Widely acknowledged as the cornerstone reference in the field, Pediatric Rehabilitation brings together renowned specialists from all sectors of the pediatric rehabilitation community to provide the most current and comprehensive information available.

The fifth edition has been substantially updated and expanded with evidence-based discussions of new theories, therapies, interventions, research findings, and controversies. Five completely new chapters focus on such emerging areas as the use of ultrasound to guide motor point and nerve injections, rehabilitation of chronic pain and conversion disorders, management of concussions, sports injuries, and neurodegenerative and demyelinating diseases in children. This edition also addresses important new directions in genetic markers and tests, cognitive, developmental, and neuropsychological assessment, and rehabilitation for common genetic conditions. Additionally, several new contributors provide fresh perspectives to the voices of established leaders in the field.

The text covers all aspects of pediatric rehabilitation medicine from basic examination and testing to electrodiagnosis, therapeutic exercise, orthotics and assistive devices, gait labs, aging with pediatric onset disability, and in-depth clinical management of the full range of childhood disabilities and injuries. "Pearls and Perils" featured throughout the book underscore crucial information, and illustrations, summary tables, information boxes, and lists contribute to the text's abundant clinical utility.

New to the Fifth Edition:
- Every chapter has been thoroughly revised and expanded to reflect current thinking and practice
- Evidence-based discussions of new theories, therapies, interventions, research findings, and areas of controversy
- Five entirely new chapters illuminating emerging areas: rehabilitation of chronic pain and conversion disorders, ultrasound-guided injections, concussion management, sports injuries, and neurodegenerative and demyelinating diseases in children

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DEDICATION

To Dr Gabriella Molnar, who passed away since the last edition. She has left a void that will not be filled. She is a recognized founder of our field of pediatric rehabilitation medicine. Dr Molnar created our first textbook, edited the subsequent two editions, and wrote numerous state-of-the-art reviews for the Child with Physical Disability. After escaping from Hungary in 1956 from the Russian occupation and communist regime, Dr Molnar displayed much foresight and courage throughout her professional career. Her guiding principle has always been that children are not miniature adults, but individuals with changing physical, intellectual, and emotional abilities and needs. At every age, therefore, the principles of rehabilitation medicine have to be adapted to these changing aptitudes. Beginning as a resident at Albert Einstein College of Medicine, Dr Molnar quickly rose through the ranks from faculty instructor to full tenured professor, while developing and running the Pediatric Rehabilitation Medicine Service. Concluding her career at Children’s Hospital and Research Center in Oakland, California, where she created a new Department of Pediatric Rehabilitation Medicine, she finished training her last of over 50 domestic and international fellows. Her speaking career has included invitations from all over the world, including Australia, Europe, Asia, and England. She has served on the editorial boards for the Archives of Physical Medicine and Rehabilitation from 1976 to 1994 and Developmental Medicine and Child Neurology from 1992 to 1997. She is a recipient of the Krusen Award from the American Academy of Physical Medicine and Rehabilitation (AAPMR), the highest honor obtainable for proven performance in clinical expertise, contributions to the literature, and administration in the field of rehabilitation medicine. Simply stated, Dr Molnar defines the standard for the rest of us to follow. Her husband’s generous contribution to the PMR Foundation created an award for lifetime achievement in pediatric rehabilitation and funds research stipends to increase the body of knowledge in pediatric rehabilitation. Her life is an inspiration to all of us.
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This is the second edition of *Pediatric Rehabilitation* that has not been under the leadership of Dr Gabriella Molnar, but her influence and wisdom are still apparent in the text.

Our field has changed again since the last edition. Every chapter in this new fifth edition has been thoroughly revised and expanded. We have covered many of the more common genetic disorders throughout the textbook and added new chapters on sports injuries, concussions, and rehabilitation of pain and conversion disorders that will be of great interest to physiatrists. We have also added a chapter on ultrasound, as many of us are actively involved in this exciting adjunct to our practice of medicine.

You will notice that some chapter authors have returned and we have asked them to incorporate new pediatric rehabilitation specialists, as it is our hope that these new coauthors will become the senior authors of future chapters and perhaps editors of future editions.

We are happy to present to you this compiled wisdom of the brightest and most enthusiastic clinicians in our tightly knit group of pediatric rehabilitation specialists.

On a somber note, the editors are saddened to announce the recent passing of Dr Ellen Kaitz. Her help in the previous and the current edition is greatly appreciated.

Michael A. Alexander
Dennis J. Matthews
HISTORY AND EXAMINATION

Maureen R. Nelson, Michael A. Alexander, and Gabriella E. Molnar†

The physiatric history and examination of a child require a blend of medical diagnostic skills to establish or confirm the diagnosis as well as knowledge of child development and behavior to evaluate functional assets and challenges for the intervention phase of rehabilitation.

SETTING THE TONE

To ensure the best cooperation, especially in the preschool age, the environment should be child-friendly. Exposure to crying and upset children should be avoided in the waiting room or other areas. Families will do better if someone else can take care of the child’s siblings rather than bring them to the appointment so that parents can focus on the interview without distraction. The examination room may have a small table and chair with an assortment of toys for children of different ages to make them comfortable and relaxed. The examiner’s attire also influences the child. Many times a good rule is to “lose the white coat,” unless it has a pocket full of toys. The child is not impressed by the coat and may be intimidated by past medical visits. A child-oriented décor such as pictures of cartoon characters or animals on the wall, small toys, and decals on instruments helps to create a playful atmosphere and alleviate the child’s fears.

Start the visit by introducing yourself, including telling the patient and parents something about yourself, and what will happen during the visit, and how long it will last. Ask the parents to tell you why they came and what specific questions they have for you.

Concerns stated by the referral source should be shared with the parents. Many parents are unsure about what information the visit can provide. This is the opportunity to explain what pediatric rehabilitation is, its focus on function, and what it can offer the child and family. The examiner should also explain that it is part of the examination to watch the child so that the parents will not feel offended by the examiner’s wandering gaze. Because observation of spontaneous behavior is one of the most informative aspects of evaluating youngsters with a disability, examination begins from the moment the child is in the physician’s view. Questions about history and illnesses should be asked in simple terms so that the family can understand them and provide proper information. It is also important to have someone clarify insurance coverage and whether additional tests or treatment can be performed on the same day or must await approval.

HISTORY

PRENATAL AND PERINATAL HISTORY

The prenatal and perinatal history includes the preconceptual period and the parents’ ages and health before and since the birth of the child. Maternal factors during gestation may lead to fetal malformations. Examples of these associations include febrile illnesses (1) anticonvulsants (2) with spina bifida; maternal diabetes with caudal regression syndrome and sacral agenesis; and rubella, thalidomide, or fetal alcohol syndromes. Weak or eventually lost fetal movements may be the earliest sign of a motor disability of prenatal origin. Prenatal care, unusual weight gain or loss, hypertension, or any other gestational problems should be explored. Mode and duration of delivery, use of anesthesia, induction, intrapartum complications, and expected and actual date of birth should be noted. Any history of previous pregnancies, deliveries, and fetal loss is significant. Prenatal cerebral damage is increased in infants of mothers with previous spontaneous abortions (3). A detailed neonatal history is essential, including birth weight, Apgar scores, onset and success of breastfeeding, as well as the infant’s age at discharge. Weak lip seal and sucking force and inadequate feeding may be preliminary signs of oral motor dysfunction. If care in the neonatal intensive care unit (NICU) was required, what were the specifics of that, including medications and ventilator support? Neonatal seizures may signal pre- or perinatal brain damage.

†Deceased.
Prematurity, particularly very low birth weight, is a frequent cause of cerebral palsy (2). Large birth weight may lead to intrapartum trauma, brachial plexus palsy, or, on extremely rare occasions, spinal cord injury, particularly with breech or other fetal malposition. When extended hospitalization was required, one should note the infant’s age, weight, and condition on discharge, including means of feeding and need for ventilatory or other supportive measures at home, since these may predict subsequent, persistent, or recurrent problems.

DEVELOPMENTAL HISTORY

The developmental history should cover all major aspects of function and behavior. For details of developmental milestones and testing, refer to Chapter 2. This discussion presents only general guidelines for the purpose of diagnostic interpretations. Discrepancies between different areas of functioning provide clues about the nature of medical diagnosis and developmental disability.

Delayed accomplishments, primarily in motor function, suggest a neuromuscular deficit. One of the earliest signs that parents report is a lack of spontaneous movements when the infant is held or placed in the crib. They may add that the baby feels limp or stiff, suggesting either hypotonia or spasticity. In all cases of motor dysfunction, it is important to clarify whether the dysfunction was a steady, continuing delay from an early age, suggesting a static disease, or an arrest or regression noted at a particular point. However, slow deterioration due to progressive neurologic disease may be masked for a time by the relatively fast pace of early motor development. Developmental history and subsequent assessment must take into consideration the interactive effect of coexistent deficits. Slow development in personal and adaptive tasks that require both motor and cognitive abilities may be related to impairment in either area. A significant cognitive dysfunction by itself may delay gross and fine motor development (4). This also frequently exacerbates the functional consequences of a neuromuscular disability and may create the impression that the motor deficit is more severe than it actually is.

A history of delay in communication development raises several differential diagnostic possibilities: (a) true language dysfunction affecting receptive or expressive domains or both, (b) oral motor dysfunction interfering with speech production, and (c) significant hearing loss. In a child with motor disability, language dysfunction may result from diffuse or focal cerebral lesions, such as head injury or cerebral palsy, particularly when cognitive function is also affected.

The ability to follow simple and, later, complex commands indicates preserved receptive language even in the absence of verbalization. Parents report a variety of responses, such as smiling, cooing, crying, pointing, or vocalization with inflection as a substitute for speech. Oral motor dysfunction is also associated with cerebral palsy, most often with spastic quadriplegia or dyskinetic disorders due to suprabulbar or pseudobulbar palsy. Bulbar palsy in medullary involvement affects speech production, for example, in spinal muscular atrophy or spina bifida with syringobulbia. There is a close association between anatomic structures and neurologic control for speech and oral feeding. Concurrent oral motor dysfunction with feeding difficulties is an additional sign of bulbar or pseudobulbar pathology and confirms the suspicion of speech production deficit. In such cases, history of early feeding is most relevant. For example, was there a good lip seal and strong suction on breastfeeding? When bottle-fed, the infant can handle 4 ounces in about 10 minutes, and feedings every 3 to 4 hours are generally adequate. The need for longer and more frequent feeding to maintain weight gain, especially during the first few months; coughing; nasal regurgitation of liquids; and then later difficulty with drinking from a cup; and difficulty with introduction of solid food due to chewing problems are early symptoms of oral motor dysfunction and a possible subsequent deficit in speech production. Augmentative communication training should be initiated early in such cases.

Hearing is an essential factor for speech development. Early cooing and babbling are innate characteristics of infants and involve the same vocal components, regardless of the language spoken in their environment. Infants with hearing loss start to fall behind after 6 to 8 months of age when learning of auditory-dependent vocalization begins. Parents may notice a decrease even in spontaneous babbling at that age. All neonates and infants at high risk for developmental disability or recurrent ear infections should have an initial and, if warranted, repeat hearing evaluations. Correction of a hearing deficit should be initiated as soon as possible after it is detected (5).

For infants and young children, the history is obtained from parents or caretakers. While gathering information from one person about another, the examiner gains an understanding of both and establishes rapport with parents and child. Early-school-age children can provide some information about themselves and should be encouraged to do so. Preadolescents and particularly adolescents generally prefer to give an account of their problems and achievements. Adolescents may wish to have privacy without the parent present, at least for part of the visit.

GENERAL HEALTH HISTORY

The examiner should determine whether the patient is an essentially well child with impairment or a sick child who has been hospitalized several times. In the latter case, one should explore in detail the frequency, reasons, tests, and treatments. Even if one has access to records,
the parents should be asked to tell the child’s history in their own words. Their account provides an insight into their knowledge and participation in the child’s care. One should ask how many visits they make to medical centers and therapists and how much time is spent in transit for the child’s care.

History of allergies to medications or other substances should be noted. An early history of allergies to different and often inconsistent formulas may indicate that the child in fact had feeding difficulties that were attributed to allergy. Multiple exposures to latex and any signs of allergy should be determined, particularly in spina bifida or after repeated surgeries. Any medications that the child takes regularly, including dietary supplements and homeopathic or alternative medications or aerosols, should be recorded with dosage and schedule.

The risk and incidence of seizures are higher in static and progressive diseases of the central nervous system (CNS). Overt or suspicious signs, type and frequency of seizures, anticonvulsants, and their effectiveness and possible side effects should be recorded.

Nutrition, with special consideration for the child’s disability, should be reviewed. Feeding difficulties or behavior problems may lead to inadequate consumption of calories and essential nutrients. Dietary intake may be lower than required for the increased energy expenditure on physical activities in children with motor disability. In contrast, caloric intake may be excessive when physical activity level is restricted and lead to obesity, commonly in wheelchair users with spina bifida (6) or muscular dystrophy, and after transition from walking with assistive devices to mobility via wheelchair. In children with caloric restriction, there is often a need for supplemental vitamins, protein, and calcium (7). Dietary information and guidance are fundamental for regulation of neurogenic bowel incontinence. Cultural and family eating patterns should be taken into consideration. Injuries, burns, fractures, and spinal cord and head trauma are followed by a period of a catabolic state. Monitoring of weight, nutrition, and fluid intake is essential during inpatient rehabilitation for major injuries, and after return to home. Caloric requirements for children are calculated from age-appropriate standards, which take into consideration growth. In children with motor disability, upward or downward adjustment in height and weight may be needed, depending on their level of physical activity and individual growth trend. Specific recommendations are available for children with spina bifida to avoid obesity (8,9). Obesity is a risk factor for secondary issues from the primary diagnosis, including pain and fatigue, as well as a cardiovascular risk and social challenge (10).

History of respiratory complications, past or present, should be explored in children with pertinent diagnoses. Central ventilatory dysfunction (CVD) is a potential severe complication of Arnold–Chiari malformation in spina bifida (11). Syringobulbia may cause similar symptoms. Nightmares, insomnia, and night sweating are complaints associated with hypercapnia, and may be reported in advanced stages of muscular dystrophy. Hypercapnia and sleep apnea may occur in diseases of the CNS. Intercostal muscle paralysis in high thoracic paraplegia with spinal cord injury or spina bifida, spinal muscular atrophy, or advanced muscle diseases leads to inefficient pulmonary ventilation and handling of secretions. With severe spastic or dystrogenic cerebral palsy, the respiratory musculature may lack coordination. Such children are prone to recurrent bouts of pulmonary infections. Coexistent feeding difficulties with minor aspirations or restrictive pulmonary disease due to spinal deformities may add to pulmonary dysfunction.

Restricted mobility of the spine and thoracic cage may be present in ankylosing spondylitis or severe systemic-onset juvenile rheumatoid arthritis/juvenile idiopathic arthritis (JIA). Detailed information about home management and use and frequency of equipment must be included in the history. Exercise dyspnea may be a sign of pulmonary compromise or deconditioning with the high energy cost of physical activities in children with some motor disabilities. Scoliosis may exacerbate respiratory disease in some of these children. Cardiac decompensation with right-sided failure, a potential complication of pulmonary dysfunction, is more likely to occur in older children or young adults with the previously mentioned disabilities. Myopathic conduction defects and arrhythmias are often symptom-free in the absence of heart failure. Consultation with pulmonary and/or cardiology specialists should be arranged when history reveals suspicious symptoms.

Visual and hearing impairments are more frequent in those with childhood disabilities. Inquiry about these aspects of function is a part of the history. Regular hearing and visual assessments are required. Prenatal infections, anoxic or infectious encephalopathy, metabolic diseases, meningitis, hydrocephalus, and head injury warrant exploration of visual and auditory function. Like all children, youngsters with disabilities are prone to a variety of childhood illnesses. In some cases, however, acute symptoms and febrile illnesses may be directly related to complications of a specific disability. Vomiting, headache, irritability, or lethargy may be prodromal signs of decompensating hydrocephalus in spina bifida, cerebral palsy (2), or an intercurrent unrelated illness. Recurrent headaches are also a manifestation of autonomic dysreflexia in spinal cord injury. Fever may represent central hyperpyrexia in severe head injury or hyperthermia due to pseudomotor paralysis in high thoracic spinal cord injury. However, these diagnoses can be made only after other causes of fever have been excluded. In those with a neurogenic bladder, urinary tract infection should always be investigated as a possible cause of febrile illness. A history of the usual pattern of the amount and frequency of voiding is essential in neurogenic bladder dysfunction. Systematic daily recording is a guide for bladder training. Fluid intake, in accordance with pediatric norms, needs
to be monitored at home, and records of both bladder and bowel schedules should be available on the medical visit.

Immunization history is part of all pediatric visits. The child in good health may not have received the recommended vaccinations because of excessive concern on the part of the family or pediatrician or the child may have been ill when scheduled for immunization.

**HISTORY OF BEHAVIOR**

The examiner should ask about the child’s behavior in terms of temperament and personality. The parents may state that the child was always a good baby, but this report may mean that the youngster never cried and slept more than expected for his or her age. In other cases, parents may report excessive crying and restlessness both while the child is awake and asleep. Some children may show excessive mood swings from lethargy to hyperactivity, whereas others are even-tempered and react appropriately. One should ask the parents whether the child is friendly, outgoing, and sociable, or shy and withdrawn, particularly in group situations. Parental guidance may be needed to encourage interactive behavior by the child. Compliance or problems with obedience, daily activity level, attention span, sleeping and eating habits, and special interests and dislikes are revealing information. Separation from the parents may be a problem for some children with disability. The parents may be uncomfortable to leave the child with relatives or other caretakers. In this context, it is important to point out the need and possible approaches to foster the child’s independence.

**EDUCATIONAL AND SOCIAL HISTORY**

Very young children may be enrolled in an early intervention program, either home- or center-based. Frequency, length of sessions, components of training, the child’s tolerance and cooperation in the program, and its effectiveness, as perceived by the parents, should be clarified. The same applies when the slightly older child attends a preschool program. In school-age children, information about the type of class—mainstream, integrated, or special education—is important. Academic expectations are different in each of these educational pathways and should be taken into consideration when report card grades are interpreted. Individualized Education Program (IEP) meetings and environmental accommodations are other pertinent details. The child may have special interests and strengths that should be further developed or difficulties in certain subjects, which may require additional help and adjustment of the IEP. Review of educational status is a consistent part of follow-up visits, and assistance should be offered when problems arise, including cognitive and neuropsychological testing.

Opportunities to meet and play with other children in addition to school or home contacts, visits and sleepovers with friends, and participation in various recreational activities are formative experiences that prepare all youngsters for social functioning and adulthood. Asking the parents to describe the child’s daily schedule, including regular and occasional activities on weekdays and weekends, yields a valuable insight into these aspects of the entire family’s lifestyle. Time spent in school, therapy, homework, play, and leisure activities with family members, friends, or alone should be noted. Housing, employment of the parents, siblings and their ages, and social support of the family provide further understanding of the physical and social environment. Some families with a disabled child experience social isolation. Information about or referral to community resources may be helpful for many families. This may include recreational and sports training and teams, theater, music, and social outings.

**FAMILY HISTORY**

In motor or other developmental disabilities, a detailed family history must be obtained to explore the possibility of a genetic disease. Health and function of the parents, siblings, and other family members on the maternal and paternal sides should be explored through several preceding generations. One should ask specifically whether there are other children in the family with developmental delay or adults with known motor disability, limb deficiency, or other malformations. Historical information is at times incomplete until further questioning brings to light additional facts. Family albums and pictures of relatives may be helpful to detect dysmorphic facial or other features. Consanguinity is an increased risk for genetic disease, especially diseases with an autosomal recessive inheritance pattern. In some autosomal-dominant conditions, mild variants of a disease may be missed until a thorough investigation of suspected family members is carried out, including congenital myotonic dystrophy and facioscapulohumeral dystrophy. In X-linked conditions, affected males typically have a maternal familial history. Diseases with multifactorial inheritance, such as spina bifida, are complex, and may or may not have a known familial history (2,8). Referral for genetic workup is necessary whenever there is the possibility of a genetic condition. Pregnant mothers of affected children should be referred for genetic counseling. Prenatal diagnostic testing is available.

**STUDIES**

Radiographic imaging is useful for a variety of children. For those with bone abnormalities, plain films will be
EXAMINATION

This chapter provides only general guidelines for the format and structure of the pediatric rehabilitation examination at different ages. Specific details of diagnostic signs and interpretation of findings are discussed in subsequent chapters about different disabilities.

OBSERVATION

The examination begins as soon as the family and child enter the examination room, before the child is actually touched or asked to perform. Sometimes, it may be the most informative phase of the examination. Specific behaviors to observe and note include reaction to separation from the parents (especially in young children); apparent visual and auditory awareness; temperament (calm or hyperactive, compliant, or challenging); spontaneous exploration and interest in toys, games, or books in the room; style, concentration, attention span, or distractibility during play; level and manner of motor activities; attempts to engage the parents and the examiner in conversation, vocabulary, complexity of language, and quality of speech; and interaction with parents or examiner (appropriate, shy, or demanding). Observations of the parents’ response and their way of handling the child’s behavior are also revealing.

EXAMINATION BY AGE

For infants and young children, the examiner must create an atmosphere of trust. Friendly advances during history taking or while the child is at play allay initial fears and anxiety. At this age, most, if not all, of the examination can be accomplished with the child in the parent’s lap if the child remains fearful. Interactive play in this phase of the examination can incorporate developmental testing by offering toys for grasping or raisins to test pincer grasp. Blowing bubbles makes most youngsters comfortable and happy, and one can assess their visual motor coordination as they reach to pop them. Balls are also extremely versatile and nonthreatening items to engage a child in his or her exam in a variety of ways. Hearing, vision, cranial nerves, and postural abnormalities also can be observed.

As the parent gradually undresses the child, gentle touch and tickling or funny sounds with a smile help to maintain relaxation and to facilitate hands-on examination. Inspection and palpation of body parts and gentle movements to examine tone are performed at this point. The examiner should be prepared to improvise if the child shows increasing anxiety.

The actual hands-on examination, consisting of bodily handling and manipulation, is the last stage; anxiety-provoking or painful tests are deferred to the end. If the examination requires placement of the child on a table, the parent can sit at the end and let the child’s head rest on his or her lap. With anxious children, performance of gross motor activities, such as sitting, crawling, standing, or walking, also can be conducted with the family’s help. One should note the quality of movements, postures, weakness, incoordination, asymmetry, or reflex abnormalities that reflect a motor deficit. Range of motion, deep tendon reflexes, or primitive reflexes that need physical manipulation should be examined after evaluation of active mobility. Tests that require instrumentation, such as sensation, fundoscopy, otoscopy, and oral function, conclude the examination.

Giving choices involves the preschool child in the examination. For example, the examiner may ask, “Should we look at your arm or leg first?” On the other hand, questions such as “Can I look at your arm?” should be avoided because if the child says “no,” confrontation results. Parents can often bring out many capabilities of their children without the examiner touching them.

SCHOOL-AGE AND ADOLESCENT PATIENTS

The customary method of systematic medical examination is applicable. Children with cognitive deficit need to be approached according to their cognitive rather than chronological age. Children in this age group, particularly adolescents, are usually embarrassed about walking in underwear in front of their parents. Shorts or a bathing suit is more acceptable. Adolescents may be seen with and without their parents. Their concerns may be different from those of the family and should be addressed with respect for their privacy.

The scope of the examination is expanded to reflect the growing child’s increasing functional needs in activities of daily living (ADLs) and other areas of competence. A comprehensive examination includes screening in educational achievements, reading, writing, and arithmetic. Formal psychological or psychoeducational testing follows in case of deficits.
GROWTH

Parameters of physical growth should be routinely measured on each visit and plotted on the standard growth chart. Height and weight are obtained at all ages, and head circumference is measured in children under 3 years and thereafter in children with deviations. Serial monitoring is necessary in hydrocephalus, regardless of etiology, and microcephaly, which reflects defective brain growth. In spina bifida and other disabilities that require full-time wheelchair use, arm span measurement is recommended instead of height (8). Extremity length and girth are recorded in children with localized growth disturbance due to neurogenic weakness, epiphyseal fracture, or arthritis. In growth disturbances that involve one side of the body, one must determine whether the condition represents hemihypertrophy or hemiatrophy. Hemihypertrophy unrelated to neurologic causes requires investigation for renal tumor.

INSPECTION

General appearance and special features may help to establish a diagnostic entity. Dysmorphic facial features, epicanthal folds, increased intercanthal distance, external ear anomalies, and malformations of the toes or fingers suggest a prenatal disorder, possibly teratogenic or genetic, and at times, an identifiable syndrome (12). Blue sclerae are a sign of osteogenesis imperfecta. Asymmetrical facial and palpebral fissures and pupils may indicate facial palsy or Horner’s syndrome, whereas craniofacial asymmetry and vertical strabismus may be present in torticollis. Dolichocephaly is typical in premature infants and children. A bald spot or area of short, thinning hair over the posterior skull is commonly a sign of weak neck musculature. In infants and young children, the fontanelles and cranial sutures should be palpated for patency, tension, asymmetry and vertical strabismus may be present in torticollis. Extraocular, facial, and tongue muscle weakness may represent cranial nerve dysfunction, myopathy, or other neurologic disease. Involuntary eye movements and nystagmus are noted in cerebellar or other CNS disorders.

The skin should be inspected for telangiectasias, nevi, or other lesions. Café au lait spots or pigmented skin areas are seen in neurofibromatosis. In children with ataxia, telangiectasias may be seen over the flexor surface of the knees and elbows. Malar rash suggests a rheumatic disease. The combination of adenomatous rash, seizures, and hemiplegia is seen in tuberous sclerosis. Hairy patches, dimples, or other skin lesions over the spine are frequent signs of spina bifida occulta (8). A small sinus, dermal tract, or pilonidal cyst in the gluteal crease also may accompany occult spina bifida. Sudden weakness in such cases may indicate an infection penetrating into the spinal canal or a neurologic complication related to underlying malformation in or around the spinal cord. In children with sensory deficit, the involved area must be routinely examined for skin lesions, pressure abrasions, ulcerations, and infections. Foot deformities, varus or valgus deformity, or claw toes lead to abnormal weight distribution and callus formation consistent with the pathologic posture. Calluses over the dorsum of the feet and knees, the so-called “housemaid’s knee,” develop in older children whose preferred mode of locomotion is crawling. Multiple scars, bruises, and abrasions in various stages of healing may indicate frequent falls or child abuse/nonaccidental trauma (NAT).

Asymmetry in the size of skeletal muscles should be noted in terms of location and distribution. Anterior axillary and upper chest muscle atrophy may represent absent pectoralis muscle or atrophy due to a brachial plexus injury. Congenital clubfeet or multiple joint deformities are manifestations of prenatal muscle weakness due to spina bifida, arthrogryposis, or myotonic dystrophy, other muscle diseases, or may be idiopathic. A hypertrophic, “muscle-bound” appearance is a sign of myotonic dystrophy. Deformed, fusiform, dimpled joints may be seen in arthrogryposis. Lower extremity joint positions reflect the distribution of muscle weakness in newborns with spina bifida. Pseudohypertrophy of the calf muscles is an early sign of Duchenne muscular dystrophy. Symmetrical, well-developed musculature of the shoulder girdles and upper extremities is a convincing indication of functional crutch walking or effective wheelchair locomotion. An enlarged limb with bruit detectable by palpation or auscultation may signal an arteriovenous shunt and increased blood flow in the extremity.

Flaring of the ribs, or the so-called bell-shaped chest, suggests ineffective intercostal muscle function in children with motor unit disease or high spinal cord dysfunction. In scoliosis, the thoracic cage may develop asymmetry.

PALPATION

In infants and young children, the fontanelles and cranial sutures should be palpated for patency, tension, and size with the child in sitting position and while the child is quiet and not crying. A tense fontanelle in a vigorously crying child does not necessarily mean increased intracranial pressure. In the case of ventriculoperitoneal shunt, the reservoir may be checked for ease of emptying and speed of refill. Skin should be felt for texture, temperature, and absent or excessive perspiration. Pseudomotor paralysis in spinal cord injury eliminates sweating below the level of the lesion, and compensatory excessive perspiration occurs above the level of the lesion with high environmental temperature. Vasomotor dysfunction with coldness to touch and paleness or slight cyanosis of the skin may be present in severe upper motor neuron impairment. It is seen in the lower extremities of some children with cerebral palsy. Subcutaneous abnormalities
may be palpable, such as hard calcific deposits in dermatomyositis or neurofibromatous nodules along the course of peripheral nerves. When arthritis is suspected, each joint should be felt for the cardinal signs of inflammation, warmth, discomfort, and swelling due to synovial thickening and effusion.

Much can be learned from palpation of muscles. Tone and bulk are reduced in lower motor neuron paralysis; in long-standing denervation, the muscle tissue feels less resilient and fibrotic. The pseudohypertrophic calf muscles in Duchenne muscular dystrophy have a typical rubbery, doughy, hard consistency. A fibrotic nodule may be palpable in the sternocleidomastoid muscle in congenital torticollis. In an infant who has an isolated knee extension contracture, a palpable nodule in the quadriceps indicates fibrotic muscle changes at the site of previous repeated intramuscular injections. Localized pain and swelling accompany injuries to soft tissue or bone. Osteoporotic fractures in lower motor neuron lesions with sensory deficit show swelling but are painless. Tenderness in multiple muscle groups with weakness, fatigue, or skin rash is suspicious for myositis due to collagen disease or parasitic or viral infections.

ORGAN SYSTEMS

Although the primary health care of children with disabilities remains the responsibility of the pediatrician, the pediatric physiatrist should perform a selective general physical examination. The emphasis is placed on organ systems that are at increased risk in certain handicaps and may affect both overall health and successful rehabilitation.

Vital signs, including blood pressure and heart rate, are obtained in all patients. In myopathies and collagen diseases, cardiac auscultation should be performed because of the possibility of associated heart disease. In a child with developmental delay, the presence of a heart murmur may suggest an undiagnosed syndrome. Blood pressure monitoring is particularly important in spinal cord injury, neurogenic bladder, Guillain–Barré syndrome, and residual poliomyelitis, as well as in children receiving stimulant medications.

In disabilities that cause ineffective ventilation and involve the risk of minor aspirations, auscultation of the lungs may be revealing. Myopathies, thoracic spinal cord dysfunction due to injury or malformation, severe spastic quadriparetic cerebral palsy, and any disability with oral motor dysfunction are such indications.

Abdominal and rectal examinations are essential in children with neurogenic bladder and bowel dysfunction to evaluate bladder distention, bowel or rectal impaction, and anal sphincter tone. Stool consistency, intermittent or continuous bladder incontinence, and gross appearance and microscopic examination of the urine should be noted. Umbilical movements in response to eliciting superficial abdominal reflexes help to delineate the spinal cord level in thoracic lesions. Absent abdominal muscles result in loose skin folds resembling a prune; seen in prune-belly syndrome.

NEUROMUSCULAR SYSTEM

Examination of neuromuscular function consists of testing reflexes, tone, active motion, strength, and coordination. Limited understanding and cooperation in infants and young children requires adaptation of traditional methods of testing. After 4 to 5 years of age, the standard examination is generally applicable.

In infancy, reflex testing includes age-appropriate responses that reflect early immaturity and subsequent maturation of the CNS. In newborns and young infants, state of alertness, activity, and comfort influence muscle tone (13–16). If the baby is anxious, upset, restless, or crying, this part of the examination should be postponed. Valid assessment may require several attempts. In the first few months of life, flexor tone predominates. Hypotonia or hypertonicity signals neurologic abnormalities. Increased tone is the symptom of corticospinal or basal ganglion damage. Myopathy, cerebellar dysfunction, and lower motor neuron lesions due to anterior horn disease, neuropathy, or spina bifida all can result in hypotonia. However, a hypotonic stage usually precedes the appearance of increased tone in anoxic brain damage (17). This stage of hypotonicity tends to last longer in dyskinetic cerebral palsy than in spastic types. On passive motion of hypotonic muscles or extremities, no resistance is felt. The infant with generalized hypotonia is limp and floppy with handling and, in severe cases, may feel like a “rag doll”—a descriptive term for this finding. In hypotonia related to motor unit disease or lower motor neuron lesion, deep tendon reflexes are diminished or absent. In contrast, they are present or increased in floppy infants during the transient hypotonic phase of CNS damage (17).

Spastic hypertonicity and related postures are influenced by position in space and the effect of gravity. The child should be examined in supine, prone, and vertical positions to elicit typical postures. Perhaps the most dramatic yet common example of this is the increased hip adduction into scissoring, extension of the legs, with plantar flexion of the feet when a child with spastic cerebral palsy is suddenly lifted into vertical suspension. Resistance to both slow and fast stretching of muscle should be tested to differentiate rigidity from spasticity (18). In infants and young children, one may use a number of developmental reflexes to examine active movements and strength (19). The Moro reflex includes shoulder abduction followed by forward flexion of the arm. Eliciting palmar or plantar grasp reflexes demonstrates finger or toe flexor function. Asymmetric responses in the upper extremities may suggest Erb’s paralysis or hemiplegia. Unilateral or bilateral absence of protective extension
response is likewise suggestive of weakness in the respective extremity. A 4-month-old infant elevates the head and trunk on extended arms in the prone position. Scapular winging during this activity is a sign of a weak serratus anterior muscle (20). In older children, the wheelbarrow maneuver demonstrates the same finding (20). Lifting up under the axilla elicits spontaneous active shoulder depression. When these muscles are weak, the shoulders slide upward, virtually touching the ears. These signs suggest proximal weakness, possibly due to myopathy.

Young children often adopt ingenious substitutions or compensatory movements to cope with weakness of particular muscles. With weakness of the deltoid, they may fling the arm forward by momentum or substitute the long head of the biceps for shoulder flexion. In advanced shoulder and elbow weakness, they may “walk up” the arm on the torso, using their fingers to get the hand to the mouth. Combat crawl is a usual way of crawling in lower extremity paralysis. Deformities around a joint commonly reflect an imbalance of strength in muscles acting on the joint. The deformity is in the direction of overpull. Such imbalance may be spastic or paralytic.

Visual observation during performance of functional activities to detect muscle weakness should consider the child’s age and the achievements expected for the child’s developmental stage. Walking on tiptoes, squatting and rising without using the arms for assistance, and straight sitting up from the supine position without rolling to the prone position or to the side are mastered by children around 3 years of age (21). Thus, the inability of younger children to perform these activities in a mature pattern should not be interpreted as weakness of the plantar flexors, hip and knee extensors, or abdominal muscles. Testing for Trendelenburg’s sign and grading the triceps surae by having the child rise on the toes of one leg must be deferred until 4 years of age, when children develop adequate balance.

The standard technique of manual muscle testing can be used after school age, except in children who have serious behavioral problems or cognitive impairment (22–25). The customary grading system of scores from 0 to 5 or 0 to normal is used. Above fair grade, the wide range of normal variations in growth patterns should be considered in judging good versus normal strength. Because children are adept in using substitution for movement, the examiner must pay special attention and adhere to precise technical conduct of testing individual muscles. Side-by-side comparison may detect even mild neurologic weakness, although disuse atrophy or mild bilateral neurologic weakness may escape detection. Quantitative strength determination with comparison of both sides is helpful to demonstrate unilateral disuse atrophy in such strong muscles as the quadriceps. This determination is particularly advisable in teenage athletes after knee injury. Resumption of training for competition before virtually equal bilateral quadriceps strength is regained predisposes them to recurrent injuries. Testing of strength in upper motor neuron lesions requires the well-known considerations for position in space and orientation of head and major joints, which may affect recruitment of motor units and produce synergistic movement patterns.

A common sign of central movement disorders is impaired coordination. Proprioceptive sensory loss or parietal lobe syndrome may contribute to incoordination. Movement abnormalities associated with cerebellar dysfunction, basal ganglion disease, dyskinetic disorders, or spastic incoordination present with specific distinguishing signs. The detection of a coordination deficit is based mostly on observation of gross and fine motor function in children less than 2 to 3 years of age. Concurrent mild delay of motor development is not unusual. After 3 years of age, the examination becomes more specific for testing the quality of performance in complex and more advanced developmental skills. Around 3 years of age, the child can walk along a straight line, unsteadily placing one foot in front of the other. In comparison, facility at tandem walking at 5 years of age is a good illustration of continuing refinement of motor skills with age. The pediatric physiatrist may be asked to evaluate the appropriateness of coordination in children without an overt physical disability (26). Clumsiness of handwriting and drawing, difficulties in physical education or sports, and other subtle signs may be present. Such children may have a motor incompetence of apractic nature, sometimes related to visuomotor perceptual deficit (27). It also may be associated with learning and behavioral dysfunction. A number of tests are available for examining motor proficiency and dexterity in children without physical disability (28,29). Tasks to evaluate youngsters with minor neurologic dysfunction include imitation of gestures (30), hopping (31), handclapping (32), and pegboard performance (33,34).

**MUSCULOSKELETAL SYSTEM**

Examination of the musculoskeletal system includes inspection and palpation of bones and soft tissues, measurement of active and passive joint range of motion, and assessment of stance and gait (35–38). It is complementary to neuromuscular assessment. As in previous parts of this chapter, only developmental variations are discussed.

Bone configuration and joint mobility change during the growing years (39,40). Full-term infants may lack as much as 25 degrees of elbow extension because of predominant flexor tone. In contrast, joint hyperextensibility and hypotonia allow increased passive motion in preterm infants. The scarf sign is a good illustration of excessive joint mobility in premature babies. Holding the infant’s hand, the examiner draws one arm across the chest, like a scarf, toward the contralateral shoulder. In premature infants, the elbow crosses the midline, indicating hypotonic laxity of the shoulder and elbow joints. Full-term
neonates have incomplete hip extension with an average limitation of 30 degrees as a result of early flexor tone predominance (39,40). The limitation decreases to less than 10 degrees by 3 to 6 months. At birth and during early infancy, hip external rotation exceeds internal rotation (39,41). With the resolution of early hip flexion attitude, internal rotation gradually increases. Differences between bilateral hip abduction, apparent shortening of one leg, and asymmetric gluteal and upper thigh skin folds are highly suggestive of congenital or acquired hip dysplasia or dislocation (40). Alignment of the femoral neck in neonates is consistent with prenatal coxa valga and increased anteversion. Femoral inclination is 160 degrees, and the angle of anteversion is 60 degrees. Respective adult measurements of 125 and 10 to 20 degrees develop postnatally and are accelerated by weight-bearing.

Persistent fetal configuration in nonambulatory children with physical disabilities enhances the effect of neurogenic muscle imbalance on the hip joint and contributes to acquired hip dislocation in spina bifida and cerebral palsy. The popliteal angle is 180 degrees in the hypotonic preterm infant, compared with 90 degrees in full-term neonates. A combination of increased flexor tone and retroversion of the proximal tibia causes this limitation of knee extension in mature newborns. By 10 years, tibial retroversion resolves spontaneously. An early varus configuration of the tibia contributes to the physiologic bowleg appearance in infancy and corrects itself by 2 to 3 years of age. A systematic review of skeletal development, with examination of the spine and extremities, is presented in Chapter 10.

Normal variations of stance and gait should not be mistaken for pathology in the growing child (37,42,43). Gait abnormalities evident on clinical observation include asymmetric stride length and stance phase in hemiparesis; toe walking and scissoring with lower extremity spasticity; crouch posture and gait in diplegic cerebral palsy; Trendelenburg’s gait in motor unit diseases and hip dislocation; gastrocnemius limp with lack of pushoff in L4 to L5 weakness due to spina bifida; and various types of gait deviations associated with involuntary movements, such as ataxia, tremor, or dyskinesias, in dysfunction of the CNS.

SENSORY EXAMINATION

A complete examination of all peripheral sensory modalities is possible only in older children (44). Nevertheless, some modalities can be tested in infants and young children, and provide significant information. An infant who cries and squirms to move away from pinprick obviously perceives pain (45). A sleepy infant may be slow to respond and requires repeated stimuli. Withdrawal of the leg from painful stimuli may represent the triple flexion spinal withdrawal reflex in thoracic spinal cord lesion and should not be mistaken for active movement and presence of sensation. Comparing the infant’s reaction to pinprick on the arms or face differentiates actual sensory perception in such cases. Older infants respond to touch and vibration by turning toward or moving away from the stimulus. The presence of superficial reflexes signals an intact afferent and efferent reflex arc. The neurosegmental levels are T8 to T12 for abdominal reflexes, L1 to L2 for the cremasteric reflex, and S4 to S5 for the anocutaneous reflex. In spina bifida, absence of these reflexes generally coincides with sensory deficit in the respective dermatomes. In young children who cannot be tested for proprioceptive function, ataxia and incoordination may suggest absence of this sensation. Testing of position sense is usually reliable by school age.

Cortical sensory function is impaired in parietal lobe damage (44,46). The most frequent childhood example is hemiparetic cerebral palsy. Disproportionately poor spontaneous function, neglect, and visual monitoring during use of the arm and hand are suspicious signs. Objective evaluation is generally feasible after 5 to 6 years of age, using the same technique as in adults for stereognosis, two-point discrimination (47), and topognosia with single or double sensory stimulation. Testing for graphesthesia may be attempted by using a circle or square. Around 8 years of age, the traditional number identification gives more accurate information. Cutaneous sensation and proprioception must be intact, and adequate cognitive ability is a prerequisite for testing cortical sensory function.

The child’s age and ability to cooperate need to be considered in the examination of special senses. Moving a bright light or attractive object across the visual field is used to test vision in infants. At 1 month, the infant will follow to midline and at 3 months, from side to side through a 180-degree arc. The Stycar test and the illiterate E chart are used for screening preschool children at risk for visual deficit (48,49). At an early age, unilateral impairment or loss of vision and visual field defects, such as hemianopsia, are more likely to remain undetected than bilateral deficits. A child with strabismus or suspicion of diminished vision should see an ophthalmologist as soon as the problems are discovered. Early treatment with eye patching or corrective lenses is necessary to prevent amblyopia ex anopsia, or suppression amblyopia, partial loss of vision caused by cortical suppression to prevent diplopia (50,51). Central dysfunction of visual attentiveness, discrimination, and information processing may be misinterpreted as diminished vision and require both ophthalmologic and neuropsychological investigation. Cortical visual impairment usually shows improvement over time.

Screening of auditory function is a routine procedure in the neonatal nursery, pediatric office, and school. The examination of handicapped infants and children also should include a simple screening of hearing, eliciting the blink or startle reflex. Responses to handclapping; to speech of conversational loudness or whisper; perception
of finger rubbing near the ear; and reaction to tuning fork, bell, or cricket toy are methods of testing. Absent, lost, or delayed speech, articulation deficits, inattentiveness to sound, a history of recurrent otitis media, head injury, or failure to pass the screening test indicates a need for complete evaluation of auditory function (45,50,52,53).

FUNCTIONAL EVALUATION

The pediatric rehabilitation examination is meaningless if the physiatrist does not construct from it a coherent picture of the child’s functional achievements. This evaluation both complements and integrates the variety of information derived from all phases of the examination.

The developmental diagnostic evaluation is a convenient, functionally oriented assessment tool for infants and preschool children (21,54). Language, fine motor and adaptive skills, gross motor abilities, and personal-social behavior are the four major areas of function in the organizational framework of developmental testing. The same functional domains are considered in the evaluation of older children and adolescents. However, in these age groups, the examination includes a wider range of developmental expectations and abilities to function in school and society. ADLs and gross mobility skills need to be assessed in this context. In addition to speech, testing of language function includes other modes of communication: reading, writing, spelling, and, if indicated, augmentative communication. Drawing, design construction, arithmetic problems, and questions about handling hypothetical situations in daily life offer a brief, preliminary insight into cognitive and learning abilities. A number of specific assessment instruments were designed for various childhood disabilities (55–58). These instruments are useful functional assessment tools for their designated conditions and appropriately complement the customary developmental evaluation.

INFORMING INTERVIEW

Informing the family about the findings of the examination and their implications is an important responsibility of the physician. Factual information must be imparted with a caring attitude. Informing the parents about a diagnostic label is insufficient without explanation of its meaning. The parents need to know the estimated prognosis, including the uncertainties of early prognostication, particularly in CNS dysfunction, with the possibility of multiple handicaps. Future needs in care and functional rehabilitation should be outlined. One should emphasize the need to avoid focusing on the physical disability alone and to consider the child’s developmental and social needs. Effective counseling and communication skills are essential for establishing a partnership between the physician and family to ensure the successful outcome of a comprehensive rehabilitation program. Information for ongoing support is crucial.

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