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REVIEW PAPER

Motor development in infants – conditioning factors and assessment methods

Joanna Chomicz-Wlazły

Department of Clinical Psychology and Special Education, Faculty of Rehabilitation, Józef Piłsudski University of Physical Education in Warsaw, Poland

ABSTRACT

Infancy is characterised by a significant increase of motor abilities. Early diagnosis and therapy of infants with developmental disorders is an important topic, considering the number of children at risk of improper development. Although the survival rate of premature infants and high-risk infants has increased, premature infants are at a higher risk of developmental delays and physical disabilities.

Motor development in infancy can be assessed in various ways. This article presents information on developmental processes in the human brain as well as typical and atypical motor development and factors conditioning motor development in infants. In addition, selected assessment methods of infant motor development are characterised and evaluated.

KEY WORDS:

infants, motor development, assessment methods of motor development, brain development.

INTRODUCTION

Pregnancy is a time of intense maturation processes in the central nervous system of the foetus. However, nine months in the womb is not a sufficient period for full brain development. In the first 12 months after birth, the baby's brain increases in size by a factor of three times; there is also an increase in the number of furrows in the cerebral cortex, growth of nerve cells, and the appearance of synapses between them. Brain development translates into clinical features of the child's development, which is most intense in the first year. In the first weeks of life, it is very important to determine the level of motor skills and competence in the sensory field of the newborn, as well as to detect any pathological features. Movement activity in the first weeks of life manifests in the form of reflex action, which allows the assessment of the neurological state of the newborn. The reflex action is a transient process, which undergoes evaluation and is aimed at shaping the function [1] (Fig. 1).

The development of the human brain is a long-term process that begins during the early phase of foetal life and reaches maturity around the age of 30 years, in the form of the adult's brain. Distinct abnormalities in brain development have important implications for predicting developmental disorders in children. Many methods of brain function assessment at an early age are used in diagnosis. There are a variety of methods – from a typical neurological examination at the doctor's office, which does not require specialised equipment, to more or less sophisticated methods, such as neuroimaging (ultrasound, magnetic resonance, computed tomography) and neuropsychological tests using electroencephalography or visual/somatosensory-evoked potentials. A question aris-

ADDRESS FOR CORRESPONDENCE:

Joanna Chomicz-Wlazły, Department of Clinical Psychology and Special Education, Faculty of Rehabilitation, Józef Piłsudski University of Physical Education in Warsaw, 34 Marymoncka St., 00-968 Warsaw, Poland, ORCID: 0000-3454-3372, e-mail: j.chomicz@wp.pl

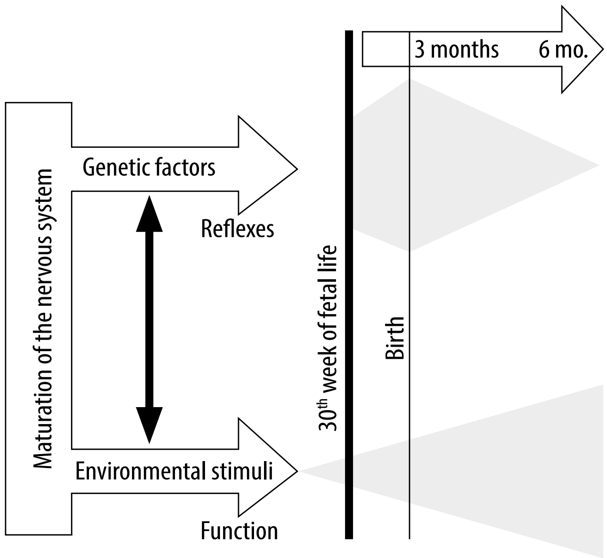

FIGURE 1. Suppression of reflex action parallel to the development of the intended function. Our own study based on Kułakowska [1]

es as to whether such diversity of assessment methods is sufficient to predict the child's motor development [2].

Despite the progress in medical sciences, diagnosis of children with developmental disorders (including cerebral palsy) is still a big challenge for specialists. The progress in science has increased the survival rate of infants from very premature births (children born before 32nd week of pregnancy) to 85%. Unfortunately, the incidence of developmental disorders in this group is still high and amounts to approximately 10–15%. In addition, 25–50% of premature children have mild developmental disorders. The lower the foetal age at the moment of termination of pregnancy, the greater the risk of such disorders [3, 4].

TYPICAL MOTOR DEVELOPMENT

Motor development is a process in which the child acquires new patterns of movement and skills. It is a complex process and its course is conditioned by many factors, such as: the child's unique characteristics (body mass, muscle strength, the presence of additional disorders) and environmental characteristics, such as living conditions, family structure, as well as the presence and type of toys (children's environment). Acquiring motor skills is an important developmental task in childhood. During the first year of life, infants reveal a wide range of movement skills, such as sitting, crawling, standing up, walking, reaching, grasping, chewing, talking. Thanks to such an intense development, the infant begins exploring its surroundings and getting to know the world. All children, except those with severe disorders, have the potential for development and learning a variety of movement patterns and more specialised motor skills [5–7], also referred to as milestones. In the past, the assessment of milestones had greater clinical value. Slower development of one function usually has no clinical value, whereas the occurrence of general delay in development is clinically relevant [8].

ATYPICAL MOTOR DEVELOPMENT

Atypical motor behaviour may be caused by developmental changes in the maturing brain. It is possible that the damage of the maturing brain results in neuromotor dysfunctions in infants, but it does not affect the developmental achievements in the later period. A reverse situation is also possible – when after apparently typical development in the early stages of infancy more serious dysfunctions are revealed, for example cerebral palsy. When we speak of atypical motor development in the first year of life, most often we mean delays in achieving milestones, more or less pronounced muscular tension disorders, retained reflexes, or limited variability in the repertoire of motor behaviours, which is a characteristic symptom of early brain damage. Other symptoms may arise as a result of brain damage, but they may also be associated with other complications during early development, e.g. premature labour [8].

RISK FACTORS OF DEVELOPMENTAL DISORDER

Early motor development is associated with a variety of factors occurring during pregnancy and after delivery. Previous studies show the relationship between Apgar scores in the first and fifth minute after delivery and subsequent motor development. Foetal movements during the last three months of pregnancy are associated with motor development in the first year of life. Similarly, the development of a newborn is associated with later results in motor development during infancy [6].

While analysing risk factors, an increasing incidence of perinatal factors – such as perinatal complications, prolonged delivery, caesarean section, and use of forceps – was discovered in children with mild motor disability. There were also factors associated with the child, such as neonatal jaundice, toxaemia, intrauterine hypotrophy, premature delivery, or post-term pregnancy [9]. Gender also affects development. Cerebral palsy is more common in boys [9, 10].

ASSESSMENT OF MOTOR DEVELOPMENT IN INFANCY

Early diagnosis and early, deliberately chosen therapy are the foundation of modern paediatric physiotherapy. The proper research tools are an indispensable element of a reliable and accurate diagnosis, which allows the child to be qualified for therapy and allows the effects of the therapy be to checked [11]. Modern research confirms that early intervention (at the time of greatest brain plasticity) is most effective. Physiotherapists, occupational therapists, paediatricians, and other specialists working in primary health care play a particularly important role in early diagnosis [12].

Motor development affects other fields of development and can be a predictor of future cognitive development. Both high- and low-risk infants, even if they grow up correctly, may have developmental problems in the pre-school and school period, such as learning disabilities or motor disorders [13].

SELECTED TOOLS USED IN THE ASSESSMENT OF INFANT MOTOR DEVELOPMENT

One of the best-known methods of diagnosing developmental disorders in infants is Vojta neurokinesiological diagnostics. Its goal is to assess the development of posture and movement in infants. Spontaneous motor skills, reflexes, and body postures in seven trials are analysed [14]. Apart from the Vojta therapy, there is also the NDT-Bobath method, which deals with improvement and diagnosis as well. The study scheme in this method was developed by Kong. The following elements are assessed: a study of movement behaviour, spontaneous activity, adaptation of the child to changing external conditions, and observation of the postural reflexes in various positions. Unfortunately, in order to be able to use the above methods, appropriate training should be completed, which is an obstacle for many diagnosticians who want to use these tools. Courses of the above methods are very expensive and last for a couple of weeks [15].

Both in the Vojta method and the NDT-Bobath method, spontaneous movements are evaluated. They are a manifestation of movement activities. Prechtl, a pioneer in the field of early neurological development research, introduced an assessment of the newborn's condition, based on the observation of spontaneous motor skills. Prechtl noted that the quality of spontaneous movements, in particular general movements (GMs), gives information about the state of the nervous system of the foetus and newborn. The Prechtl method is a trustworthy and reliable diagnostic tool. GMs consists of a series of large movements of different speed and amplitude that engage all parts of the body (hands, legs, neck, trunk). GMs can last from a few seconds to several minutes or longer. GMs stay in the same form after birth. They appear in early foetal life and last up to about 3–4 months. In the period of 2–4 months of life (the age of fidgety movements) GMs have the highest predictive value. GMs start and end gradually, they are also complex, they occur often, and last long enough to be observed and evaluated. When assessing GMs, we define them as normal, mildly abnormal, or definitely abnormal. Speaking of abnormal movement patterns, we mean reduced complexity, variability of global movement patterns or lack thereof, as well as lack of smooth movements (monotonous and poor movements) [2, 16, 17]. In the description of GMs, variation and complexity play a fundamental role. Thanks to the ability to perform movements in the joints, such as flexion–extension, abduction–adduction, and external–internal rotation, frequent changes in the direction of movement of the body parts are possible. Variety is the basic feature of proper functioning of the central nervous system. On the other hand, stereotypy is a feature of early brain damage [18]. The big advantage of the above method is its non-invasiveness and the possibility of obtaining an objective diagnosis effective in 98% of cases. Among the disadvantages is the age limit of the patient (the highest predictive value at the age of 2–4 months). To be able to use the Prechtl method, it is necessary to complete the relevant training. In Poland, trainings do not take place frequently, which significantly impedes the possibility of obtaining qualifications, thus resulting in a lack of trained diagnosticians.

The traditional neurological examination, capturing large developmental disorders, plays an important role in the assessment of motor development. Newborn examination is very important upon determining the corrected age, regardless of the child's weight. Predicting development at this stage is limited due to the immaturity of higher brain structures, especially the cortex. Therefore, the correct result of a neurological examination in a newborn is not an indicator of proper development in the future [1]. The reason for immediate neurological diagnosis should be the occurrence of alarming symptoms, the so-called red flags. Red flags are "historical and clinical clues that may indicate the presence of a serious underlying disorder". Developmental delay or regressing skills can be caused by raised intracranial pressure. The key importance of delayed motor development lies in alerting clinicians to signs of cerebral palsy, hypotonia, or muscular dystrophy [19].

In order to determine the level of development in infants as well as to monitor changes in motor skills that appear in the first year of life, standardised tests for the evaluation of neuromotor development are very useful. One such tool is Alberta Infant Motor Scale (AIMS). It is a standardised observation scale used to assess the motor development of infants from birth until the development of independent walking (0–18 months). The scale was created by Piper and Darrah, who developed it at the beginning of the 1990s in Canada, where they examined 2202 children. AIMS consists of 58 elements, collected in four positions: pronation (21 elements), supination (9 elements), sitting (12 elements), and standing (16 elements). Each activity is assessed, and then points are awarded depending on whether the activity occurs (is observed or not). During the assessment, three features are recognised: antigravity movements, weight-bearing, and posture. AIMS can be used by all persons involved in the development of a child, who have knowledge in this field and have basic information concerning movement.

The AIMS scale can be used not only to assess development for diagnostic purposes, but also to monitor therapeutic programs. It is used in scientific research to assess motor development, both in babies born on time and in premature babies. The influence of various factors on the motor development of infants is assessed: the degree of prematurity, type of child's position during childbirth, congenital torticollis, plagiocephaly, and hypoxic ischaemic encephalopathy [20–22].

AIMS has been recognised as a clinically necessary tool, which predicts abnormal development of infants [23]. The limitation in using the scale consists of the lack of appropriate reference standards for the Polish infant population. Until now, Canadian reference standards have been available [20]. In recent years, the AIMS scale has been standardised also in other countries, e.g. Greece, Taiwan, and Brazil [21, 24, 25]. In Dutch studies, it was confirmed that infants achieve significantly lower results in the test than the presented norms established on the Canadian population, and that the scale requires the establishment of new reference standards for other European countries [26].

The advantage of the AIMS scale is its ease of use and short time required for testing. This is especially important for people working in state institutions, where often the time to examine the patient is significantly reduced. Moreover, using AIMS does not require any training, and the methodology of the study has been thoroughly described. It is worth noting that in comparison to the traditional clinical trial, the AIMS scale emphasises functional skills and quality of movement.

A relatively new tool for qualitative assessment of motor skills in infants is called the Infant Motor Profile (IMP). It is a standardised tool used for assessing infants aged 3–18 months or until they develop independent gait. IMP was created in 2008, and the authors are Heineman and Hadders-Algra from the Netherlands. The IMP requires recording a film presenting the child's movement skills in five positions: supine, prone, sitting, standing, and walking. In addition, small motor skills are assessed: reaching, grasping, and manipulation of objects while sitting on a parent's lap. In younger infants, the assessment starts in the supination position, during which spontaneous motor activity of the child is observed and assessed without toys and external distractors. The baby should stay in this position for 3–5 minutes. In older children, the assessment usually starts with a sitting position (on a parent's lap or on a mat) [27–29].

The IMP consists of 80 elements collected in five subscales: variation, variability, fluency, symmetry, and performance. A detailed description can be found in Table 1.

TABLE 1. Characteristics of Infant Motor Profile (IMP) subscales (our own study)

Subscale	Number of items	Assessment
Variation	25	The size of the movement repertoire
Variability	15	Child's ability to select adaptive motor strategies from his/her repertoire
Fluency	7	Ability of the infant to finetune motor output
Symmetry	10	Presence or absence of stereotyped asymmetries
Performance	23	Achievement of motor milestones

Researchers from the Netherlands assessing the validity of the IMP noticed that the week of delivery, socio-economic status, and Apgar score in the fifth minute were significant determinants of the IMP result in the study group. In the subgroup of infants born prematurely, the results of IMP were significantly associated with brain injury in the ultrasound image and with socioeconomic status.

IMP is based on the neuronal group selection theory, according to which in typical development the child is at first characterised by primary variability in motor behaviour. Children with perinatal complications in the form of brain damage show more stereotypical behaviour with less variability [28]. Heineman *et al.* tried to determine whether children with cerebral palsy aged 18 months differ from healthy children as regards the IMP result in infancy. In the group of infants born on time there was no case of cerebral palsy. It was instead diagnosed in eight premature babies. Children with diagnosed cerebral palsy received lower IMP results [29].

The advantages of IMP include the possibility of using this tool in a wide age group of infants, aged 2–18 months. Unfortunately, to be able to evaluate a child using the IMP, you have to finish the training. Training is most often conducted in English or Dutch and is rarely organised. In Poland, the IMP is not yet popularised. Currently, research is being conducted on establishing reference standards in the Dutch population.

Another relatively new test, developed in the US in 2004 by Campbell *et al.*, the Test of Infant Motor Performance (TIMP), is designed to assess babies aged up to four months, born prematurely (from the 32nd week of pregnancy) as well as infants born on time. The test allows the identification of infants with developmental delays and disharmonious motor development, and determination of the direction of development. In addition, TIMP helps in defining the goals of therapy and in assessing its effects [30]. The test was developed for physiotherapists and occupational therapists and consists of two scales: one for assessment based on observation of 13 spontaneous motor behaviours and the other one consisting of 29 induced trials. Afterwards, the test results are applied to the observation sheet and, after conversion, to the percentile grid. The TIMP test takes approximately 36 minutes [31]. The child is assessed in the presence of a guardian/parent. TIMP is also used in children with many complications, who attain significantly lower scores than healthier children. TIMP assessment of development of children who were later diagnosed in terms of cerebral palsy, showed that these children presented low results in the TIMP test as early as on the seventh day of correctional age [32]. To date, studies on the simultaneous accuracy of TIMP and AIMS have been performed, and it has been shown that both tests share common features and similarly identify comparable groups of infants with weaker results in motor development [33]. TIMP has also been tested for accuracy and compared with the Bayley Scales of Infant Development (BSID). The usefulness of the test in assessing the motor development of newborns and infants aged up to four months has been confirmed.

TIMP allows the identification of the components of postural and selective motion control, which is very important for the proper development of functions such as: position changes, movement against the force of gravity, adjustment to care activities, self-regulation ability, head and body orientation for searching, and listening to caregivers and interacting with them [34]. The advantages of this test are its ease of use and short time needed to conduct the examination. It is accompanied by a special card with photos of required positions, which greatly facilitates the evaluation. The disadvantage of the test is the inability to use it for older babies aged over four months and the need to complete paid training to use the test.

A similar tool is a relatively new test – the Harris Infant Neuromotor Test (HINT) by Harris. It is a non-invasive screening tool used to assess neuromotor development, cognitive development, and behaviour. It is designed to assess babies aged from 2.5 months up to 12.5 months. The examination lasts about 30 minutes, during which the researcher interviews the parent and observes spontaneous movements in various positions, including induced positions. The way that the child plays with his/her parents is also assessed. In the last section, consisting of 21 elements, the infant's skills are assessed in five positions: supine, prone, transition from supine to prone, sitting, and standing. In addition, muscle tone, antigravity movements, cooperation, stereotypical behaviours, and head circumference are assessed [35]. HINT is a reliable and trustworthy tool used both by clinicians and researchers. This test allows the detection of motor and cognitive delays [36, 37] and is useful in screening tests. The big advantage of this test is the fact that it can be used by nurses, physiotherapists, occupational therapists, and doctors, and it is very easy and quite fast to use. Moreover, it can be used in infants aged up to 12.5 months.

Each of the abovementioned scales has its advantages and disadvantages. All presented tests and scales are available in English; there are no Polish elaborations or reference standards for the Polish population. Most of the mentioned scales require proper training. However, the advantages of the above scales and tests lie in the fact that they do not require expensive, specialised equipment.

The selection of the appropriate scale or test depends on various factors, including the age of the child, the purpose of assessment, time possibilities, and the qualifications of the diagnostician. Since there is no tool that meets all conditions, the selection criteria are very important. Because the available tools complement each other, it is recommended that more than one tool be used in clinical practice, especially for predicting the development of children with neurological disorders.

It is impossible to list all available scales and tests used to assess the development of infants. This study contains a description of the latest or most frequently used tools in diagnosis. The remaining scales used in the assessment of infant development are characterised in Table 2.

TABLE 2. Other scales used in the assessment of infant motor development (own study)

Assessment tool	Short name	Purpose	Age group	Time to administer
Bayley Scales of Infant Development 2nd/3rd [38]	BSID-II/III	Assessment of motor and mental development and behaviour	1–42 months	20–60 min
Peabody Developmental Gross Motor Scale [39]	PDMS-GM	Assessment of gross and fine motor development	0–6 years	45–60 min
Paediatric Evaluation of Disability Inventory [40]	PEDI	Assessment of gross and fine motor development	6 months – 7 years	45–60 min
Movement Assessment of Infants [41]	MAI	Assessment of cognitive and motor functions	0–12 years	45–60 min
Structured Observation of Motor Performance [42]	SOMP-I	Assessment of motor development	0–10 months	15–30 min
Early Intervention Developmental Profile [43]	EIDP	Neurodevelopmental assessment	0–6 years	> 30 min
Toddler and Infant Motor Evaluation [44]	TIME	Assessment of psychomotor development	4 months – 3.5 years	10–55 min
The Denver Developmental Screening Test-II [45]	DDST-II	Assessment of gross and fine motor development, and behaviour	0–6 years	Variable

CONCLUSIONS

The prenatal period is the foundation of human development. The reflex reactions and spontaneous activity controlled by the developing nervous system constitute a very important stage of development. Thanks to the progress of medicine, it is possible to effectively sustain pregnancies at risk much more often, which also affects the survival of premature newborns. Because, as a consequence, the number of children with abnormal development is increasing, there is a need for early detection of developmental disorders and for early therapeutic intervention.

Predicting a child's development is a difficult task, especially due to the fact that there are significant differences between children, which is a normal feature of development.

There is no perfect tool for assessing an infant's motor development, which is why it is very important to know many possible tests and choose appropriate scales in the neurodevelopment assessment. There is a need to introduce reliable and standardised tools to the diagnostic practice allowing for early assessment of the infant and assessment of the effects of therapy. This will allow the best possible results and the best choice of therapy.

DISCLOSURE

The author declares no conflict of interest.

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