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Infant developmental milestones and adult intelligence: A 34-year follow-up

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ABSTRACT

Background: A number of studies suggest a positive association between faster infant motor development and intellectual function in childhood and adolescence. However, studies investigating the relationship between infant motor development and intelligence in adulthood are lacking.
Aims: To investigate whether age at achievement of 12 motor developmental milestones was associated with adult intelligence and to evaluate the influence of sex, parental social status, parity, mother's cigarette consumption in the last trimester, gestational age, birthweight, and birth length on this association.
Methods: Mothers of 9125 children of the Copenhagen Perinatal Cohort recorded 12 developmental milestones during the child's first year of life. A subsample of the cohort comprising 1155 individuals participated in a follow-up when they were aged 20–34 years and were administered the Wechsler Adult Intelligence Scale (WAIS). Associations between motor developmental milestones and IQ were analysed by multiple linear regression adjusting for potential confounding factors.
Results: Later acquisition of infant developmental milestones was associated with lower subsequent IQ, and the majority of significant associations were found for Performance IQ. Correlations were generally small ($r < 0.10$), but significant interactions were found between parental social status and age of attaining developmental milestones, with associations being significantly stronger in the offspring of lower social status parents. The effects remained significant after adjusting for possible confounding factors.
Conclusion: This is the first study to find significant interactions with parental social status, thereby suggesting that associations between early motor development and intelligence are stronger in infants of low social status parents.

1. Introduction

Studies have shown wide variations with respect to the age when motor developmental milestones are achieved in healthy infants [1,2]. While previous studies have mainly concentrated on individuals with motor developmental delays [3,4], studies of the subtle developmental differences within the "normal" range have been conducted more rarely [5–7]. Hence, it is still an open question whether there is a relationship between the age of attaining developmental milestones and later intellectual functioning in the normal population.

Studies on infant developmental milestones and intellectual function have primarily been conducted with relatively short follow-up intervals and focused on outcomes in childhood and adolescence. Thus, infant motor development, especially age of walking, has been found to be associated with Stanford Binet IQ at 3 years [8], Wechsler Preschool and Primary Scale of Intelligence at 64 months [9], Wechsler intelligence scale for children at 6–11 years [10], cognitive tests at age 8 [6], parent-reported attention problems at 8 years [11], educational capacity at 14 years [12], and higher teacher ratings at 16 years [7]. Whether these associations persist into adulthood and infant motor development predicts adult intellectual functioning is still not sufficiently investigated. In studies with adult cognitive outcomes, infant motor development has been found to predict better educational level [7], executive function [5], reading comprehension [6], and verbal fluency [6]. However, in general, studies have not included a broader diversity of infant developmental milestones (other than standing and walking), have only included few potential confounding factors, have not investigated possible interaction effects, and have not included comprehensive measures of adult intelligence.

The mechanisms underlying infant motor development and the association with adult cognitive outcomes have not been identified, and several issues need to be further investigated such as: 1) Is the association confined to the specific motor developmental milestones, standing and walking, which have been the major focus in previous research, or is it also present for other developmental milestones, such as smiling, lifting the head and grasping after things? 2) Is the effect confined to intelligence measures in childhood and adolescence or does it also apply to intelligence in adulthood? 3) Is the association confounded or

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modified by prenatal and early postnatal factors, such as for example parental social status?

We set out to examine these questions in a large Danish general population birth cohort in which prospective information was available on the age of achievement of infant motor development in addition to adult scores on Wechsler Adult Intelligence Scale (WAIS). Thus, the aims of the present study were to examine whether age at attaining 12 motor developmental milestones was associated with IQ in adulthood and to evaluate the influence of a number of potential confounders and moderators on any observed associations. All data were collected prospectively.

2. Methods

2.1. Study sample

The Copenhagen Perinatal Cohort (CPC) was initially established with data on 8949 mothers and their 9125 consecutive deliveries at the Copenhagen University Hospital between October 1959 and December 1961.

When the cohort was established, demographic, socioeconomic, prenatal, and postnatal medical data were recorded prospectively and during pregnancy, at delivery, and at a 1-year follow-up [13]. Developmental milestones were obtained from the mothers who were instructed to use a standardized diary to record the ages (in weeks or months) at which the child reached 12 developmental milestones. The diary was brought to the hospital at a 1-year examination described elsewhere [13]. If the mother did not return the diary, an effort was made to obtain retrospective data on milestones. Table 1 shows the recorded milestones during the first year.

A subsample from the CPC participated in the Prenatal Development Project (PDP) follow-up study, between 1982 and 1994, which focused on the developmental effects of prenatal and perinatal factors, in particular the effects of prenatal exposure to prescribed maternal medications [14]. On the basis of perinatal records, 1575 potential participants were contacted, and 1155 (73%) completed the Danish version of the original WAIS [15]. Information on at least *one* developmental milestone was available for 950 (82.3%) potential participants, but 13 twins were excluded because data for twin pairs are not statistically independent. The final sample included 937 singletons (476 males and 461 females) with a mean assessment age of 27.6 years (SD = 4.3; range 20–34 years). Of the remaining 420 contacted individuals, information on at least *one* developmental milestone was available for 307 potential participants, of whom 7 were twins.

Table 1
Comparison of participating and nonparticipating subjects.

	Participants N = 937		Nonparticipants N = 300		P value[b]
	N	Mean (SD)	N	Mean (SD)	
Milestones[a]:					
Smiles (weeks)	803	5.5 (2.2)	260	5.4 (2.2)	0.71
Lifts head on stomach (weeks)	775	3.5 (2.3)	248	3.5 (2.2)	0.70
Holds head when sitting	720	3.1 (1.1)	226	3.3 (1.3)	0.07
Grasps after things	732	3.9 (1.0)	230	4.0 (1.1)	0.30
Rolls	705	5.8 (1.6)	226	5.9 (1.9)	0.30
Sits without support	863	6.9 (1.3)	272	6.9 (1.5)	0.78
Crawls	646	8.8 (1.6)	194	8.6 (1.7)	0.25
Crawls longer distance	564	9.3 (1.5)	173	9.2 (1.5)	0.46
Stands with support	848	8.5 (1.7)	272	8.5 (1.7)	0.89
Stands without support	458	10.3 (1.4)	131	10.2 (1.6)	0.23
Walks with support	751	9.9 (1.4)	223	10.0 (1.4)	0.34
Walks without support	323	11.6 (1.3)	102	11.7 (1.5)	0.59
Parental characteristics:					
Social status (1 to 8 point scale)	846	4.9 (1.8)	271	4.5 (1.7)	0.0008
Parity	936	2.0 (1.2)	298	2.0 (1.2)	0.70
Cigarette consumption last trimester (number per day)	928	3.7 (5.0)	296	3.8 (5.4)	0.13
Infant characteristics:					
Gestational age	845	39.2 (1.9)	279	39.3 (2.1)	0.60
Birthweight, g	937	3269 (555.3)	300	3275 (587.1)	0.87
Birth length, cm	935	51.2 (2.5)	300	51.3 (2.6)	0.45

[a] Milestones are measured in months unless otherwise indicated.
[b] The P values refer to T-tests of differences between the two categories.

2.2. Developmental milestones

Details of differences between the 937 participants and 300 nonparticipants with regard to milestones, parental characteristics, and infant characteristics are presented in Table 1. The rate of missing data on individual milestones varied from 7.9% (sits without support) to 65.5% (walks without support) depending on the recorded milestone. The EM algorithm [16] was used to construct a dataset with missing milestone data replaced by imputed data. This dataset was utilized to conduct principal component analysis of all 12 milestones. The first three components explained 67% of the variance, and both varimax and promax rotation defined three factors: (A) The smiling, and lifting head factor comprised milestones 1–3; (B) The rolling, crawling, sitting and grabbing factor, milestones 4–8; and (C) The standing and walking factor, milestones 9–12 (for details, see [17]). We also calculated the mean of the scores on all 12 milestones (D). To derive mean milestone scores for the three factor means and the overall mean, the distribution of each milestone was linearly standardized to a mean of 0 and a standard deviation of 1. Next, the means of the standardized scores were calculated. If a subject had missing data on one or more milestones, the mean of the available milestone scores was calculated. Finally, the three factor means and the overall mean were re-standardized to a mean of 0 and a standard deviation of 1. Since data were available for at least one milestone for all participants, there were no missing data on the overall mean of the 12 milestones, while the percentages of missing data were 9.1, 3.1 and 4.2 for the three factor means respectively.

2.3. Wechsler Adult Intelligence Scale

The WAIS [15] generates three IQ scores: Verbal (6 sub-tests), Performance (5 sub-tests), and Full-scale IQs (sum of the 11 sub-tests). It was individually administered by three psychologists who were all completely blind to the participants' early development and other prenatal and perinatal information. IQ scores were derived from Danish test norms [14].

2.4. Covariates

The following variables were considered potential confounders and included as covariates in analyses of the three WAIS IQs: (1) Sex; (2) Parental social status (was measured at the 1-year examination and was based on the social grouping of the Centre International de l'Enfance [18], in which points, 0–5, are given according to A) the occupation of the breadwinner, B) the way in which the breadwinner earns his/her wages (public relief, daily wage, weekly wage, monthly salary and own business or capital); C) the education of the breadwinner; D) the character of the living accommodation (its size, the number of persons per room, its position, etc.). When the data were first computerized more than 40 years ago, the original 0–20 point scale was converted to a scale ranging from 0 to 8 (with 8 being the highest SES) [19]. In the present study, sample frequencies of the 8 SES categories were: n = 2, 32, 51, 64, 41, 44, 24, and 13 respectively (in addition to 29 with missing values); (3) Parity; (4) Mother's cigarette consumption in the last trimester; (5) Gestational age; (6) Birthweight; and (7) Birth length. All variables were included as linear continuous variables (except for parity, included as a binary variable coding whether this was the mother's first child or not). Associations of covariates with the overall mean of milestones and Full-scale IQ respectively are shown in Table 3.