

Pattern and rate of motor skill acquisition among preterm infants during the first four months corrected age

Padrão e ritmo de aquisição das habilidades motoras de lactentes pré-termo nos quatro primeiros meses de idade corrigida

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Abstract

Objectives: This study aimed to characterize the pattern and rate of motor skill acquisition among preterm infants from newborn to four months corrected age, in comparison with a group of full-term infants. **Methods:** Twelve healthy preterm infants (mean gestational age=33.6 weeks \pm 1.25) and 10 healthy full-term infants (mean gestational age=39.1 weeks \pm 0.73) participated in the study. These infants were assessed monthly (0-4 months of age) using the Test of Infant Motor Performance (TIMP). **Results:** The motor performance pattern increased over the months in both groups, with variability in the total scores at all ages. The preterm group presented a higher mean score than shown by the full-term group between one and four months of age. In the full-term group, the motor acquisition rate was higher from age newborn to one month than from age three to four months. It was also found that the caregivers of the preterm infants began toy stimulation earlier than did the caregivers of the full-term infants. Both groups presented mean scores below the TIMP values. **Conclusions:** The preterm infants presented a pattern of motor development similar to the typical pattern regarding the sequence of abilities achieved. The preterm infants also presented a faster rate during the neonate period at one month of age. This suggests that correction for prematurity is unnecessary for preterm infants with these characteristics and that follow-up programs should instruct parents and caregivers to begin stimulation with toys at one month of age, thereby providing early exploration of various motor skills.

Keywords: premature birth; infant development; performance test.

Resumo

Objetivos: Este estudo objetivou caracterizar o padrão e o ritmo de aquisição das habilidades motoras de lactentes nascidos pré-termo nos quatro primeiros meses de idade corrigida, comparando-os com um grupo de lactentes a termo. **Métodos:** Participaram do estudo 12 lactentes pré-termo saudáveis, (MD=33,6 semanas de idade gestacional, \pm 1,25) e 10 lactentes a termo saudáveis (MD=39,1 semanas de idade gestacional, \pm 0,73). Eles foram avaliados mensalmente (zero a quatro meses de idade) com o *Test of Infant Motor Performance* (TIM). **Resultados:** O padrão de desempenho motor aumentou ao longo dos meses em ambos os grupos, constatando variabilidade nos escores totais em todas as idades. O grupo pré-termo apresentou escore médio mais elevado do que o a termo entre um e quatro meses de idade. Nesse grupo, o ritmo de aquisição motora foi maior de zero a um do que de três a quatro meses. Verificou-se também que os cuidadores desses lactentes iniciaram a estimulação com brinquedos anteriormente aos cuidadores do grupo a termo. Ambos os grupos apresentaram escores médios inferiores aos do TIMP. **Conclusões:** Os lactentes pré-termo apresentaram padrão de desenvolvimento motor semelhante aos típicos quanto à sequência de habilidades adquiridas e ritmo acelerado no período de recém-nascido (RN) a um mês de idade. Sugere-se que lactentes pré-termo com essas características não necessitam de correção do grau de prematuridade e que programas de acompanhamento orientem os pais e cuidadores a estimulá-los, desde o primeiro mês, com brinquedos, propiciando a exploração precoce de diversos padrões motores.

Palavras-chave: nascimento prematuro; desenvolvimento infantil; avaliação de desempenho.

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Introduction

Motor skill acquisition during the first year of life is extremely important for future overall development, given that this period is marked by constant and rapid changes in the rate and pattern of motor development. The first year of life can also be influenced by various risk factors, such as premature birth and low birth weight¹. Preterm infants show more evident impairments in overall motor performance during their first year of life, possibly due to the transient dystonia associated with prematurity², and several studies have indicated that preterm birth carries a significant risk of delayed motor development³⁻⁵.

It is still a challenge for researchers to evaluate the acquisition and refinement of movement quality, postural control and alignment, balance, coordination, and functional skills over the first months of life in order to classify the development of preterm infants⁶⁻⁸. Thus, studies have sought to establish the profile of the pattern and rate of motor skill acquisition in typical infants in an attempt to set standards to assess the normality of performance⁹. Studies along these lines remain scarce, both among typical infants¹⁰ and among infants with specific diagnoses such as cerebral palsy¹¹, Down syndrome¹², and preterm infants¹³. The hypotheses proposed have been that preterm infants present a nonlinear pattern and slower rate of motor skill acquisition than the full-term group.

The present study aimed to characterize the pattern and rate of motor skill acquisition among healthy preterm infants during newborn to four months corrected age, in comparison with a group of full-term newborns, using the Test of Infant Motor Performance (TIMP)¹⁴. Such knowledge might contribute to accurately identifying infants who need early intervention. It may also facilitate the differentiation between preterm infants with real motor deficit and preterm infants whose particular acquisition rate would not involve future motor impairment.

Methods

Study design

This was a longitudinal study on a convenience sample that was selected from among the infants born at Santa Casa de Misericórdia de Araraquara (nursery and neonatal intensive care unit - NICU), between September and December 2007, who resided in this municipality and fulfilled the inclusion and exclusion criteria. Because this was a convenience sample,

all of the preterm infants participated in a follow-up program provided by the City Hall of Araraquara (SP), Brazil, in which monthly guidance was given by a multidisciplinary team.

Inclusion criteria

The infants were selected in accordance with the following inclusion criteria. The preterm group was composed of healthy infants with gestational age at birth between 31 and 36 weeks and six days, adequate weight for gestational age, and five-minute Apgar score above seven. The full-term group was composed of healthy infants with gestational age between 37 and 41 weeks, adequate weight for gestational age, and five-minute Apgar score above seven.

Exclusion criteria

In both groups, infants were excluded if they presented congenital abnormalities in the nervous and musculoskeletal systems; diagnoses of genetic syndrome; symptoms of withdrawal syndrome associated with reports of maternal alcohol and drug abuse; positive serological tests for gestational infections; and sensory (hearing and visual) deficits detected during the neonatal period.

Participants

Twenty-nine infants who were born at Santa Casa de Misericórdia de Araraquara (SP), Brazil were selected. Their parents were living in the urban area of this municipality and agreed to participate in this study. However, seven infants were subsequently excluded (five full-term and two preterm infants) because of change of address or because the mother decided not to continue in the study. The 22 remaining infants were divided into two groups: a) preterm group composed of 12 newborns (four females and eight males) ranging from 32 to 36 weeks gestational age (mean = 33.6 weeks; SD = 1.25 weeks) with mean weight of 1968 grams (SD ± 527 grams); and b) full-term group composed of 10 infants (seven females and three males) with a mean gestational age of 39.1 weeks (SD ± 0.73 weeks) and mean weight of 3270 grams (SD ± 574 grams).

General procedures

The present study was approved by the Ethics Committee of Universidade Federal de São Carlos (UFSCar), São Carlos (SP), Brazil, approval no. 160/2007. The parents and/or guardians of the selected infants signed an informed consent form. All infants were evaluated with the original version of the TIMP¹⁴. They were filmed during this stage using a Sony D8 digital camera.

The TIMP is an instrument with recognized predictive validity^{15,16} and ecological validity¹⁷. It is capable of discriminating between infants at various degrees of risk for motor deficits^{18,19} and detecting lower functional motor performance as early as age three months²⁰. This instrument evaluates infants' posture and selective control over movements from 32 weeks gestational age to four months corrected age¹⁴. The test consists of 42 items (13 observed and 29 elicited) that evaluate both head control and spatial orientation in different positions in response to visual and auditory stimuli. It is constructed as a hierarchy of difficulty, i.e. starting with simple items and progressing to items of greater complexity that require greater motor maturity. The total raw score is obtained by summing the scores from all items: for the observed items, the score is zero when the item is not observed during spontaneous movement and one when it is observed; the elicited items can be scored on a five point scale (0 – 4) or a seven point scale (0 – 6) according to the performance. After summing the observed and elicited items, the raw score ranges from 0 to 142 points. To use this test, investigators were trained by a skilled researcher (study of test manual and specific training CD-ROM). After that, intraclass correlation coefficients (ICCs)²¹ were obtained: intra-observer coefficient of 0.87 and inter-observer (three investigators) of 0.88.

Test procedure

The infants were evaluated on five occasions, always by the same investigator for each infant. The first evaluation was made no later than the fifth postnatal day for the full-term group and no later than the fifth day corrected age for the preterm group. At the time of this first contact with the parents, they were interviewed to obtain information on the gestational and perinatal history, socioeconomic level, schooling level, mother's age, and family composition (number of children). The birth data (weight, gestational age, Apgar score, and complications) were gathered from the hospital medical files (NICU and nursery).

The remaining evaluations took place when the infants were one, two, three, and four months of age, on the birth date (± 7 days) and using corrected age for the preterm group. On these occasions, information was also obtained from the parents regarding the infant's routine in relation to the main caregiver and the daily stimuli (toys) that were presented to the infant, using a structured questionnaire. The evaluations were performed at the infants' homes, thus making it possible to observe them in their natural environment. The evaluations lasted around 30 minutes, during the interval between feedings. The infants were undressed, and then the TIMP was applied, starting with the observable items followed by the elicited items.

According to the TIMP manual, during these evaluations, the infants should be in state 3 (drowsy, with eyes opening

and closing), state 4 (awake, with eyes open and minimal body movements), or state 5 (totally awake, with vigorous body movements), as defined by Brazelton²¹. If the infant cried, the caregiver was allowed to soothe him or her; if the infant did not calm down, thus making it impossible to conclude the test, another appointment was set for the next day.

Description of the variables

In the present study, the independent variables were the infant's age and birth condition (full-term or preterm). The dependent variables were the total TIMP score, motor skill acquisition and the percentage of motor skill acquisition each month, and the normative data provided by the TIMP.

Total score

This was the sum of the scores obtained from all of the items in the TIMP (both observed and elicited).

Motor skill acquisition

"Motor skill acquisition" was defined as the behavioral changes observed in the infant over the months. These changes were related to the emergence of new skills and were calculated in terms of acquisition of points within the total TIMP score compared to the preceding month:

$$\text{Motor acquisition} = [\text{score for month } X - \text{score for month } (X-1)]$$

Through this variable, the pattern of motor skill acquisition was characterized to determine whether or not it was linear (increase in motor performance occurring in a gradual and sequential manner).

Monthly percentage motor acquisition

The monthly percentage motor acquisition was obtained through the following equation:

$$\% \text{ acquisition} = [\text{score for month } X - \text{score for month } (X-1)] / \text{score for month } X * 100$$

Through this variable, the rate of motor skill acquisition was characterized to determine whether or not this rate was similar each month, i.e. whether or not it was constant over time.

Normative data from TIMP

The progression curve of the mean scores in each group was compared with the progression curve of the normative TIMP values for the same ages.

Statistical analysis

The statistical software packages SPSS 13.0, Statistica 7.0, and GraphPad 3.05 were used to perform the analyses. Firstly, the economic and sociodemographic characteristics were

compared using the chi-square test (main caregiver, mother's schooling level, number of pregnancies, economic class, and stimulation received) and Student's t test (mother's age) to determine whether the groups were similar regarding these variables. For the dependent variables, which did not present normal distribution, the following tests were selected: the Mann-Whitney test for intergroup analysis, comparing the total scores obtained in the full-term and preterm groups each month, and to find any differences in acquisition between the two groups at each age in relation to the total score (one month minus newborn, two months minus one month, three months minus two months, and four months minus three months); and the Friedman test to compare the percentage of monthly acquisition within each group (intragroup analysis). If significant differences were found, the Dunn post-hoc multiple comparisons test was performed. To compare the mean monthly scores in each group with the mean monthly score provided by the TIMP, the Kruskal-Wallis test was performed in relation to both the gestational age condition (full-term, preterm, and TIMP) and the chronological age condition (0=newborn, 1=one month, 2=two months, 3=three months, and 4=four months). The Kendall correlation (for ordinal variables) was performed to determine whether the groups correlated with each other. The α value used was $p < 0.05$.

Table 1. Characteristics of the infants studied.

VARIABLES	PRETERM	FULL-TERM	<i>p</i> value
Mother's age ¹ mean ± SD	31±8	28±5	0.261
Mother's schooling level ²			
Elementary	3	2	0.896
High school	6	6	
University level	3	2	
Number of pregnancies ²			
Primiparae	4	2	0.484
Multiparae	8	8	
Main caregiver ²			
Mother	10	9	0.650
Others	2	1	
Stimulation (toys) ²			
1M	9	2	0.035*
2M	9	5	0.285
3M	11	6	0.225
4M	12	9	0.513
Social Class (ABEP#) ²			
B1	-	2	0.175
B2	3	-	
C1	6	5	
C2	3	3	

Brazilian Association of Research Companies (ABEP)²² presents the social classes in decreasing order. B1 and B2 = upper middle class; C1 and C2 = middle class. ¹ Two-sample Student's t test, ² chi-square test; * statistically significant.

Results

The preterm and full-term infants were initially characterized in relation to economic and sociodemographic conditions and in relation to the stimulation with toys in each month. Table 1 shows that, in relation to the economic and sociodemographic characteristics, there were no significant differences between the groups, which were thus comparable with each other. With regard to the start of stimulation, it was prevalent from the first to the third month in the preterm group compared to the full-term group, and it was significant ($p < 0.35$) only in the first month.

The number of infants evaluated each month was 12 in the preterm group and 10 in the full-term group. Three evaluations were excluded due to colic (full-term group: one newborn and one at age four months) and due to reactions to routine vaccinations (preterm group: one at age two months), which affected the performance of these infants in two subsequent attempts (on two consecutive days).

Total score

Figure 1 shows that, over the months, there was a progressive increase in motor performance evaluated through the TIMP in both groups. There was a clear variability in the infants' total scores at all ages.

Motor acquisition and percentage of monthly motor acquisition

There were no significant differences in the motor acquisition and the percentage of monthly motor acquisition between the groups as a function of time, but there was a significant difference in the percentage of monthly motor acquisition in the preterm group ($p = 0.016$). This difference in percentage gain in relation to the score for the previous month occurred between the intervals of newborn-one month (52%) and three-four months (12%).

Normative data of the TIMP scale

The Kendall correlation showed a strong, positive, and significant correlation between the full-term, preterm, and TIMP groups (correlation coefficient=1). However, the Kruskal-Wallis test showed no statistically significant differences between them. Nonetheless, Figure 2 shows that the infants evaluated had lower scores than predicted by the test in the period between birth and three months and that the preterm group had a higher mean score than the full-term group in the period

between one and four months, thus reaching the mean predicted by the test.

Discussion

In relation to the total TIMP score each month, there were no significant differences between the preterm and full-term groups of infants. This may be explained by the variability in performance observed between the members of each group. In each group, there were infants with high and low performance, according to the standards supplied by the test. This can be understood from the perspective of dynamic systems that emphasize interactions between intrinsic factors (maturation of various organic systems), motor activities, and the environmental and sociocultural context²³⁻²⁶. Although the preterm and full-term infants were healthy in relation to the clinical characteristics of birth, it is believed that each infant's environment and the stimulation received were determined by the intrinsic dynamics of each family. For this reason, the quantity and quality of stimuli received varied for each infant, generating different extrinsic restrictions within the sphere of the task and context and culminating in asynchronous development of the various subsystems. Furthermore, in this respect, Kamm, Thelen, and Jensen²⁷ and Rocha, Tudella, and Barella²⁸ stated that, although the subsystems act together for acquisition of skills and behavior, they present individual stages and rates of maturation.

One interesting finding was the difference in the percentage of motor acquisition in the preterm group over the course of time. There was an accelerated and significant increase in performance in the period between birth and one month of age compared to the period between three and four months of age. This behavioral pattern was not observed among the full-term infants. According to data in the literature, premature infants need to adapt to the action of gravitational force and to sensory stimuli (pain, sounds, light, and manipulation) using nervous and muscle systems that are still immature. However, the exposure of an immature organism to these stimuli will influence the maturation process. Thus, upon reaching 40 weeks corrected age, the preterm infants presented characteristics that differed from those of full-term infants, with lower TIMP scores. It is known that preterm infants' difficulties in integrating and modulating the stimuli received by different subsystems (such as tactile, visual, and vestibular stimuli) affect muscle activation and consequently postural control. This frequently leads them to present a lower level of behavioral organization than seen among typical infants of this age^{29,30}.

It is believed that the greater speed of motor acquisition between birth and one month corrected age occurs because this

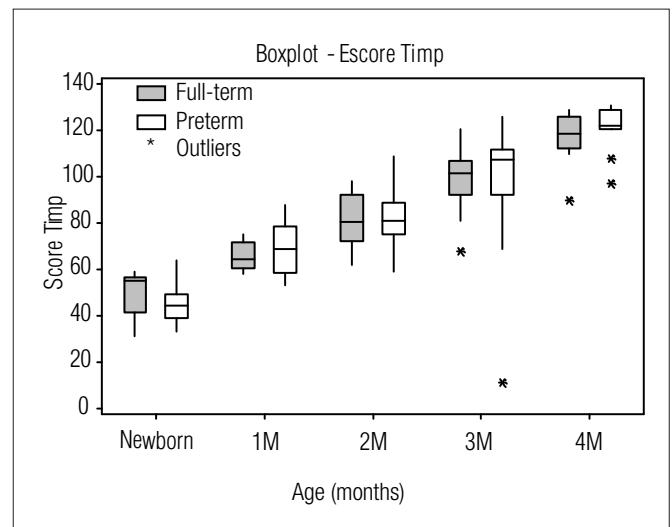


Figure 1. Total TIMP score over the months.

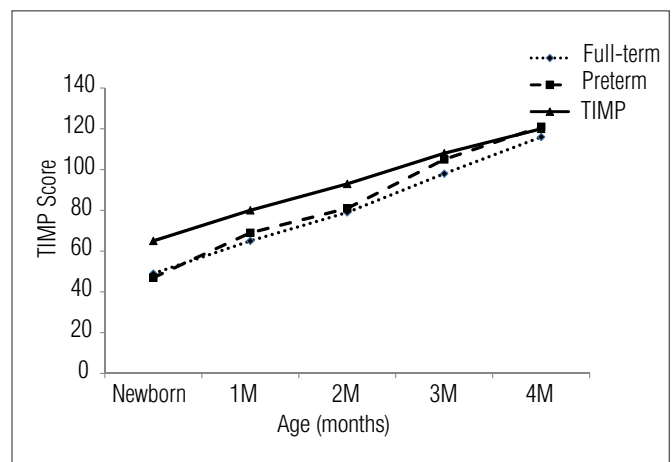


Figure 2. Comparison between mean monthly total scores of the preterm and full-term groups and the mean normative values of the TIMP scale.

is the period during which infants achieve their peak capacity to adapt to the stimuli received through a self-organization process²⁷, combining motor and perceptual components while performing each activity to organize and reorganize their responses to stimuli from the environment. Similar results were obtained by Medoff-Cooper and Ratcliffe³⁰, who observed that preterm infants presented significant neurobehavioral maturation between the ages of 40 and 44 weeks (postconception). This suggests that these infants develop strategies to deal with the organic disadvantages and thus adapt to the environment through behavioral organization (sucking/swallowing/breathing and alertness) and intense motor maturation. Corroborating these findings, Lopes, Lima, and Tudella¹⁰ observed 70 typical full-term infants, with application of the Alberta Infant Motor Scale (AIMS), and did not find any significant difference in raw score between zero and one month of age, indicating that, for full-term infants, this period is not marked by the same adaptations as observed among preterm infants.

The results obtained demonstrate that the preterm group had a relatively better performance than the full-term group, as evidenced by the comparison between the total scores of both groups with the normative TIMP values. This result differs from other studies that have stated that preterm infants generally present a poorer performance compared to full-term infants, even after correcting the chronological age. These differences may be due to variation in the eligibility criteria for the infants, such as gestational age and birth weight^{31,32}, and experimental design¹³, along with differences in the period studied (which ranged from 40 weeks of age to two and a half years of chronological age) and particular cultural characteristics (different nationalities), thus hindering a direct comparison.

Regarding the intrinsic (organic) restrictions, the gestational age correction may have been partly responsible for the better performance of the preterm group. The group studied had a mean gestational age of 33.6 weeks, which is classified as moderate prematurity³³. The infants' ages were corrected as part of the assessment protocol, in accordance with the TIMP scale. Several studies have demonstrated that infants born with a moderate degree of prematurity present a prognosis for motor development that is close to normal. In a longitudinal study, Persson and Stromberg³⁴ found little difference regarding the mean motor performance level between groups with different motor impairment risks, particularly between the group of moderately preterm infants and the control group. Campbell and Hedeker¹⁷ compared five groups of infants with different degrees of motor impairment risk and also observed that there was no significant difference in performance on the TIMP scale between full-term infants (low risk) and preterm infants without significant clinical complications (medium risk). Thus, the better performance among the preterm infants evaluated may have been due to the age correction, which was applied to a group of infants who already presented motor skill acquisition similar to typical acquisition given the moderate degree of prematurity. Further studies are needed to determine the range of gestational age for which this correction is necessary, the time until which this correction should be made, and the domains for which it should be made³⁵.

Another factor that may have influenced the better performance of the preterm infants was the fact that they had been participating in a periodic follow-up program provided by the municipal outpatient service, in which the parents and/or caregivers received guidance on positioning and adequate means of stimulating their infants. The guidance received may have helped to overcome the patterns of insecurity often observed among the parents of premature infants, who usually seem apprehensive about manipulating and stimulating their children³⁶. It is believed that this follow-up may have influenced the extrinsic (environmental) restrictions, thereby providing the infants with early exploration of different motor patterns, such as ear-

eye-head and hand-eye coordination, reaching and exploring objects, among others. Consequently, this may have favored motor acquisition at an age close to what the scale suggests.

This idea is reaffirmed through comments made by the mothers of the preterm infants assessed who had already had full-term children. They had perceived differences in the way in which daily care and stimulation were performed in the two situations and reported that they felt more at ease leaving their full-term children sleeping and spending a good proportion of the day in the crib or stroller, which was not the case in relation to children who were born premature. They also stated that they felt the need to give more attention and stimulation to the preterm infants, in order to compensate for the problems that they presented at birth. In agreement with this idea, Andraca et al.²³ stated that the mother's responsiveness to the infant's demands and her capacity to interact with it had a direct effect on the motor and cognitive performance that it would attain.

In view of the results obtained, it can be stated that the initial hypothesis that the pattern of motor skill acquisition of preterm infants would differ from that of full-term infants was not confirmed as both groups presented statistically similar patterns. Regarding the hypothesis that preterm infants would acquire motor skills at a slower pace than full-term infants, it was observed that while the full-term infants presented a linear increasing pattern of motor acquisition, the preterm group presented a higher rate of motor skill acquisition between birth and one month corrected age, maintained an increasing rate between the first and third months, and presented a decelerating rate between the third and fourth months. Despite this, the two groups achieved similar final values, compared with the TIMP scores. Similar findings were presented by van Haastert et al.¹³, who evaluated 800 preterm infants between one and 18 months corrected age and concluded that the characteristic pattern of motor development of preterm infants would be a variation of the typical pattern of motor development.

Limitation of the study and future research

It was not possible to evaluate a greater number of infants to allow the generalization of the conclusions, nor was it possible to make separate evaluations of infants with different degrees of prematurity. Furthermore, the results suggested that, for this group, it would not be necessary to correct for the degree of prematurity when evaluating motor skill acquisition. However, in order to generalize this observation, studies with more extensive population-based samples will be necessary.

For future studies, it would be of interest to apply validated tools to evaluate mother-infant bond and interaction and thus determine how these factors might affect the speed of motor and cognitive skill acquisition among preterm infants. It would

also be of interest to conduct studies comparing the use of chronological age and corrected age with the aim of determining which of these would have greater predictive value for motor prognosis among preterm infants.

Conclusions

Knowledge of the rate and pattern of motor skill acquisition among preterm infants can help professionals to ascertain whether these infants' development is taking place as expected, or whether they present motor deficits. Through such knowledge, it will be possible to judge the best moment to start or indicate an intervention, thus boosting the intrinsic capacities of these infants. This knowledge may also minimize unnecessary indications for interventions that, in addition to being a burden on the public healthcare system, generate high levels of stress for the families involved.

From the results obtained, it is concluded that these healthy, preterm infants with gestational age above 32 weeks presented a pattern of motor skill acquisition that was similar to that of typical infants with regard to the sequence of skills acquired, but

with a particular pace that can be considered a variation within the spectrum of normality. From a clinical point of view, it is important to note that, for infants with characteristics resembling those of the infants that comprised this study, it is recommended that follow-up programs should focus not only on evaluating the infants but also on instructing their parents and caregivers in the particular features of these infants' motor development, thereby minimizing parents' fear of manipulating and providing daily care so that they can correctly stimulate their children. With this care, it is believed that it will be possible to strengthen the mother-child bond and promote full development of the intrinsic capacities through favorable extrinsic constraints.

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