

Impaired human motor control

INTRODUCTION

Movement disorders are the predominant symptoms suggestive of an impaired functioning of motor systems and are often best observed during gait. The physical signs obtained during the clinical examination give little information about the pathophysiology underlying the movement disorder. Various diseases or traumatic accident may affect the human motor control system (figure 6-1), resulting in the dysfunction of certain subsystems of the body, motor dysfunction (impairments). Impairments may lead to disabilities (not being able to perform certain tasks), which may impose handicaps to a person (the disabilities are experienced as a restriction in daily life). This may have serious consequences in one's daily life.

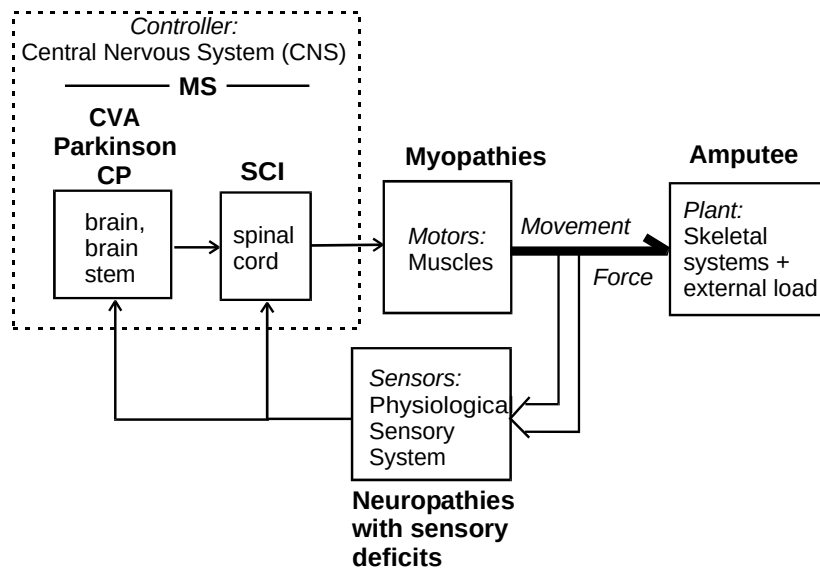


Figure 6-1. Motor impairments may concern several subsystems of the human motor control system. CVA: CerebroVascular Accident (stroke); CP: Cerebral Palsy, MS: Multiple Sclerosis; SCI: Spinal Cord Injury.

OBJECTIVES

This chapter :

- will show that motor impairments have consequences on the levels of disabilities.
- will summarise the impairments and disabilities resulting from several diseases and traumas of the motor system.

CONTENT

6.1 International Classification of Impairments, Disabilities and Handicaps

In 1980 World Health Organisation (WHO) published the International Classification of Impairments, Disabilities and Handicaps (ICIDH). The ICIDH concepts have been widely adopted.

6.1.1 IMPAIREMENT

Definition : Any loss or abnormality of psychological, physiological, or anatomical structure or function.

Any tissue, organ or system can respond in only a finite number of ways to the seemingly unlimited combinations and permutations of etiological factors. These responses are impairments, also called clinical features or manifestations of the disease or condition. It should be noted that function, as referred to in the ICIDH definition of impairment, is the function of a body part or organ, not the whole-person function.

6.1.2 DISABILITY

Definition : Any restriction or lack of ability, resulting from an impairment, to perform an activity in the manner or within the range considered normal for a human being.

Any causal relationship between impairment and disability is a loose and multi-factorial. It may also be bi-directional. Because so many factors (e.g. motivation, emotional status, fatigue, pain etc.) influence the final performance, even with the most accurate list of impairments, one can make only an educated guess about the functional limitations.

6.1.3 HANDICAP

Definition : A disadvantage for a given individual resulting from an impairment or a disability that limits or prevents the fulfilment of a role that is normal (depending on the age, sex, social and cultural factors) for that individual.

If an impairment represents the problem at the tissue and organ level, and disability represents the problem at the whole-person level, then handicap represents the problem at the environmental and society level. For clinical purposes, one may think of a handicap as an extrinsic limiting factor, or a factor in the environment that limits function.

A revision of ICIDH is under way. This second version will emphasise on abilities to perform activities and one's ability to participate in one's personal and social environment. Details can be found on the WHO website. (<http://www.who.ch1>).

Since handicap is dependent on one's social and environmental factors, it is individual in nature and may be different for different persons. Hence, in the following section only commonly occurring impairments and disabilities in some of diseases and conditions are discussed.

6.2 Motor disorders

Motor impairments may concern the Central Nervous control system (in case of Stroke, Cerebral Palsy (CP), Parkinson's, Traumatic Brain Injury (TBI), Spinal Cord Injury (SCI)), the 'wiring' in the brain itself or in the spinal cord (Multiple Sclerosis (MS)), the sensory system, the muscular actuators (muscular dystrophy), or the skeletal system (amputees). This is represented in figure 6-1.

6.2.1 SPASTICITY

Before one considers specific CNS disorders it is vital to understand spasticity. It occurs in a variety of CNS disorders. Spasticity or spastic hypertonia has both diagnostic and therapeutic significance. Spasticity is a diagnostic hallmark of an upper motor neuron (UMN) lesion and represents one of the most important impairments. Spasticity is defined as "a motor disorder characterised by a velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper-excitability of the stretch reflex, as one component of the upper motor neuron syndrome." Heightened muscle tone may result from changes intrinsic to the muscle or from altered reflex properties. Increased motor neuronal excitability and enhanced stretch evoked synaptic excitation of motor neurons are mechanisms stretch reflexes can be enhanced.

Two distinct parameters may be altered in the pathological stretch reflex – the "set point," or angular threshold of the stretch reflex, and the reflex "gain," the amount of force required to extend the limb in proportion to the increasing joint angle.

Spasticity is one component of the UMN lesion, other features include loss of dexterity, weakness, fatiguability, as well as various reflex release phenomena. These other features of the UMN lesion may well be more disabling to the patient than the changes in the muscle tone.

6.2.2 STROKE

Today the term *Stroke* indicates the sudden and surprising nature of symptomatic cerebrovascular disease and is preferred over Cerebrovascular Accident or CVA. Stroke is defined as a sudden neurological deficit characterised by loss of motor control, altered sensation, cognitive or language impairment, and disequilibrium or coma caused by nontraumatic brain injury resulting from occlusion or rupture of cerebral blood vessels.

Impairments

The causes of stroke can be grossly categorised as haemorrhagic or ischaemic. Intracranial haemorrhage (15%) can be further divided into intracerebral haemorrhage (10%) and subarachnoid haemorrhage (5%). The remaining 85% of strokes are caused by ischaemic brain injury resulting from large- (40%) or small vessel (20%) thrombosis, cerebral embolism (20%), and other less common causes (5%). Specific impairments appear when focal regions and neural systems within the brain are damaged. The study of brain topography has proved quite useful for predicting neurological impairment after focal brain injury. Stroke on one side of the brain may cause motor impairments on the other side of the body (*hemiplegia*), i.e., a left sided infarct or haemorrhage will cause right sided loss of motor function. Common stroke related impairments affect motor control and strength, motor co-ordination and balance, muscle tone (spasticity), sensations. In addition there are impairments in the

areas of language and communication and cognitive functions. There are also other impairments associated with stroke such as apraxia, neglect, dysphagia, and bladder and bowel dysfunction. Trunk control and stability, co-ordination of movement patterns, and balance all involve complex extra pyramidal systems that are frequently disrupted by stroke. Loss of motor control and strength is due to disruption of descending axons from the cortical cells from the primary motor area. These axons descend via the internal capsule to the pyramidal tract in the brainstem and the corticospinal tract in the spinal cord. Initially weakness and poor control associated with reduced resting muscle tone is present. As the voluntary movements return non functional mass flexion and extension are first noted. Synergy patterns are seen. Later independent movement patterns could be seen. Spasticity develops shortly after the stroke. If the recovery of the voluntary motor activity is incomplete then spasticity usually remains. Loss of sensations can have a significant effect on joint and skin protection, balance, co-ordination and motor control. Anatomical localisation of lesions within the CNS predicts various combinations of physical and cognitive impairments.

Disabilities

The one-sided motor impairments may have impact on the mobility functions and on hand functions. Patients have problems with completing activities of daily living (ADL). Many of the motor tasks need to be relearned. The cognitive impairments and aphasia may reduce to capability to communicate with other people and to comprehend the meaning of signals from the environment.

6.2.3 PARKINSON'S DISEASE

Impairments

Parkinson is a neuro-degenerative disease, resulting in the progressive decline of heterogeneous populations of neurones in the higher centres of the Central Nervous System. The cause of Parkinson disease is still unknown (Marani, Veltink et al. 2000). It results in impaired control of the spinal circuitry and, thus, impaired motor control. Aspects of the impaired motor control are (Hilten 1993):

- the inability to initiate and perform movements fluently. Aspects are:
 - *akinesia*: the inability to initiate movements
 - *hypokinesia*: reduced movement
 - *bradykinesia*: slow movements
- *tremor*: oscillating movement with a base frequency of 4 to 6 Hz.
- *rigidity*: increased stiffness
- *impaired postural stability*

Further movement disorders may appear as a side-effect of the levodopa medication.

Disabilities

The typical patient with moderate Parkinson's disease assumes a flexed posture, has difficulty initiating gait, walks with a shuffling gait. The base support is usually narrow. Once walking begins, the patient has great difficulty in changing direction, stepping over or moving around an obstacle or stopping. During gait, associated movements such as arm swing, trunk rotations are reduced or absent. The patient can topple over due sudden 'freezing'.

Due to a variety of movement disorders the patient has great difficulty in ADL and mobility.

Treatment

Individuals with Parkinson are treated with the medicine *Levodopa*. This medication reduces the movement disorders. However, after several years of medication, additional movement disorder may result, called *dyskinesia* (increased abnormal involuntary movements) and the efficacy of the medication may decline.

If severe motor disorders can not be decreased effectively anymore with medication, surgical interventions may be applied:

- *pallidotomy*: coagulation of part of the pallidum, a centre in the brain, involved in central motor control
- *deep brain stimulation*: continuous stimulation of the pallidum using an implantable stimulator

6.2.4 CEREBRAL PALSY

Cerebral palsy (CP) is a collection of diverse syndromes characterised by disorders of movement and posture caused by a non progressive injury to the immature brain. Cerebral palsy is characterised by the type of muscle tone abnormality and the body parts involved. The most common abnormality is that of increased muscle tone or spasticity. Less common are diskinctic disorders with involuntary movements, such as athetoid, choreiform, ballistic, and ataxic.

Impairments

The most striking difficulties in CP are of neuromuscular control. Abnormalities of muscle tone are frequently accompanied by muscle weakness, which can cause strength imbalance at individual joints. The major secondary effects of abnormal muscle tone, control and balance are changes in joint alignment leading to contracture and deformity. Contracture often occurs in adductors, hamstrings, and plantar flexors. Bony deformities can occur because abnormal muscle forces act on a growing skeleton.

Disabilities

The most striking functional impact of this abnormal neuromuscular control is a decrease in independence and mobility. Motor delay is common place in CP. Energy expenditure is increased of all motor activities. Children who do achieve ambulation have inefficient gait with increased energy expenditure and decreased velocity compared to their peers. Their co-ordination of movements is also poor. Contractures and bone and joint deformities can greatly limit child's functional ability. Secondary pain can worsen spasticity and contribute to the inefficiency of movement.

Treatment

Therapeutic management of the child with CP emphasises a functional aim or goal oriented approach. The two major goals are to decrease complications and to enhance or improve the acquisition of new skills.

6.2.5 SPINAL CORD INJURED (SCI) INDIVIDUALS

Impairments

In most cases, Spinal Cord Injury (SCI) is caused by traumatic accidents, e.g. car accidents, diving in shallow water, etc. The spinal cord injury limits or prohibits information exchange between parts of the CNS proximal and distal to the injury. After the initial acute phase, which requires intensive hospital treatment, the exact nature of the lesion becomes clear. Muscles supplied by nerves which arise below the level of the lesion may be completely paralysed because central voluntary signals do not arrive at the level of the spinal cord where the motor neurone population lies which drives these muscles. These muscles are usually spastic, because the central signals that modulate the sensitivity of the reflex loops are missing. In healthy individuals, these signals tune the reflex loops depending on the external loading, and are mostly inhibiting in nature. If they are missing, unstable reflex loops may result. The severity of the impairments after SCI depends on the level and the degree of the injury. Lower levels of SCI (in the thoracic and thoraco-lumbar regions) result in paralysis of the lower extremities (*paraplegia*), while higher level injuries (cervical region) may result in paralysis of the upper extremities along with lower extremities (*quadriplegia*). The injury may be *complete* or *incomplete*. In incomplete SCI, the muscles under the level of the lesion may be still partly under voluntary control and there may be some relearning of motor control. This is not the case for complete SCI: no relearning of voluntary activity has been shown, although some non-functional activation patterns generated below the lesion may still be triggered when the extremities are moved (Dietz, Wirz et al. 1998).

It should be noted that the impairments do not only concern skeletal muscles, but may also affect bladder, bowel, and sexual functions; in the case of higher lesions, diaphragm and chest muscles.

Disabilities

A complete paraplegic is completely wheelchair dependent as far as mobility is concerned. He may be ADL self sufficient. Subjects with quadriplegia are not only wheelchair dependent but they are also dependent on helpers for their ADL and other activities. Micturition, defecation, and sexual function require assistance. Very high cervical level lesion patients require assisted respiration.

6.2.6 MULTIPLE SCLEROSIS

Multiple sclerosis (MS) is an inflammatory disease of the CNS that is characterised by areas of demyelination.

Impairments & Disabilities

In Multiple Sclerosis (MS) the conduction of action potentials along the myelinated nerve fibres is impeded due to process of demyelination. Therefore, the signal transmission in the motor control system is impeded. Following symptoms are present at the onset of the disease Weakness (40%), paresthesia (30%), gait difficulty (25%), optic neuritis (20%) diplopia (15%), ataxia (10%), nutrition problems (10%), and vertigo (5%). Fatigue plays an important role in the disability. The actual source of fatigue is not well understood, but may result from a combination of weakness, spasticity, ataxia, depression and heat. Mobility problems are most common complaints of the patients with MS. Various ADL are often affected in patients with

MS. Brainstem lesions can result in dysphagia. Problems with balance, mobility, ataxia, spasticity and weakness frequently lead to difficulty with hygiene, dressing, toileting and communication. Cognitive and psychiatric changes are also often encountered in patients with MS. Bladder and bowel dysfunction is a frequent complaint. The course of the disease is variable.

6.2.7 NEUROPATHIES

Peripheral neuropathy is a common diagnosis with many causes and varied prognoses. As far as motor control is concerned, in cases of sensory deficits the system lacks feedback for the peripheral receptors such as tactile, machano-receptors, muscle spindles and golgi tendon apparatus. Movements tend to be exaggerated and lack fine control.

6.2.8 MYOPATHIES

Myopathies are a group of muscle diseases whose most common primary symptom is proximal limb muscle weakness. There are a variety of myopathies which differ in aetiology, course, specific muscle involvement and associated problems. These include the muscular dystrophies, and the myopathies that are congenital, metabolic, endocrine, infectious, collagen-vascular, toxic or secondary to other aetiologies. The most common muscular dystrophy is Duchenne muscular dystrophy (DMD) and it is more severe and quicker in progression than other dystrophies. Other dystrophies include Becker's, facioscapulohumeral, myotonic, the limb girdle type and Emery-Driefuss type.

Impairments & Disabilities

DMD is an X-linked recessive myopathy. It typically becomes evident at approximately 3 to 5 years of age. Early difficulties are clumsiness, poor walking and frequent falls. The weakness begins in the pelvic and then the shoulder girdle muscles. It is generally symmetrical. It finally progresses to respiratory and distal limb muscles. DMD progresses with a predictable pattern but variable rate of functional loss in different children. The clinical course is progressive respiratory and limb muscle weakness, contractures, and reduction of physical function. Ambulation ceases at approximately 12 to 13 years of age. Death usually occurs at the age of 20 years and is due to respiratory insufficiency.

6.2.9 AMPUTEES

Impairments

The commonest causes for amputations of part of the lower limbs are vascular, malignancy and traumatic. Occasionally an amputation is performed to improve function in cases of congenital limb deficiencies. Vascular diseases requiring amputation include diabetes mellitus, arteriosclerosis, and buerger's disease. Trauma to the limb often involves vascular or nerve injury, burn injury, frost bite or non healing fracture. These render the affected limb less functional than a prosthetic limb. The types of amputation by level are partial foot, Syme, below-knee or trans-tibial, knee disarticulation, transcondylar or supracondylar, transfemoral or above knee, hip disarticulation, and hemipelvectomy.

Disabilities

Encountered difficulties with mobility are dependent on the level of the amputation.

REFERENCES

- World Health Organization (1980). International Classification of Impairments, Disabilities and Handicaps. Geneva.
- Dietz, V., M. Wirz, et al. (1998). "Locomotor capacity and recovery of spinal cord function in paraplegic patients: a clinical and electrophysiological evaluation." *Electroencephalogr Clin Neurophysiol* 109(2): 140-53.
- Hilten, J. J. v. (1993). Assessment of motor activity in Parkinson's disease. Leiden, Rijksuniversiteit Leiden: 151.
- Marani, E., P. H. Veltink, et al. (2000). Inleiding Biomedische Technologie - De ziekte van Parkinson. Enschede, BMTI, UT.