



Early diagnosis of abnormal development of preterm newborns: assessment instruments

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Abstract

Objective: To review the literature regarding screening psychomotor tests for the early identification of developmental problems.

Sources: A search on SciELO, PubMed and Google Scholar was performed using the terms "prematurity," "developmental delay," "cerebral palsy," "early diagnosis" and "evaluation tests."

Summary of the findings: A total of 455 references were listed, and 174 studies were selected for this review based on title, relevance, and abstract. Only original and electronically available material, from 1985 forward, with information on design, applicability, and psychometric properties of those tests was included.

Conclusions: Screening tests are important to speed the beginning of treatment measures in order to allow for better developmental outcome. Among the many tests that can be employed for this purpose, the DENVER II and the Alberta Infant Motor Scale are the most often used in Brazilian studies. The Movement Assessment of Infants is starting to be used in our country. Two other tests are recommended in the literature due to their high sensibility and specificity: the Test of Infant Motor Performance and the General Movements.

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Introduction

In the last few years the incidence of preterm births has grown considerably. Better support care provided to pregnant women and the great technological improvement of the equipment used in the neonatal intensive care units (NICU)

increased the possibility of survival for these babies.^{1,2} Preterm newborns present with several associated comorbidities such as long-term ventilatory support, bronchopulmonary dysplasia, cerebral hemorrhage and jaundice that contribute to increase the risk of developmental impairments.³⁻⁵ The direct and indirect consequences related to prematurity can cause damages that impair the child's future development.²

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Table 1 - Number of studies found for each one of the developmental screening test

Tests	General	Brazil	Preterm	Brazil Preterm	Used in this review
DENVER II	55	14	11	5	20
AIMS	35	10	20	6	22
MAI	12	2	6	2	9
GM	61	1	27	1	12
TIMP	16	0	13	0	19
Total	179	26	77	14	79

AIMS = Alberta Infant Motor Scale; GM = General Movements; MAI = Movement Assessment of Infants; TIMP = Test of Infant Motor Performance.

Approximately 30% of the preterm children develop severe motor impairments and are often diagnosed with cerebral palsy. The rates of neuromotor disorders can reach as much as 50% of the very low birth weight preterm children ($\leq 1,500$ g) and the extremely low birth weight preterm children ($\leq 1,000$ g).^{1,2,6,7} Several studies have demonstrated that not only those children at high risk suffer impairments in the future. Preterm children at low risk for developmental deficits have shown difficulties related to other developmental areas besides the motor area.^{5,8-11}

Studies involving preterm children at school age have found a higher incidence of learning disorders, attention deficits, hyperactivity and behavioral problems in this population.¹²⁻¹⁴ These future impairments can be reduced with early intervention. Screening for detection of abnormalities and developmental risks makes it easier to establish a therapeutic intervention, especially while the child is growing and his/her neuropsychomotor development is not fully achieved.^{15,16} Several elements related to the characteristics of prematurity and its comorbidities are used to determine the developmental risk. However, such factors do not guarantee the existence of developmental impairment.¹⁷⁻²⁰

In the city of Rio de Janeiro, a large portion of the follow-up care services for preterm newborns use development scales in an informal fashion and do not use standardized diagnostic measures that have been proven to be efficient for the assessment of movements and the definition of abnormality markers. In addition, there are few standardized assessment instruments for the early detection of problems in the Brazilian population,²¹ which leads health professionals to use standardized measures designed for foreign populations, even though there are no Brazilian studies confirming whether the characteristics of such instruments are appropriate for the native population.

The objective of this study is to review the literature in order to critically analyze the main characteristics and properties of the tests most often used to detect developmental

disorders. As a result of this review, we intend to provide the foundation for future normative studies using such tests, as well as to make information available to support the choice of an assessment instrument for clinical practice in Brazil.

Sources

A review of the literature was performed including the studies published during the last 25 years on the databases SciELO, CAPES platform, PubMed and Google Scholar. The key words used in this survey were: prematurity, developmental delay, cerebral palsy, early diagnosis, and evaluation tests. These key words were found in Brazilian and international journals.

Summary of the findings

Four hundred and fifty-five titles were found. Of these, 174 studies were selected to be included in this review. The studies were selected based on their title, relevance and abstract. All articles are electronically available. We only used studies available from 1985 that fulfilled the need for information on design, applicability and psychometric properties of the screening tests.

Among the several tests used in Brazilian studies for assessment of development, the Bayley Scales of Infant Development II and the Denver Developmental Screening Test II are two of the most commonly used (Table 1).

The Bayley II Scale is an updated version of the test comprising the analysis of three subscales: mental, motor and behavioral. It is a standardized scale that has been validated for the North American population, and it is mainly recommended for the early diagnosis of abnormalities. However, since the main focus of the present literature review is to analyze the screening scales, the Bayley II will not be discussed here.^{14,22}

The Denver is basically a developmental screening test, and even though it was designed many years ago, its version used in the most recent studies is a reviewed and updated version taking into consideration recent changes. Other tests, which have been based on more current developmental theories, have also been designed with this purpose during the last 2 decades. The Alberta Infant Motor Scale (AIMS) and the Movement Assessment of Infants (MAI) are assessment instruments based on more recent developmental theories that have been used in Brazilian researches. In addition to these instruments, other two scales (the Test of Infant Motor Performance – TIMP and the General Movements – GM) have demonstrated sensitivity for the early detection of abnormalities according to the literature. These tests were designed to identify problems in the first months of life, mainly to screen abnormalities in preterm newborns.

Description of the tests

Denver II

The Denver Developmental Screening Test was designed by Frankenburg & Dodds in 1967 (Colorado, USA). It has been widely used for screening children with developmental delay. Although it was adapted and validated to be used in several countries, this instrument has received severe criticism because some of its items are difficult to administer, there are few items for some areas and there have been sociocultural changes since the instrument was designed. In addition, the original version provided unreliable scoring and administration methods considering the current standards, what made it difficult to use the test in researches. As a consequence of these problems, a new version of the test was designed.^{22,23} The Denver Developmental Screening Test II is the most recent version, and it has the purpose of assessing and identifying children at risk for developmental delay (Table 2).

The items are administered directly to the child, or the guardians answer the questions (Table 3).²¹⁻²⁴ The test is easy to perform and provides a training and guidance manual regarding its use. It can be administered by several health professionals and, therefore, it is one of the tests most commonly used to screen developmental delays even in Brazil.^{22,24-33} Although the test has not been validated for our population, an informal cultural adaptation has been carried out to make its administration easier.²⁴

Another advantage is the wide age group reached by this test, which makes a long-term follow-up of child development possible. This new version of the test was also carefully standardized and validated for the population of the State of Colorado, USA, and it seems to have higher sensitivity regarding the identification of delay in comparison with the first version, mainly in terms of language acquisition.^{23,34-36}

One of the disadvantages highlighted by the researchers is the fact that, since the test was not designed with the purpose of diagnosing delays, but to guide the care provided to the child, its results present little prognostic value, especially for those cases with a small number of failing responses.^{22,25-27,36-40} Even though the test reaches a wide age group and allows for the longitudinal follow-up of development, it does not seem to be sufficient to assess qualitative changes over time and perform early detection of subtle psychomotor alterations.^{22,26,29}

MAI

The Movement Assessment of Infants is often used by therapists in the USA. The test was designed by Chandler and two other pediatric physical therapists in 1980 and it was based on clinical experience and on literature review about normal child development. Its purpose is to assess the motor development of children up to 1 year old at high risk for motor disorders aiming at contributing to establish the bases for early intervention.^{41,42} This test was also designed to follow the effects of physical therapy, as well as to provide support for researches serving as an assessment instrument.^{36,42} It requires specific skills from the assessor and intense handling of the child. The test consists in the assessment of tonus, primitive reflexes, automatic responses of straightening, balance and self-protection, in addition to voluntary movements resulting from visual and auditory stimuli or through the manifestation of motor landmarks.^{36,43} It is advisable that the professional intending to administer the test receive accurate training. The MAI should be used by physical and occupational therapists who provide pediatric care, but it can be administered by several health professionals with experience in child development.^{36,43} Each questionable score is a risk point to classify the child as normal or questionable. When summed up, these points offered a total risk criterion; the higher the score, the higher the risk for developmental delay (Table 3).^{42,43} Although the authors of the test did not design a normative scale, there are risk profiles for 4, 6, 8 and 12 months of age.^{36,42-44}

The criteria established in the initial study were questioned in later studies carried out by Harris et al.,⁴⁵ who have demonstrated moderate reliability and questioned the cutoff points proposed, suggesting new cutoff points for total risk.³⁹ In subsequent studies, other authors agreed with these findings.⁴⁶⁻⁴⁸ The predictive and simultaneous validity was also checked in a sample of high-risk children, with 81% of identification at 4 months in children diagnosed with cerebral palsy later (Table 2), but a significant number of false-positive (44%) was found, which led the researchers to the conclusion that, although there is significant correlation with cerebral palsy for some items, only a moderate correlation is verified when the total risk score is used.^{39,43,44,46} The lack of risk criteria for other ages also impairs the use of the test in researches. Other important criticism associated with the test

Table 2 - Main characteristics of the screening tests

Test	Aspects assessed	Age group	Time of administration	Validation in Brazil	Reliability
DENVER	Motor	0-6 years	20 minutes	No	Inter-rater: 0.99
	Behavioral language				Test-retest: 0.90
MAI	Motor	0-1 year	60/90 minutes	No	Inter-rater: 0.72
					Test-retest: 0.76
					Sensitivity: 81% (4 m)
					Specificity: 44%
AIMS	Motor	0-18 months	20 minutes	No	Inter-raters: 0.96-0.99
					Test-retest: 0.86-0.99
					Correlation: $r = 0.97-0.99$
					Sensitivity: 77.3-86.4% (4 m)
					Specificity: 65.5% (8 m)
GM	Motor	Preterm to 20 w postterm	10/50 minutes	No	Inter-rater: 92-97%
					Sensitivity: 100%
					Specificity: 96%
TIMP	Motor	32 w GA - 4 months	30/45 minutes	No	Inter-rater: 0.95
					Test-retest: 0.89
					Sensitivity: 0.92
					Specificity: 0.76

AIMS = Alberta Infant Motor Scale; GA = gestational age; GM = General Movements; MAI = Movement Assessment of Infants; TIMP = Test of Infant Motor Performance; w = weeks.

is the verification that some items are unnecessarily tested at some ages, which results in a test longer than necessary. Such aspects of the test impair the measurement of the child's skills evolution over time, restricting the use of the instrument as a tool to follow the therapeutic intervention.^{39,42,43} These findings have also been observed in a study performed in Brazil. The authors of this study have found results similar to the ones previously reported by other investigators. Even though the instrument has not been validated to the Brazilian population, it has been used to investigate and follow the development of populations at risk.^{42,49}

Finally, although the authors suggest the possibility of use by other health professionals, some items are difficult to be performed by professionals who do not work directly with child rehabilitation.^{36,41}

AIMS

The Alberta Infant Motor Scale was designed to follow the development of normal children up to 18 months old. In 1994, Piper & Darrah, two Canadian physical therapists, designed the instrument that included the neuromaturational theories and the dynamic aspects of motor development. Differently

Table 3 - Scoring system and criteria of normality

Tests	Scoring System	Criteria of normality
DENVER II	Items administered to the child or answer provided by guardians	Normal: child is able to perform expected activities (1 failure per area)
	Item classification: successfully performed, failure or refusal	Suspected: failure to perform the activities executed by 75-95% of the children (\geq two failures in more than two areas)
		Delay: failure to perform the activities executed by more than 90% of the children
MAI	Items administered to the child	Total risk score (4 months)
	Score on a numerical scale for total risk score	Low risk: \leq 10 points
	Tonus	
	1-2 = hypotonia; 3 = normal; 4-5 = hypertonia	Intermediate risk: $> 10 \leq 13$ points
	6 = both hypotonia and hypertonia	High risk: > 13 points
	Other items (ordinal progression): 1 = mature; 2-3 = immature; 4 = normal	
AIMS	Spontaneously performed items	Normal: 25-90 percentile
	Dichotomic scoring	
	Present = 1	Suspected: below 10 percentile over 6 months
	Absent = 0	High risk: 10 percentile at 4 months
	Final score applied to a percentile scale	5 percentile at 8 months
GM	GM videotaped for classification	Normal: presence of torsion/irregular movements
	Classification based on presence and frequency	Risk: poor or chaotic repertoire of GM
	Location and intensity of GM	Presence of cramped-synchronised GMs
		Absence of fidgety movements or abnormal movements
TIMP	Observed items (13) and administered items (29)	Normal: intermediate score (Mean \pm 1 SD)
	Score on ordinal numerical scale	Suspected: low score ($< -1 > -2$ SD)
	Final score applied to the normative scale	High risk: very low score (< -2 SD)

AIMS = Alberta Infant Motor Scale; GM = General Movements; MAI = Movement Assessment of Infants; SD = standard deviation; TIMP = Test of Infant Motor Performance.

from other instruments previously designed, the AIMS was created to fulfill the necessity of pediatric therapists regarding the selection and follow-up of the sequential motor development.⁵⁰

The assessment is performed based on the free observation of the child in four positions: supine (nine items), prone (21 items), sitting (12 items) and standing (16 items). The test assesses how long the child keeps the position, the

anti-gravitational posture and the child's ability to independently change positions.^{50,51} Its design allows for the gradual quantification of the development, since the scale increases the repertoire of expected responses as the child grows up. In the initial study (n = 2,203) exclusively carried out in the province of Alberta, Canada, the validity and reliability of the instrument were established. These results have been confirmed by other authors in subsequent studies. The simultaneous validity with other tests have demonstrated good correlation, sensitivity and specificity rates (Table 2).^{37,51-55}

The authors have established cutoff points in order to classify the child within a risk profile, demonstrating higher sensitivity for the identification in children older than 6 months (Table 3).⁵⁰ These findings have been checked in other studies, and the results confirmed high sensitivity rate, but the best specificity and accuracy rates were associated with results with a percentile ≤ 5 .^{37,56-59} Even though these results have been reported in most studies, some researches that analyzed the items of the test have demonstrated difficulties to assess the efficacy of the results. In a study performed by Liao & Campbell, the authors have found that, even though the test increases the level of difficulty of the responses over time, only one more point in the score can significantly change the percentile, which causes important alterations in some ages and irrelevant alterations in others.⁵⁹ These findings suggest the existence of important gaps in the increase of difficulties in terms of the items evolution. These gaps have been identified in some positions at the initial ages and in the expected ability to stand up in older children. It suggests that the results can be questionable, impairing the clinical use of the assessment instrument. As a consequence of the contradictory results, these researchers have suggested the additional use of other items to adequate the level of difficulty, in addition to the necessity of further studies to define the clinical importance of the assessment.⁵⁹⁻⁶³ Another issue that has been pointed out by some researchers is related to the differences found in the mean of the results for foreign populations. The studies have demonstrated that the common profile found was below the normative sample proposed by the authors of the test, which means that there is need for further studies that can identify the causes of these differences.^{56,57,63-65}

The AIMS is considered to be a quick test that is easy to administer, having a guidance manual available. The authors state that there is no need of training for physical and occupational therapists who work with children, but they recommend that other health professionals are trained by skilled professionals, which requires a longer period of training so that safe administration of the test is achieved.⁶³ Although the instrument has not been validated in Brazil, a cultural adaptation of the scoring instrument has been performed. Such instrument has been used to screen abnormalities in children, and it has been proven to be a useful instrument in the

follow-up of infants at risk being treated with early intervention.^{54,63,65-70}

GM

The assessment of general movements was designed to perform early detection of abnormalities in the development of preterm babies and term children at risk. The test is based on the observation of the child's spontaneous movements without external intervention or stimulus. Such observation is performed by videotaping the child laying in the supine position while she/he is awake, resting in the incubator or on bed.⁷¹

The test recommends that the assessment is performed after the third day of life, at three different moments between the preterm period and the postterm period up to 20 weeks. Special recommendations are made regarding the position and the stimuli that should be avoided so that there is no interference in the child's observation. The child cannot be upset or crying, and a pacifier cannot be used to calm the child down. These behaviors and accessories can change the expression of spontaneous movements and impair the assessment.⁷¹

The GM was designed based on the long-term observation of spontaneous motor behaviors recorded in children at risk. The studies that originated the assessment have been carried out by European researchers in the 1970s and they provided great contribution to the understanding of the initial development of preterm and term children. The great interest in the development and the lack of satisfaction with the assessment measures commonly used led Prechtl, the main researcher, to analyze in detail the spontaneous motor behavior of these babies. Using the recorded images, it is possible to identify and establish the patterns of expected movements in the first months of life, as well as to define which ones are compatible with the child's future development.⁷¹

Prechtl has identified and described the motor patterns of newborns' typical movements. These movements change as the baby grows, evolving from torsion movements (writing movements) to irregular and elegant movements (fidgety), establishing a complex and harmonious network of motor experimentation, gradually changed by voluntary attitudes. Based on these findings, the researcher and her colleagues have found that the absence or abnormalities of general movements and the presence of simultaneous spasms (cramped synchronized) constitute an abnormal motor behavior and establish the risk for the future development of the baby (Table 3).⁷¹⁻⁷⁶

Since this test is based solely on visual observation, it has received some criticism because it allows for differences in the results when the same child is observed by different assessors. The training necessary for the practical administration of the test is quite expensive and requires greater efforts from those interested in administering it. Recent studies have demonstrated that with appropriate training the differences can

be reduced and the results reach excellent reliability rates (Table 2).^{71,75-78}

The GM is a qualitative and non-invasive assessment that has proven to be efficient to perform the early detection of abnormalities at 3 months of age.^{16,77-80} The studies including this assessment have demonstrated high correlation with cerebral palsy in the future when there are cramped synchronized and absence of normal fidgety movements.⁷⁷⁻⁸²

TIMP

The Test of Infant Motor Performance was designed to assess posture and control of the selective functional movement. It has been developed with the purpose of identifying motor delay or deficit in preterm children and helping with the planning of goals of intervention in these babies. The child can be assessed while in the neonatal ICU as long as she/he presents stable clinical conditions, without signs of stress (stage 4 of Brazelton Scale). The test was initially designed to be performed by physical and occupational therapists who work directly with movements and who are experienced in early intervention in children at risk.

The items of the current test are based on the natural demands triggered by the babies and their caregivers, therefore, showing ecological validity. The most recent version of the test was designed with illustrative photos so that it can be used as an educational tool for parents regarding the babies' evolution.⁸³⁻⁸⁶

The first version of the test, which was proposed by Giro-lami & Campbell (USA), comprised 43 items and was designed for a study about the effectiveness of treatment in high-risk preterm children in 1983. The instrument was developed based on motor learning theories that highlighted the importance of stability and guidance of alignment in space and are related to the environmental interaction and the individual's self-organization neuromotor changes. The test was also organized based on the principles of other tests previously known in the scientific field. Currently, Campbell keeps carrying out investigations in order to analyze and improve the test. The most recent version of this test is a result of several studies and changes proposed based on the analytical results of the items and the collaboration of co-researchers.^{83,86}

The items of the instrument focus the assessment on the development of head control and selective limb control, assessing the typical motor repertoire of the first quarter of life in different positions in space, using visual and auditory stimuli.^{83,86}

The score increases as the child shows greater voluntary and postural control. Therefore, the test assures an increase in the level of difficulty of the response regarding the child's expected evolution according to age. The final scores are transferred to a table showing the classification according to age (Table 3).^{83,86,87} This test has proven to be sensitive to

behavioral changes and therapeutic intervention, being able to differentiate between children with different levels of alterations for a poor motor result.^{88,89}

The test was validated based on the sample selected, keeping appropriate proportions of gender and race in order to agree with the diversity of the North American population. Reliability and sensitivity were checked during validation and showed excellent results in the third month. The most recent studies have confirmed these findings, but have demonstrated moderate specificity for developmental disorders (Table 2).^{83,84,90-95}

Recently, a study involving several regions has been conducted with the purpose of determining the standard ages for the clinical administration of the test and possible differences between the groups of risk, confirming that the standards are appropriate to be used with the general population.⁹⁶ Further studies continue to investigate the association of the items with other findings from the standard neurological test and the specific association at different ages and the development of cerebral palsy.⁹⁷⁻¹⁰⁰

Conclusions

Many tests are used to screen abnormalities; however, five of these tests can be identified as being the most frequently administered in researches. Among the most popular tests in Brazil, the Denver II and the AIMS stand out. Both were designed to follow the development of normal children, but are more often used to screen developmental deviations. These tests are easy and quick to administer, and an easily understandable manual is provided to facilitate their administration. However, the Denver II has not been compared with other tests and presents low sensitivity for children younger than 8 months old. The AIMS has been validated with other tests and shows good sensitivity for children older than 6 months old, but a more detailed analysis of the properties of its items raises doubts about the adequacy of the level of difficulty for some ages, questioning the predictive value of the test for older ages.

The MAI is a test designed to identify abnormalities and to follow the early intervention. It also requires that the assessor is experienced and skilled. It does not provide normative scales, only suggesting reference criteria for some ages. It seems to be sensitive to identify abnormalities at 4 months; nevertheless, the studies performed using the test have demonstrated only moderate specificity. In addition, deeper studies on the test have identified difficulties in terms of increase of difficulties of the items over time, which arises doubts about the use of this tool as a follow-up instrument during intervention.

The TIMP and the GM are more focused on the qualitative assessment of movements, offering the best reliability and

sensitivity rates at early ages (3 months). Their administration is quite time consuming and depends on the child's behavioral state. These tests require accurate training with moderate cost of administration and certification of the professionals. Since their main purpose is the identification of early abnormalities (before 4 months), they do not provide elements that can be used as a tool for the child's long-term follow-up.

All screening instruments have advantages and disadvantages. The choice of one instrument will depend on the population and the objectives the health professional intends to achieve. The shortage of standardized Brazilian instruments highlights the importance of conducting studies in Brazil in order to check the adequacy and validation of the instruments regarding local standards.

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