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Gait in patients with stroke-related hemiparesis and methods of gait assessment

Chód pacjentów z niedowładem połowiczym po udarze mózgu i metody jego oceny

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ABSTRACT
Cerebral stroke, a serious complication of cardiovascular system disorders, has become an important medical issue in contemporary societies. Gait disorders in patients after stroke constitute a serious clinical challenge - every year, more than ten thousand patients become seriously disabled as a result of stroke. Locomotor disability is one of stroke's consequences. Patients with stroke-related hemiparesis often show gait disorders. Hemiparetic gait is characterized with a number of disorders, such as a considerable asymmetry of gait phase time, i.e. step length, or limb load – the healthy leg being overloaded. These disorders result in limiting patients' everyday activity. Therefore, objective methods of gait analysis are currently being researched. Among gait assessment methods there are clinical, or observation methods – which consist of gait description as related to the normal gait patterns; as well as quantitative, or objective methods – which consist of measuring, description and analysis of chosen parameters of human gait.

STRESZCZENIE
Udar mózgu, będący dramatycznym powikłaniem chorób układu naczyniowego, stanowi duży problem zdrowotny we współczesnym społeczeństwie. U pacjentów z niedowładem połowiczym po udarze mózgu występuje patologiczny wzorzec chodu. Chód hemiparetyczny cechuje się serią zaburzeń, w tym znaczną asymetrią czasu trwania faz chodu, długości kroku, obciążenia kończyn, polegającą na przeciążaniu kończyny zdrowej. Skutkuje to ograniczeniem aktywności w życiu codziennym. Ze względu na narastające znaczenie społeczne i powszechność udaru mózgu coraz częściej poszukuje się metod w zakresie analizy chodu tej grupy chorych. Wśród metod oceny chodu wyróżnia się metody kliniczne, obserwacyjne polegające na opisie chodu w odniesieniu do wzorca prawidłowego oraz metody ilościowe, obiektywne, polegające na pomiarze, opisie i analizie wybranych parametrów charakteryzujących chód człowieka. Celem pracy jest charakterystyka chodu pacjentów z niedowładem połowiczym po udarze mózgu i metod jego oceny.

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The aim of the study is to characterise gait in patients with stroke-related hemiparesis, as well as to discuss the methods of its assessment.

Keywords: cerebral stroke, hemiparetic gait, gait assessment methods

Słowa kluczowe: udar mózgu, chód hemiparetyczny, metody oceny chodu

Cerebral stroke, a serious complication of cardiovascular system disorders, has become an important medical issue in contemporary societies. Expert Team of the National Programme for Cerebral Stroke Prevention and Treatment reports that approximately sixty thousand new post-stroke survivors are registered in Poland every year. Gait disorders in patients after stroke constitute a serious clinical challenge - every year, more than ten thousand patients become seriously disabled as a result of stroke. Locomotor disability is one of stroke's consequences. Re-learning to walk and to load both limbs correctly early after the stroke onset is a crucial part of physiotherapy, as it helps to improve quality of life and patient's independence in everyday life. Most stroke patients regain the ability to walk on their own, yet the quality of their locomotion varies. Post-stroke gait is characterized with overload and longer stance phase of the healthy limb, asymmetry of gait phase time and step length; requires more effort and greater energy expenditure and is therefore uneconomical and inefficient. Disorders of balance, spatial orientation and coordination are common; and along with decreased speed they hinder everyday functioning and make falls more likely. 65–75% of post-stroke patients are found to encounter gait difficulties, and almost 40% of patients suffer from serious falls within a year since the stroke onset [1–8].

Stroke that damages capsula interna results in considerable motor deficits. Massive contralateral hemiparesis – increased muscle tone of upper limb flexors and lower limb extensors – results in a characteristic body posture, called Wernicke-Mann posture. Apart from motor disorders, patients suffer from sensory deficits, mainly of proprioception, that affect the kind of movement, and cause body positioning in space, body perception and field of vision deficits. These symptoms stem from the damage to the fibres of the pyramidal tract and the sensory fibres of the radiationes thalami. Patients with a typical Wernicke-Mann posture present lower limb mass extension model (simultaneous action of hip extensors, knee extensors and ankle plantarflexors). It results in a characteristic gait, called circumduction gait. In this type of gait, the leg on the affected side is extended and internally rotated, and is swung in a wide, lateral arc forward. The foot is in the plantar flexionorclub positioning. The limb is not fully loaded. Lack of ankle dorsiflexion tends to be compensated through hyperextension of the knee, as well as through tilting the body forward and to the side of the healthy limb. Patients try to consciously spare the affected limb, shorten the time of its load and move the body load onto the healthy limb. All these affect the gait phase time. The healthy limb stance phase is prolonged so that the affected limb stance phase can be shortened. The affected limb swing phase is then prolonged and consequently the healthy limb swing phase is shortened. Also, double stance phase is prolonged in comparison with healthy subjects. In consequence, hemiparetic gait becomes inharmonious, unsynchronized and asymmetrical. Step length of the affected limb is shortened, resulting from the quick swing of the healthy limb forward and lack of sense of stability of the affected limb at the stance phase. The mass lower limb extension model hinders the functional shortening of the limb in that it does not allow for flexion at the knee at the mid-swing phase. The inability to regulate the limb length results in disordered smoothness of gait, increased energy expenditure and weakened acceleration [9–15].

Another kind of hemiparetic gait, yet much less common, is the paretic lower limb mass flexion model (simultaneous hip flexion, knee flexion and ankle dorsiflexion with hallux flexion). This model allows for a part of the swing phase only and there is no Terminal Swing phase that is related to the knee extension. Limb flexion in three joints allows for lifting and swinging the limb forwards. Simultaneously, the range of the swing is limited by additional dorsiflexion of the foot. Consequently, the patient moves the limb in the coronal plane only, therefore shortening the step length [15].

The ability to maintain balance is crucial for independent gait. The damage of sensory centres, especially of proprioception, deviation from normal body positioning in space and body perception cause balance disorders in post-stroke patients. The indicator of correct balance is the symmetrical lower limb load. In post-stroke patients, the body centre of gravity while standing is shifted to the side of the healthy limb. The differences in limb load of the healthy and the affected limbs are considerable. The mean limb load of the affected limb is 36% of body mass, in comparison to equal load in healthy subjects. Another gait indicator in post-stroke patients is decreased speed, step length and cadence. It has been proved that the minimal walking speed that allows for a post-stroke patient's independence in everyday life is 0.55m/s. To be comfortably active outside, patients need to be able to achieve the walking speed of 0.9m/s. To compare that to healthy subjects, the optimal walking speed in terms of minimal oxygen use per a unit of distance is 1.3m/s [3, 15, 16].

Analysis of individual gait phases in hemiparetic post-stroke patients has found that because of the contracture of plantarflexors or the weakening of dorsiflexors of the affected foot, the first stage of the stance phase, i.e. the Initial Contact involves the forefoot or the whole foot. The Loading Response phase is characterized with flexion at the hip and hyperextension at the knee, which compensate lack of dorsiflexion at the ankle. In the full physiological load the trunk tilts to the side of the stance limb, the healthy gluteus muscles on that side contract and therefore the pelvis on the opposite side is lifted. These actions enable harmonic gait. In hemiparetic post-stroke patients, positive Trendelenburg's symptom is found. Because of the hemiparesis, the abduction muscles are not able to support the pelvis on the stance side. Therefore, the pelvis on the swing side is lowered, necessitating the compensation of the thus moved centre of gravity. The compensation is achieved through tilting the upper part of the trunk towards the stance leg, which is known as the Duchenne's sign. At the midstance stage, the affected stance limb is not fully loaded, and there might be hyperextension at the knee. The terminal stance and pre-swing phases are characterized with limited time and weakened acceleration, resulting from pathological mass synergies that limit the mobility at the hip and ankle. The Pre-Swingphase in the swing phase is characterized by the hip being lifted backwards for a prolonged time. This results from insufficient flexion at the knee, necessitated by the compensation for swinging the limb. The mid-swing is characterized with insufficient flexion at the hip, knee, and ankle, shuffling the foot and a greater abduction at the hip. The deceleration phase is characterized by lack of selective dorsiflexion at the ankle [12–14, 17–20].

Among gait assessment methods there are clinical, or observation methods - which consist of gait description as related to the normal gait patterns; as well as quantitative, or objective methods- which consist of measuring, description and analysis of chosen parameters of human gait. Observation methods are commonly used in clinical practice, as they are cheap, easily available and easy to use. Unfortunately, they are subjective, and therefore susceptible to mistakes, and their reliability depends on the skills of the analyst. The basis for understanding the observational gait analysis is the good knowledge of planes of movement, gait phases and normal gait patterns. The observation should be based on the patient's gait in the sagittal and coronal planes, in footwear and barefoot, with assistive equipment (a crutch or walking stick) if necessary, from a distance of about two metres, and should involve at least two gait cycles for each of the lower limbs. The stance and swing phases, with their individual stages, time, symmetry and smoothness, as well as mobility ranges in lower limb joints are assessed in the sagittal plane. The symmetry of lateral movements of the pelvis – the lowering on the swing limb side, symmetry of the load transmission onto the stance leg, the positive Trendelenburg's and Duchenne's symptoms, lifting the limb from the heel off to heel strike position, the limb positioning in adduction and abduction are assessed in the coronal plane [17, 21–24].

Since there are no consistent standards in the observational gait analysis, the comparison of results of different authors seems challenging. It may be difficult to simultaneously observe all the various segments of the patient's body. An approach to solving this issue is registering patient's gait with the use of two video cameras, positioned in two planes, the sagittal and coronal planes. Being able to view the material numerous times, as well as to pause it, may considerably improve the precision of observation. The observational gait analysis often uses gait scales, which provide numerical description of gait. Among various scales and tests for gait assessment, there are the ten meter walking test, twenty meter walking test; 2, 6 and 12 minute walking tests, " Get Up&Go" test, the Tinetti test, Dynamic Gait Index, and, finally, the Wisconsin Gait Scale, used for both gait disorder assessment in hemiparetic post-stroke patients, as well as for monitoring effects of physiotherapy [22, 25–27].

Quantitative gait assessment methods provide valuable information on gait parameters, yet they are expensive and time-consuming. They allow for accurate analysis of time and space indicators (step length, walking speed, cadence, percentage of individual phases in the whole gait cycle, length and time of gait cycle), kinematic parameters (mobility range at individual joints measured on the basis of trajectory of chosen points of the patient body in space during gait), kinetic parameters (forces and torques present at gait) and muscle activity at gait. Chosen parameters may be measured independently with the use of a number of technological solutions. Gait speed, step length or cadence may be assessed with the use of simple equipment such as stopwatch or tape measure. Sophisticated equipment for assessment of time and space indicators and kinetic parameters are available in forms of paths and platforms (the Zebris platform or Biodex treadmill), as well as insoles equipped with sensors that register foot pressure on the ground (Parotec insoles). Electrogoniometers (Noraxon solutions) are used to analyze kinematic gait parameters - they are placed directly on the patient body in the axis of rotation of the analyzed joint and therefore allow for movement range measurement in dynamic conditions. Dynamometric platforms (AMTI, Kistler) are used for making kinetic measurements - they measure all three component forces of the ground reaction force (GRF), therefore enabling to reconstruct the points of application of the reaction force onto the surface and to calculate the torques in joints in all three planes. Modules for surface electromyography (BTS-EMG) may be used to register the analysis of electrical activity of muscles [22, 24, 28–31].

Optoelectronic computer systems (VICON, PRIMAS, ELITE, BTS SMART) are modern methods for gait analysis. The gait analysis these systems provide is quantitative, objective and three-dimensional. Optoelectronic systems are constructed of cameras emitting infrared radiation, and cameras that register movement - passive, i.e. reflecting the radiation and active, i.e. emitting light of the markers stuck onto the chosen anatomic points on the patient body. Data from all the cameras are sent to the computer, which reconstructs the trajectory of marker movement and then calculates the changes of angles between patient body segments, or kinematic parameters. The systems allow for simultaneous recording of kinetic parameters. The walking paths have floor mounted dynamographic platforms that record the ground reaction force values. The systems are equipped with digital cameras that record gait in the coronal and sagittal planes. Apart from kinetic and kinematic gait assessment, the systems record the bioelectrical muscle activity. All the recorded signals are averaged, then a report is generated in either a numerical or graphic form, separately for each of the limbs. The software allows for averaging the data collected in a number of patient gait cycles. The test report allows for comparison of the patient result with norms for healthy subjects [22, 24, 32–36].

Taking into consideration all of the above, gait assessment in patients with stroke-related hemiparesis is a diagnostic challenge. Having become an increasingly common medical issue, stroke has had increasing impact on societies. Therefore methods of gait analysis of post-stroke patients are being intensively studied. Clinical practice has usually employed observational methods for analysis of human locomotion, yet such methods are not fully objective. Consequently, a need has arisen for using quantitative methods of gait assessment. These methods enable a full and complex locomotion analysis, crucial for both diagnosis and therapy.

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