Figure 2  Unadjusted mean reading comprehension z-score in children with permanent childhood hearing impairment at age 10 years and 13.5 years by age of confirmation of hearing impairment at age 6 years.

DISCUSSION

The study of teenagers with PCHI, who were involved in trials of UNHS, is the first to describe the effects of UNHS on early confirmation of PCHI on outcomes beyond the primary school age. The superiority of the early confirmed PCHI group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03), remained statistically significant throughout the period of follow-up. This suggests that the early confirmed group had better reading comprehension scores at primary school age (see Patients and methods) with and without UNHS.

Comparison of the recalculated reading comprehension scores at primary school age (see Patients and methods) with the present study showed that the early confirmed group had a larger and statistically significant difference in reading comprehension scores (mean inter-group difference 0.06 per year, 95% CI 0.02 to 0.13, p=0.04). This difference became more pronounced in the late confirmed group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03).

The study of teenagers with PCHI, who were involved in trials of UNHS, is the first to describe the effects of UNHS on early confirmation of PCHI on outcomes beyond the primary school age. The superiority of the early confirmed PCHI group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03), remained statistically significant throughout the period of follow-up. This suggests that the early confirmed group had better reading comprehension scores at primary school age (see Patients and methods) with and without UNHS.

Comparison of the recalculated reading comprehension scores at primary school age (see Patients and methods) with the present study showed that the early confirmed group had a larger and statistically significant difference in reading comprehension scores (mean inter-group difference 0.06 per year, 95% CI 0.02 to 0.13, p=0.04). This difference became more pronounced in the late confirmed group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03).

The study of teenagers with PCHI, who were involved in trials of UNHS, is the first to describe the effects of UNHS on early confirmation of PCHI on outcomes beyond the primary school age. The superiority of the early confirmed PCHI group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03), remained statistically significant throughout the period of follow-up. This suggests that the early confirmed group had better reading comprehension scores at primary school age (see Patients and methods) with and without UNHS.

Comparison of the recalculated reading comprehension scores at primary school age (see Patients and methods) with the present study showed that the early confirmed group had a larger and statistically significant difference in reading comprehension scores (mean inter-group difference 0.06 per year, 95% CI 0.02 to 0.13, p=0.04). This difference became more pronounced in the late confirmed group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03).

The study of teenagers with PCHI, who were involved in trials of UNHS, is the first to describe the effects of UNHS on early confirmation of PCHI on outcomes beyond the primary school age. The superiority of the early confirmed PCHI group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03), remained statistically significant throughout the period of follow-up. This suggests that the early confirmed group had better reading comprehension scores at primary school age (see Patients and methods) with and without UNHS.

Comparison of the recalculated reading comprehension scores at primary school age (see Patients and methods) with the present study showed that the early confirmed group had a larger and statistically significant difference in reading comprehension scores (mean inter-group difference 0.06 per year, 95% CI 0.02 to 0.13, p=0.04). This difference became more pronounced in the late confirmed group, who had not received cochlear implants (mean inter-group difference 0.08 per year, 95% CI 0.01 to 0.15, p=0.03).
hearing peers and is likely to impact on their life chances through educational achievement and employment. 24

Non-verbal ability was very similar in the early and late conﬁrmed groups and adjustment for it was included in the regres-
sion model. This suggests that the deﬁcit in reading scores in the late conﬁrmed participants did not result from a general cogni-
tive deﬁcit but rather from the speciﬁc impact of delayed access
to optimal language input early in life on language-related abili-
ties. The early and late conﬁrmed groups did not show differ-
ent proportions of genetic and non-genetic aetiologies of
deafness nor of disabilities additional to deafness that might
account for the observed differences in reading z-scores.

Factors other than age at conﬁrmation of PCHI appeared to
determine reading outcomes for that minority of participants
who had received cochlear implants 36 although this subgroup
analysis was not preplanned and should be treated with caution.
A greater dependency of teenage reading ability of the
implanted subgroup on age at implantation than on age at con-
ﬁrmation may explain this difference but studies of larger
numbers of cochlear implantees are needed to determine this.

The effects of early conﬁrmation were seen in those born in
periods with and without UNHS and the effect of UNHS
appears to be dependent on the increase in rates of early con-
ﬁrmation of PCHI to which it leads. The same NHS district and
regional audiology teams delivered, in almost all cases, the care
of both screened and unscreened and of both early and late con-
ﬁrmed populations in this study 31 and the different outcomes
between these groups are likely to reﬂect the effect of UNHS
and of early conﬁrmation rather than any differences in the ser-
vice to which they were exposed. A 2013 birth cohort in the
UK would, nevertheless, be likely to show a much stronger rela-
tionship between birth in periods with UNHS and reading out-
comes. Effective postscreening audiology and other services for
those screening positive for PCHI in the newborn period, which
were largely absent in the period from 1992 to 1997 for the
population described in this report, are now in place 18 19 and
therefore screening positive on UNHS in the UK would be
more likely to lead to conﬁrmation of PCHI by age 9 months.

The annual attrition rate (ie, 3% over 17 years since UNHS
or 4% over the 9 years since assessment at primary school)
among children with PCHI eligible for the present study is low
for a teenage population with a chronic medical condition but
limited the power of the study to examine change in reading
comprehension between the primary school and teenage assess-
ments. In spite of this limitation in power, the inter-group dif-
fences on the prespeciﬁed primary outcome of reading
comprehension were large enough to be both statistically signi-
ciﬁcant and clinically important.

CONCLUSIONS

As the Millenium Development Goals project approaches its
2015 target, UNESCO, UNICEF, the World Bank and WHO are
increasingly considering early child development, in which
infant hearing is a critical component, as a key determinant of
subsequent health 21 37 and this report is therefore timely.
Conﬁrmation of PCHI by nine completed months of age was
associated with signiﬁcantly better performance on reading com-
prehension, the prespeciﬁed primary outcome variable, and the
effect size of this beneﬁt of early conﬁrmation of PCHI had
increased from moderate to large between assessments at the
ages of 8 and 17 years. This strengthens the case for national
governments to fund UNHS programmes that increase the rates
of early conﬁrmation of PCHI in the many developed and
developing countries where UNHS for PCHI is currently under
discussion but not yet adopted as national policy. 18–40

Acknowledgements We thank the research assistants Eleanor Couthard, Joanne
Pickersgill, Lisa Shipway and Zahra Taghizadeh; the audiologists Margaret Baldwin,
Allyson Bumby, Adrian Dighe, Harpreet Nijar, David Reed, Joy Roberts, Sue
Robinson, Salim Suleman, Rosbin Syed and Huw Thomas; and the other medical
and educational professionals who supported this study. We thank particularly the
participating teenagers and their families.

Contributors HP oversaw the conduct and analysis of the study, drafted the initial
manuscript and approved the ﬁnal manuscript. JK, MM, JS and SW assisted in the
design and supervision of the study, assisted with manuscript preparation and
approved the ﬁnal manuscript. JLP assisted in the design and supervision of the
study, supervised the statistical analysis, assisted with manuscript preparation and
approved the ﬁnal manuscript. HB and ET assisted in the supervision of the study
and approved the ﬁnal manuscript. HMY undertook the statistical analysis and
approved the ﬁnal manuscript. CRX designed and supervised the study, assisted in
manuscript preparation and approved the ﬁnal manuscript.

Funding This work was funded by The Wellcome Trust (Grant number 089251/Z/09/Z) which had no role in the design, conduct of the study, collection analysis and
interpretation of the data, preparation, review or approval of the manuscript, or the
decision to submit the manuscript for publication.

Competing interests None.

Ethics approval Southampton and SW Hampshire Research Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement The authors are willing to share all unpublished data
from the study with bona ﬁde researchers. The database can be made available
to them through discussion with the corresponding author and the Wellcome Trust.

Open Access This is an Open Access article distributed in accordance with the
terms of the Creative Commons Attribution (CC BY 4.0) license, which permits
others to distribute, remix, adapt and build upon this work, for commercial use,
provided the original work is properly cited. See: http://creativecommons.org/ licenses/by/4.0/.

REFERENCES

screening in the detection of congenital hearing impairment. Health Technol Assess

2 Eisenberg LS. Current state of knowledge: speech recognition and production in

3 Moeller MP, Tomblin JB, Yoshinaga-Itano C, et al. Current state of knowledge:

4 Luckner JL, Cooke C. A summary of the vocabulary research with students who are

5 Luckner JL, Hardley CM. A summary of the reading comprehension research

6 Wauters LN, Van Bon WHJ, Tellings A. Reading comprehension of Dutch deaf


8 Thomas MSC, Johnson HM. New advances in understanding sensitive periods in

9 Kennedy CR, Kimm L, Dees DC, et al. Controlled trial of universal neonatal
screening for early identiﬁcation of permanent childhood hearing impairment.

permanent childhood hearing impairment: an 8-year follow-up of a controlled trial.

11 Kennedy CR, McCann DC, Campbell MJ, et al. Language ability after early detection

12 McCann DC, Worsfold S, Law CM, et al. Reading and communication skills after
universal newborn screening for permanent childhood hearing impairment. Arch Dis
Child 2006;91:293–7.

13 Worsfold S,Mahon M, Yuen HM, et al. Narrative skills following early conﬁrmation

14 Pimperton H, Kennedy CR. The impact of early identiﬁcation of permanent
childhood hearing impairment on speech and language outcomes. Arch Dis Child
2012;97:468–53.

15 Nelson HD, Bougatsos C, Nygren P. Universal newborn hearing screening:
 systematic review to update the 2001 US Preventive Services Task Force
The impact of universal newborn hearing screening on long-term literacy outcomes: a prospective cohort study

Hannah Pimperton, Hazel Blythe, Jana Kreppner, Merle Mahon, Janet L Peacock, Jim Stevenson, Emmanouela Terlektsi, Sarah Worsfold, Ho Ming Yuen and Colin R Kennedy

Arch Dis Child published online November 25, 2014

Updated information and services can be found at:
http://adc.bmj.com/content/early/2014/11/24/archdischild-2014-307516

Supplementary Material

Supplementary material can be found at:
http://adc.bmj.com/content/suppl/2014/11/24/archdischild-2014-307516.DC1.html

These include:

References

This article cites 33 articles, 12 of which you can access for free at:
http://adc.bmj.com/content/early/2014/11/24/archdischild-2014-307516#BIBL

Open Access

This is an Open Access article distributed in accordance with the terms of the Creative Commons Attribution (CC BY 4.0) license, which permits others to distribute, remix, adapt and build upon this work, for commercial use, provided the original work is properly cited. See:
http://creativecommons.org/licenses/by/4.0/

Email alerting service

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections

Articles on similar topics can be found in the following collections

Open access (102)
Child health (3332)
Screening (epidemiology) (471)
Screening (public health) (471)
Epidemiologic studies (1544)
Disability (234)
Ear, nose and throat/otolaryngology (266)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/