Early Human Development 103 (2016) 85–90

Contents lists available at ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Early developmental outcomes predicted by gestational age from 35 to 41 weeks

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ARTICLE INFO

Article history:
Received 3 April 2016
Received in revised form 30 June 2016
Accepted 17 July 2016
Available online xxxx

Keywords:
Late preterm birth
Early term birth
Ages and Stages Questionnaires
Developmental delay

ABSTRACT

Background: Recent studies have indicated that children born only a few weeks earlier than their due date experience more health and cognitive problems than previously realized.
Aims: Our study investigated whether gestational age (GA) at birth (35–41 weeks) predicted developmental outcomes at 8, 12, 20, or 24 months of age.
Study design: Archival records of developmental screening scores collected between 2006 and 2012 were analyzed using negative binomial and logistic regressions models.
Subjects: Eight-month (N = 3319), 12-month (N = 2303), 20-month (N = 1461) and 24-month (N = 1222) old children were assessed in a county-wide developmental screening program.
Outcome measures: Ages and Stage Questionnaires (ASQs) scores.
Results: After controlling for demographic covariates, from 35 weeks of gestation on, each additional week of gestation (through 41) significantly reduced the overall risk for developmental delay at 8,12, 20 and 24-months of age. Gestational age also uniquely predicted specific risk for delay in the domains of *communication*, *personal-social*, *fine-motor*, and *problem solving* at various time-points during the first two years of life.
Conclusions: With each additional week of gestation past 35 weeks there was a graded decrease in the overall risk of developmental delay as well as in specific domains such as *communication* across the first two years of life. This evidence for the "dose-response" effect of GA on later development suggests that close monitoring of developmental outcomes for children born before 40 weeks is warranted.

A growing number of studies (for reviews, see [1,2]) have reported adverse clinical and developmental outcomes for children born between $34^{0}/_{7}$ and $36^{6}/_{7}$ weeks of gestation (i.e., late preterm birth-LPT). Lately, studies suggested that such risks for developmental problems might not be limited to LPT children. Children born only a few weeks early (i.e., early term-ET: 37 to 38 weeks of gestation) have been found to experience more developmental problems than previously realized [3,4]. Given that about a third of all births occur between 34 and 38 weeks of gestation [5], it is imperative to understand the risks these children might be facing after birth.

Previous studies reported that compared to children who were born full-term ($39^{0}/_{7}$–$40^{6}/_{7}$), children born LPT and ET experience higher morbidities [6,7], slower neurological development [8–10], worse cognitive performance [11,12], more school-related problems and poorer academic achievements [13–15], lower education and socioeconomic attainment as adults [16], and a higher risk for cognitive impairments in late adulthood, especially for those with lower education level [17]. Therefore, it is important to identify any problems early in development. With proper interventions, later negative developmental outcomes might be mitigated.

Our study focused on early developmental outcomes as measured by a popular developmental screening tool, the Ages and Stages Questionnaires (ASQs [18,19]), among children who were born between 35 and 41 weeks of gestation. Our study adds to the current body of research in the following ways: a) we considered the development of a wide range of abilities assessed by the ASQ in the first two years. Some of them, such as those involved in the social and communication areas, have not often been examined in previous studies. Most of the earlier studies on early development have focused on health outcomes and to a lesser degree on cognitive abilities; b) our study delineated the risk for developmental delays as a function of GA (35–41 weeks). By treating GA as a continuous rather than a categorical variable (i.e., LPT or ET), we could provide a clearer picture of the "dose-response" effect of GA on early

Abbreviations: GA, gestational age; LPT, late preterm birth; ET, early term birth; ASQ, Ages and Stages Questionnaires.

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http://dx.doi.org/10.1016/j.earlhumdev.2016.07.006
0378-3782/

development; and c) we examined the relationships between GA and ASQ scores at *four* different time points during the first two years of development. It allowed us to see how consistently GA predicted developmental outcomes in infants from 8 to 24 months of age. We hypothesized that the risk for potential developmental delays would decrease as a function of GA from 35 to 41 weeks.

1. Methods

This study is a retrospective analysis of infant developmental screening results collected by the Family Futures' Connections program, a non-profit, child development support program in Michigan. Family Futures uses county birth records to contact the families of all infants born in three Michigan counties and offers free enrollment in the Connections program that provides age appropriate developmental screening tools, the Ages and Stages Questionnaire (ASQ [18,19]), across the first five years of childhood. Approximately 10.5% of families invited through the birth record mailings completed at least one ASQ during the time-period from which the sample for this study was drawn. As a group, the participants in the program are fairly representative of the surrounding population on demographic characteristics such as race and income, but show a higher proportion of college graduates than is typical for the area. See Table 1 for demographic information on each sample and 2010 census data for the area [20]. After families complete an ASQ they receive general developmental information targeted to their child's age and a report of their child's scores. If there are any developmental concerns (e.g. a low score), parents are also contacted by parent coaches who provide additional developmental resources and referrals for follow-up.

1.1. Participants

The deidentified developmental screening results analyzed in this study were drawn from the Connections program's archival records using the following inclusion criteria: children who had: a) been enrolled in the program after Jan. 1, 2006 and a completed 4-month or 8-month screening by Aug. 25, 2012, b) been born between 35 and 41-weeks of gestation, c) had complete demographic information, and d) had at least one completed screening at either 8, 12, 20, or 24-months of age. Although not a specific exclusion criteria for the study, it is important to note that the ASQ administration practice of discontinuing screenings for children who have been identified as having a documented developmental delay or neuro-atypicality [18,19]. As a result of this practice, our analyses only included scores from children not known to have an actual developmental delay or atypicality at the time of screening. From this pool, four samples were created. The 8-month-old sample included all children eligible under the inclusion criteria who also had a completed ASQ at the 8-month time-point ($N = 3319$). Twelve-month-old ($N = 2303$), 20-month-old ($N = 1461$), and 24-month old ($N = 1222$) samples were created in a like fashion. Demographic information for each sample is presented in Table 1.

1.2. ASQ administration

The ASQ is a standardized developmental screening and monitoring tool used to help identify potential developmental delays in five different areas: communication, gross-motor, fine-motor, problem solving, and personal-social. The psychometric properties of the ASQ have been investigated extensively and found to be excellent [18,19]. Validity studies comparing results from the ASQ to results from professionally administered standardized tests such as the Battelle Developmental Inventory have found that across test intervals, both the sensitivity and specificity of ASQs are high (85–92% and 78–92%, respectively), whereas over-identification and under-identification of delays tend to be low (6–13% and 1–13%, respectively) [19]. Test-retest reliability is also high [19]. The validity of ASQ scores has also been reported in non-English speaking community samples [21,22].

The ASQ screening tool contains 21 questionnaires administered at pre-specified age intervals ranging from 2 to 60 months. The questionnaires are designed to be completed by parents/primary caregivers [18,19]. Families involved in the Connections program choose the method (paper & pencil or on-line) and the language (English or Spanish) of the questionnaires that they complete. Parents were contacted about the appropriate ASQ 20 days before the age for which that ASQ was designed. For example, families receive the 12-month ASQ or an on-line invitation to the ASQ when their child turned 11 months and ten days of age and could return it any time within the ASQ defined window for that screen.

1.2.1. Measures:

1.2.1.1. ASQ scoring. Children are classified as in the *normal* or *low* range in each ASQ domain. A *low* score signifies that a child obtained a score ≥ 2SD lower than the mean score of other children tested. A *low* score indicates that a child should be further tested for the presence of a possible developmental delay, but is not itself a diagnosis of a developmental delay. Because the definition of a low score (≥2SD below mean) remained consistent across ASQ versions (ASQ-2 to ASQ-3) developmental screening data obtained using either version of the ASQ were included in these analyses. Adjusted ages of administration were used for any infant born earlier than 37 weeks as per the ASQ administration guidelines [19]. For example, an infant born at 36 weeks received the first invitation for the 12-month ASQ at the actual age of 8 days after their first birthday rather than 20 days before.

1.2.1.2. Gestational age. Gestational age (GA) was gathered via parent report on the demographics form submitted at entrance to the Connections program and was treated as a continuous predictor.

Table 1
Demographic, gestational age and overall risk for developmental delay score information for each sample.

Sample	8-Month	12-Month	20-Month	24-Month	2010 Census Information for area (all ages)
Size	$N = 3319$	$N = 2303$	$N = 1461$	$N = 1222$	
Gender (% Male)	53	52	52	53	49
Ethnicity (% Caucasian)	76	78	82	82	80
Mean family income (Median)	58,088 (62,500)	60,062 (62,500)	62,722 (62,500)	62,547 (62,500)	------ (52,176)[a]
Mother's education % 4-year college degree	60	63	64	63	33[a] (adults over 25)
Gestational age mean (SD)	39.36 (1.23)	39.36 (1.22)	39.30 (1.28)	39.30 (1.28)	
Overall risk score (0–5) Mean (SD)	0.19 (0.54)	0.11 (0.39)	0.19 (0.53)	0.15 (0.48)	
# of Children with one or more low ASQ scores (%)	484 (14.6%)	199 (8.6%)	214 (14.6%)	134 (11.0%)	

[a] 2010–2014.