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# Does gestational duration within the normal range predict infant neuromotor development?

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**Abstract**

*Aim*: To examine the extent to which infant neuromotor development is determined by gestational duration and birth weight within the normal range.
*Methods*: The study was embedded within the Generation R Study, a population-based cohort in Rotterdam, the Netherlands. An adapted version of Touwen's Neurodevelopmental Examination was used to assess 3224 infants (1576 males and 1648 females) at corrected ages between 9 and 15 weeks. Non-optimal neuromotor development was defined as a score in the highest tertile.
*Results*: Infant neuromotor development was significantly affected by gestational duration (odds ratio 0.8, 95% confidence interval 0.7;0.8). Adding a quadratic term of gestational duration to the model revealed a highly significant curvilinear association between gestational duration and neuromotor development; after adjusting for post-conceptional age this was still significant. Although babies with a 1 kg lower birth weight had a 30% higher risk of non-optimal neuromotor development, this association disappeared after adjustment for post-conceptional age.
*Conclusions*: Our findings indicate that differences in infant neuromotor development can be explained even by variations in gestational duration within the normal range. If an infant is found to have minor neuromotor delays, account should be taken of this.
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## 1. Introduction

Neuromotor assessment is an accepted means of measuring the maturity and intactness of an infant's central nervous system. Its relevance is demonstrated by the fact that impaired development of the central nervous system in the first year of life is expressed mainly in neuromotor delay. As numerous follow-up studies have shown [1–4], neuromotor development in preterm and low birth weight infants can often be slightly or even markedly delayed. However, in infants born in the normal range of gestational duration or birth weight, it is unknown whether there is an association between gestational duration and neuromotor development.

Research on infant neuromotor development has led to the postulation of several theories. According to the neuromaturational theory, development is not influenced by exposure to the intrauterine or extrauterine environment, but is merely a consequence of the maturation of the central nervous system. Following this reasoning, neuromotor development is thus determined particularly by post-conceptional age [5]. Alternatively, under the dynamic systems theory, a central role in neuromotor development is played by interaction with the environment, to which maturation of the brain is subordinate [6]. The degree of neuromotor development is thus determined largely by exposure to the extrauterine environment, i.e. postnatal age.

Different associations between birth weight and neuromotor development are also postulated in two seemingly opposing theories. The foetal origins theory posits that an adverse foetal environment leads to developmental adaptations that permanently program the foetus' structure, physiology and metabolism [7]. The adverse foetal environment manifests itself in foetal growth retardation and low birth weight. According to the same theory, foetal growth retardation and subsequent low birth weight are risk factors for health and developmental problems in both childhood and adulthood. In the brain sparing theory, however, it is assumed that the brain is comparatively well protected against an inadequate supply of nutrients. This would mean that birth weight in the normal range is not associated with neuromotor developmental delays.

Our study therefore had three objectives. The first was to examine whether gestational duration within the normal range determines neuromotor development. The second was to establish how important it is that this time is spent in utero — in other words, whether an infant's risk of neuromotor problems is still affected by gestational duration when post-conceptional age is kept constant. The third was to determine whether there is a relationship between birth weight within the normal range and neuromotor development.

## 2. Methods

### 2.1. Participants and design

This study was embedded within the Generation R Study, a population-based cohort study from foetal life until young adulthood. The Generation R Study has been described in detail elsewhere [8,9]. Briefly, pregnant women who were resident in the city of Rotterdam at the time of their delivery and whose delivery data lay between April 2002 and January 2006, were asked by their midwives to participate. For the current study, the parents of a total of 7893 children were approached for postnatal participation; 7045 children were eligible for a neuromotor assessment.

The aim was to visit all eligible children at the corrected age of 3 months, as this is when a major transition in neuromotor development takes place [10]. In order to examine all children at this age, our planning of the date of assessment took account of the expected date of delivery. Because the assessments were conducted during a home visit, it was not logistically possible to visit all children at exactly the same age. As a result, neuromotor assessment was performed in 4721 children at the corrected ages between 9 and 20 weeks (response rate 67%). For the present study, only the measurements between 9 and 15 weeks corrected age were used ($n = 3224$). Because assessments after 15 weeks corrected age were collected using an age-adapted version of the neuromotor instrument, results cannot be compared easily with assessments in the 9–15 week age range.

The study was approved by the Medical Ethics Committee of Erasmus Medical Center, Rotterdam. Written informed consent was obtained from all adult participants.

### 2.2. Age and birth weight

Although gestational duration was first determined by foetal ultrasound examinations, we also calculated it on the basis of the last menstrual period [11]. We then calculated postnatal age or chronological age as the difference between the date of assessment and date of birth. Finally, we operationalized post-conceptional age as the sum of gestational duration and postnatal age. Date of birth and birth weight were obtained from midwives and hospital registries.

### 2.3. Outcome: Neuromotor assessment

Because it has proved to be difficult to identify abnormal development in infancy, a full neurological age-adequate examination should always be carried out to assess tone, elicited responses, and other observations, such as the infant's spontaneous movements and behaviour. We therefore selected items from Touwen's Neurodevelopmental Examination [12], adding items to measure active and passive muscle tone according to the modified method of de Groot et al., which is described in detail elsewhere [13]. Briefly, this method maintains the multiple domains of the original Touwen instrument, but puts extra emphasis on the notion that a discrepancy between active and passive tone serves as an early sign of poor posture and deviant motor development. We categorized all measured items in three groups: tone, responses, and other observations. Most tone items were scored as normal, low and high tone. Responses, and other observations, could be present, absent, or excessive. All assessments were performed by trained research assistants who were blinded for the gestational duration of the infants.

We calculated scale values by summing the non-optimal items. This produced a total score and three subscale scores for tone items, responses, and other items. A low value for each scale indicates appropriate neuromotor development; a high value indicates impairment. Due to their low reliability, asymmetry items were not included (see below). As we were studying a non-clinical population, the outcome measures were very skewed. For this reason, and also because we wished to study the effects of small variations, we categorized the

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