neurological diseases, walk disturbances,
hemiparesis, sciatic neuralgia, Parkinson disease

Janusz S. ZBROJKIEWICZ*, Jan PIECHA**,
Andrzej WAJGT*

THE GAIT ABNORMALITIES REVIEW OF SEVERAL NEUROLOGICAL DISEASES

This study was based on observations of 117 patients suffering from motor disturbances. Among them 42 cases with hemiparetic syndrome, mostly after cerebral stroke, 52 cases affected by acute sciatic neuralgia, and 23 patients with recognition of Parkinson - disease symptoms. To the control group 16 healthy adults was selected from our medical staff. All subjects were examined using pedobarographic equipment - Parotec System for Windows (PSW) [1]. Based on these observations several pattern solutions have been introduced. They concern gait disturbances in three distinguished neurological diseases. These findings extracted a new data from the PSW records and options and new diagnostic techniques based on the gait characteristics observation.

1. INTRODUCTION

Patients suffering from neurological diseases demonstrate various motor disturbances, losing the motor control means causing the gait disorders (Fig.1).

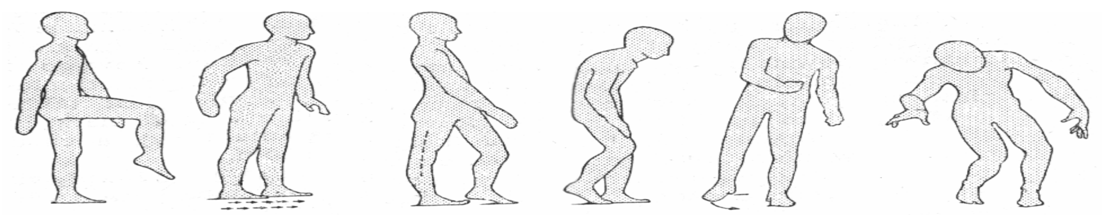

Fig. 1. Several postures illustrating neurological diseases

For a pathological level of the disease description very deep diagnosis has to be undertaken, with high knowledge of the physiological and pathological gait characteristics. First, the most important factor for gait – model analysis gives a musculoskeletal system. This model has to describe the intact bones and joints with well functioning muscles.

The second main factor for physiological gait description gives a nerves system model that initialises and controls the muscle motor functions and body balance. Complexity of this system excludes a separate analysis of the disturbances reasons. In the central nervous

* Clinic of Neurology Silesian Medical University, Katowice, Poland
** Division of Computer Systems, University of Silesia, Katowice, Poland, mail: piecha@us.edu.pl

system (CNS) motor cerebral cortex provides impulses for muscle contraction, the cerebellum intact of body balance and limbs coordination, and substantia nigra regulates the muscle tone. All these impulses are transferred via spinal cord and peripheral motor nerves into the muscles. From the other hand, nerve fibbers conduct impulses from muscles, tendons, joints and bones afferent to the CNS.

The third factor of physiological gait functions are vision and vestibular system. This way the gait disturbances are most common symptoms caused by various neurological reasons.

A gait analysis history

In XIX century, the precursor of gait investigation Gilles de la Tourette invented simple technique for gait analysis, described in 1872 by Piltz and Billroth. In 1976 it was also described by Omisuse (after Bechterev). This technique use the methods of gait functions description, where the gait characteristic data is recorded on a straight line drown on a band of paper 7-8 m long and 0,5m wide. The patient feet were covered by iron oxide (Fig.2)

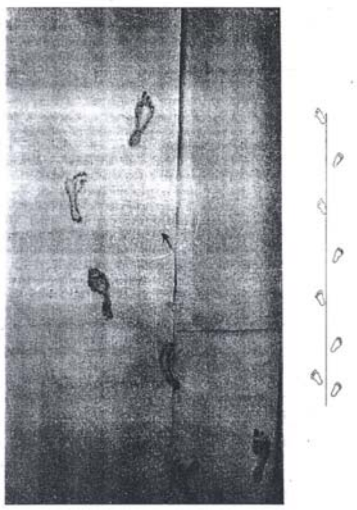

Fig. 2. The gait footprints of a Gilles de la Tourette's technique

In many research laboratories today various complex and very expensive equipment is available. Modern devices for gait examination are still based on an idea of Gilles de la Tourette. They use the dynamometric platforms or mats covered by number of sensors.

An example of the equipment was presented in Fig.3 where 14' portable carpet with 16.128 sensors, captures electronic footprint instantly. Variability characteristics of a gait and a body balance are analysed on line [2].

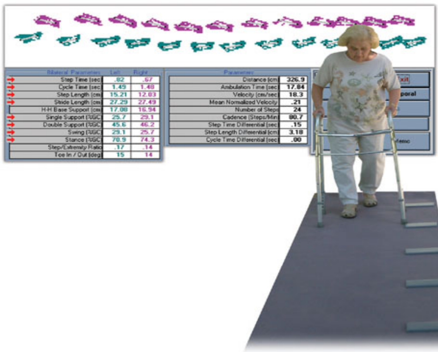

Fig. 3. The GAITRite Portable Walkway System (trade offer.)

This kind of dynamometric platforms [3] are usually supported by various additions with optical analysers of video-cameras or electromyography for immediate registration of muscles work (Fig. 4 – of Diagnostic Gait Laboratory in Children’s Memorial Health Institute in Warsaw).

This complex apparatus efficiently supports scientific investigations, but it is extremely expensive for everyday usage. The paper authors were searching portable technologies providing all necessary data for body balance analysis. With a high degree of reliability and lower costs. This way the Parotec System (PSW) was chosen [4].

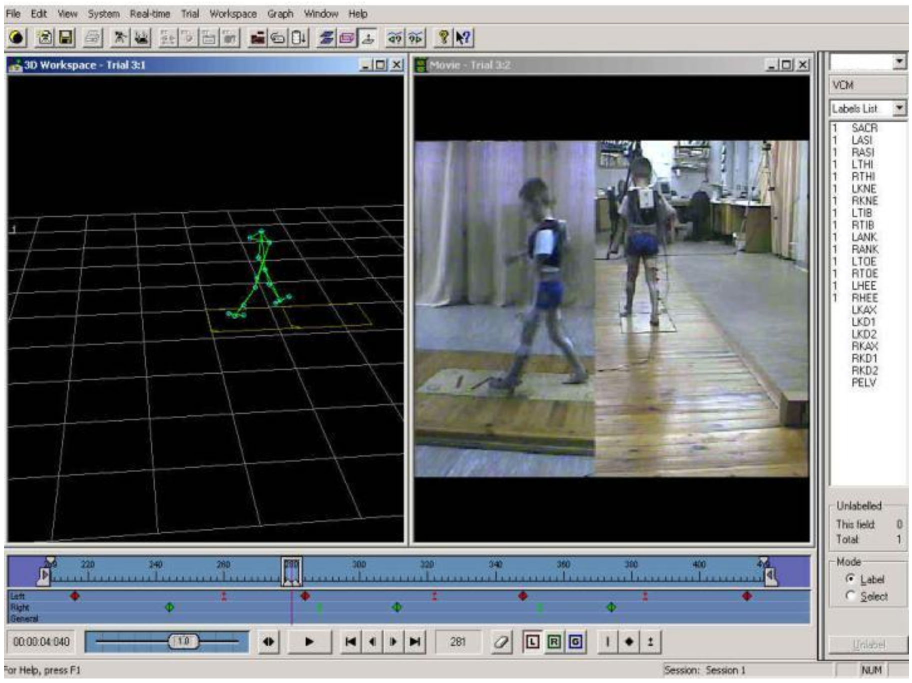

Fig. 4. Diagnostic Gait Laboratory in Children’s Memorial Health Institute

The PSW [1] is a portable computer aided measuring equipment that allows collecting information describing a way of walking (Fig.5).

Fig. 5. The PSW equipment and simplified interface (by Paromed GmbH)

The PSW collects source records, of static (while standing) and dynamic (while walking) data. The static part of the data record shows pressure distribution on insoles surface, in points where sensors are installed. It also allows observing a movement of patient's gravity centre.

The dynamic data interfaces show the whole record characteristics describing many factors of the patient gait. Ex. trajectories of the pressure (the insoles load) central point flow for a walk stability description, local impulses of energy and a time diagram of the pressure distribution.

2. PROBLEM DESCRIPTION AND SUBJECT SELECTION

A main goal of this study was examination of the PSW ability of collecting data representing readable factors, describing the gait disturbances, for selected subjects of neurological disorders (hemiparesis, acute sciatic neuralgia and Parkinson’s disease). Representative patterns of motor disturbances in this three groups of the diseases were also created.

Subjects

The 117 ambulatory or hospital adult volunteer subjects were recruited for the study. The selection criteria included acute musculoskeletal injures, several dementia or difficulties in understanding of verbal instruction, vestibule or visual affection, other non neurological muscle impairment, bones or joints disorders with a local foot-pathologies. To the control group a 16 healthy adults, from medical staff, have been selected.

I. The hemiparetic gait

Majority cases of so called hemiparetic syndrome were observed as a result of a brain stroke [5,6].

Definition: The hemiparetic gait is a cerebrovascular disease in which sudden disturbances in regional blood perfusion are noticed.

In 80 % of cases the stroke implies ischemia, 20% of strokes haemorrhage. The state after the stroke will be noticed as:

- a face muscles paresis or paralysis, hand and/or leg paresis or paralysis; usually one-sided (Fig.6),
- face, hand and/or leg anaesthesia; one-sided generally,
- gait disturbance in loosing balance and giddiness.

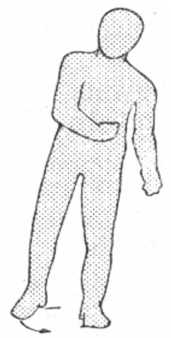

Fig. 6. Right-sided hemiparesis

The 42 ambulatory or hospital adult volunteer subjects, with the recognised hemiparetic syndrome were recruited. The 36 patients were at least 12 months post cerebrovascular accident (stroke), 5 of them were diagnosed as multiple sclerosis and 3 patients were post several head injuries.

In a static part of examination the readable movement of a body weight was observed and a body gravity centre moved towards the affected body side. These characteristic features were in direct relation to the hemiparesis severity. Patient was fixing the body weight on the affected limb (in majority of cases in a heel region). The healthy leg was used for a walk assistance only.

However, in a group of patients with a moderate or slight hemiparesis, the point of the body gravity centre was kept in a normal position. Moreover, in three check cases with a very slight hemiparesis the gravity centre movement to the opposite side; to the affected body part was noticed.

The severe left-sided hemiparesis after the cerebrovascular accident, with 55 points in Barthel's scale, has been presented in Fig.7. The patient fixed 98% of a body weight on an affected leg, with a 56% in a heel region. In Fig.8 the patient footprint of an affected foot shows the time increase of a floor contact (1820 ms instead of 960 ms). The foot gravity centre moved from the heel region to fingers, with irregular speed.

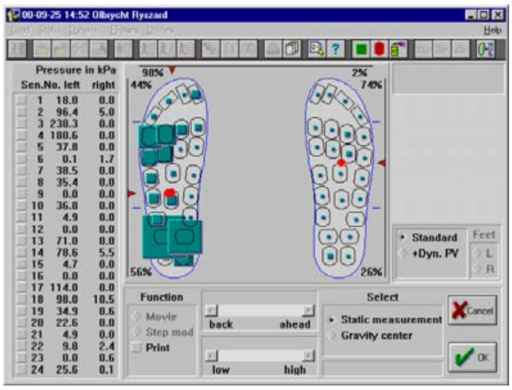

Fig. 7. Severe left hemiparesis;
with a moved body weight

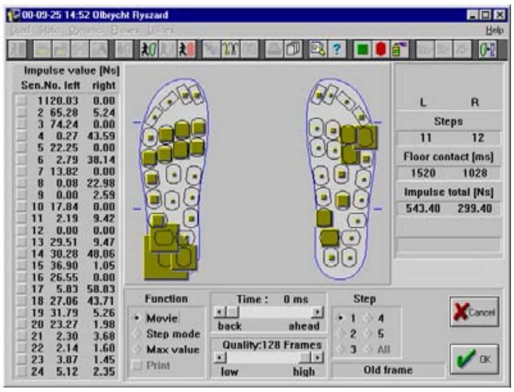

Fig. 8 .The floor contact time increase

The dynamic part of the data records examination allows finding regularities for a new time characteristics. The floor contact and impulse values (the equivalent of energy absorbed by the foot surface) increase within the heel zone of an affected foot. On a healthy foot the same phenomena was observed within the metatarsal zone; the foot gravity centre was reasonable closely focused in the metatarsal zone. In the affected foot they move from a heel zone to fingers in pendulum mode, with an irregular speed.

Majority of this discussed disturbances were observed within a first and a second phase of the step. The time diagrams of a pressure distribution show a distinct increase of an entrance phase and a support phase of the step, with significant shortage of a push-off phase. These abnormalities strictly correspond to walking with hemiparesis. The step overlap time is stable for both feet and it is independent from severity of motor ability destruction.

The discussed results allow us creating regular patterns for a gait disturbances defining hemiparetic syndromes:

- the body weight moves to the patient’s affected limb and on the paretic limb this overload lasts longer,
- the patient has also troubles with lifting the affected limb,
- the affected limb is somewhat thrown forward then the healthy limb is put to the paretic one,
- the affected limb is fixed at a knee-joint, bent into a floor and inside; the foot is carried over a curve, slightly up - in minimal grade,
- a toe is often hooking a ground.

II. The sciatic neuralgia

Definition: The term sciatic neuralgia describes the cluster of clinical signs causing pathology of nucleus pulpous - so called lumbar disc herniation. The lumbar pain is often radiating to the left or right lower limb. The pain is called sciatica or sciatic neuralgia, due to compression of spinal radix in one of five vertebral spaces.

In an early stage of the disease patient fills pain, chronic - slowly growing, sometimes more acute with sudden onset. This character of pain usually signalises that a lumbar disc prolapsed – out from spinal column, towards a vertebral canal. Nucleus pulpous is prolapsed centrally or laterally onto a left or a right side (Fig.9). The lateral localisation of lumbar disc herniation was commonly observed in this kind of pathologies.

Fig. 9. Scoliosis with pain and muscle contraction in acute sciatic neuralgia (by K.Levit)

The sciatic pain is often very strong and after two or three weeks of pharmacological therapy patient is directed to a rehabilitation clinic.

Patient is walking slowly, avoiding extension of sciatic nerve and changing position. In majority of cases, predominantly in lumbar region, the lateral curvature of spinal column - called scoliosis is visible.

52 hospital adult volunteers, aged from 24 to 72, with recognised sciatic neuralgia were recruited (Fig. 10, Fig.11). This population consisted of two equivalent groups; 26 cases each: the first group was recognised with a pain radiation to the left, and the second group to the right lower limb [7].

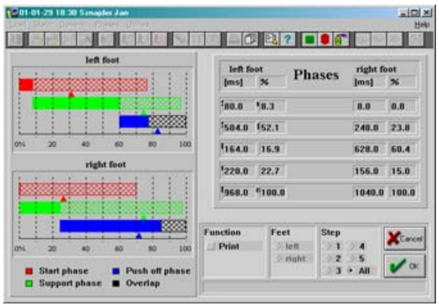

Fig. 10. The right lateral sciatic neuralgia - a floor contact time and impulse increase

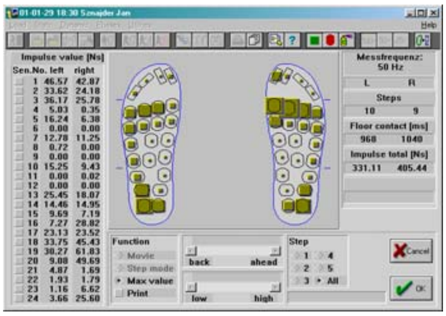

Fig. 11. This same case – elongation of support and push off phase on right side

In a static part of PSW examination records an observable movement of a body weight and a body gravity centre towards one side was noticed; the expected result, with the conclusion that patient protected the affected limb, a body weight moved to the healthy leg.

Further observations changed this assumptions, as majority of patients were burdening the affected leg – in 34 cases from 52 (65,4%). 18 patients carried the body weight into a healthy leg.

Majority cases fixed the body weight in a heel region of a foot – above 80% of all subjects. The dynamic measures examination indicated the floor contact time and impulse values increase on healthy limb in 14 cases (26,9%). The affected limb was burdened by 34 cases (65,4%). Some irregular actions were also observed, as a shorter floor contact with higher impulse values for 2 cases, both on a healthy or on an affected limb.

Summarising these observations several pattern remarks can be find that illustrate the gait disturbances in sciatic neuralgia:

- distinct shift of a body weight and gravity centre to the affected limb,
- the body weight is fixed within a heel zone in majority cases,
- the floor contact and impulse values increase on an affected limb.

III. The Parkinson disease

Definition: The Parkinson disease (PD) is more baffling and complex of all neurological disorders, where the direct reasons are still not explained. The PD symptoms are noticed as a combination of the following actions: hands tremor, rigidity muscles (constantly tensed), the patient feels stiff, temporary paralysis and various postural abnormalities (as stooped posture).

In the PD less critical symptoms are also visible, as: shuffling gait, a mask-like face (with reduced blinking) and writing difficulties (difficult to read the patient's handwriting). The disease progresses is observed in several additional troubles, as: speech, swallowing and sleep difficulties, urination, constipation. Drooling, sweating and intolerance to heat may also occur. Thinking processes, span attention, concentration, problems-solving ability, emotional changes, depression are visible as well.

THE PD LABORATORY EXPERIMENTS ORGANISATION

The 23 ambulatory and hospital adult volunteer patients, with previously recognised PD were recruited for the experiments; age from 46 to 78 years. In 15 cases left-lateral domination of the disease was recognised (for group A), 8 cases with right-lateral domination (for group B). Majority of them had moderate stage of Parkinson's disease or were in good responsibility on anti-parkinson therapy. In 7 critical cases severe difficulties with motor activities were observed.

Pre-diagnostics indicated the gait disturbances – asymmetrical, independently from the disease duration or severity, in all cases.

In a static part of the PSW examination record a readable movement of a body weight and a body gravity centre were observed; usually to the left side of the body and most frequently within a heel region of a foot (78% of all PD cases).

For the A group (left-lateral domination) - 13 cases (86,6%) fixed a body weight predominantly in a left foot-heel region, in 2 cases (13,4%) on a right foot-heel.

For the group B (right – lateral dominance) 4 of this cases (50%) fixed a body weight predominantly on a left heel region, 3 of them (37,5%) on left forefoot and 1 case (12,5%) on right heel.

Cases with left lateral PD, in 10 subject (66,6%) trajectories of a body balance were longer on more affected limbs. For cases of right lateral PD the same effect was noticed in 5 cases (62,5%).

In early stages of PD the difference in size of foot gravity centre trajectories between primarily affected limb and the other limb were slightly visible. Anyhow, in cases of severe stage of PD the difference was significantly bigger. The example of this differences is presented in Fig.12.

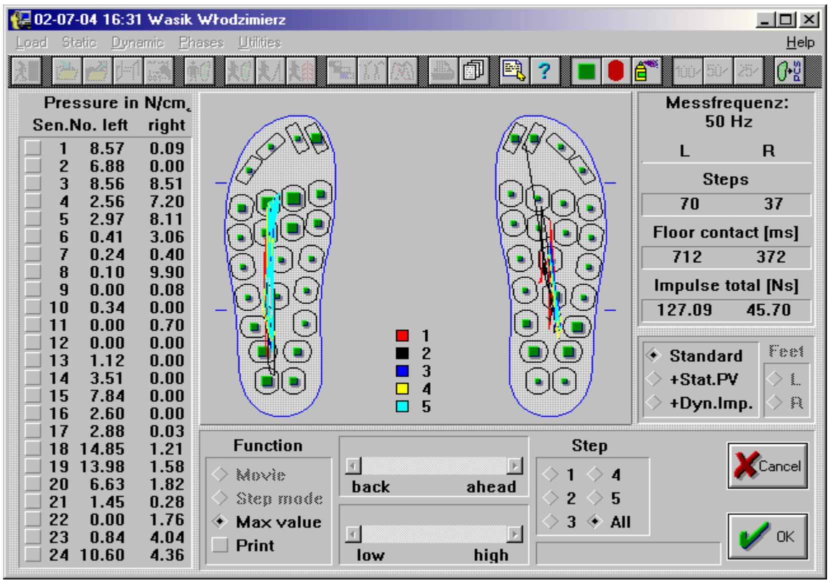

Fig. 12. 67 years old male with severe left - lateral PD: irregular trajectory on a left side; caused by tremor

In spite of these abnormalities, in majority of patients a floor contact time and impulse values increase was noticed as well. In 11 cases of left–lateral PD the increase of impulse values were visible, but only in 4 cases (26,7%) this increase was visible on a right limb.

In 5 cases of right–lateral PD (62,5%) the impulse value increase on a right limb was noticed, but for 1 case (12,5%) it was the same on both limbs (case with an early stage of the PD). In 2 cases only (25%) the increase of impulse values is visible on a left limb.

For the PSW record interpretation of the PD patients several characteristic patterns were found:

- asymmetrical lateralisation of gait disturbances (in 100% cases),
- majority of patients shifted a body weight into a left limb (78 %) and into a heel zone, independently from the side affection,
- elongation and irregularity of foot gravity centre trajectories, on more affected limb with more visible symptoms when disease severity is growing,
- in majority cases the floor contact time and impulse values increase on more affected limb,

- in majority cases the elongation of time of start and support phases on more affected limb is visible.

3. CONCLUSIONS

Although the PSW device was designed for orthopaedists the given data allows analysing various components of neurological diseases. In relation to other solutions the PSW has many advantages. Among them the most remarkable, are: portability and a low weight of the equipment, very reach interfaces visualising and interpreting various data components, friendly user software and relatively lower costs of equipment and its exploitation. This factors convinced us for doing these investigations.

After a long lasted field testing of the PSW options, several remarkable conclusion were defined. For the checked diseases (hemiparesis, acute sciatic neuralgia and Parkinson disease) the visible descriptors are available for the user. They permit preparing characteristics of gait disorders for the selected diseases.

Introducing this technology to neurological practice we can offer medicine a new quality in diagnosis, quantitative evaluation and monitoring the therapy progress. For most hemiparetic patients, individually determined physical therapy is the cornerstone in rehabilitation processes. The therapists use training, exercises and physical manipulation for hemiparetic patients body for movement, balance and coordination restoring.

The PSW can be used for recognition and quantification of the motor disorders as the check-up results can be compared with a pattern map of the foot physiology or any class of abnormalities.

These studies we made as a pattern, pioneer work for the three selected groups of patients. We are convinced that this kind of measures and devices provide operator with more data that can be fruitfully used. Our works with the system convinced us that it is a unique equipment with so reach computation options support. Anyhow various modification within the technology could be recommended. First a number of sensors can be remarkable reduced that reduces the equipment costs; not loosing its ability of neurological diseases diagnostics. Several interfaces should be better presented, for extracting the right scale of the characteristic features changes and several options are not needed for diagnosis of neurological diseases.

This kind of equipment would be very useful in rehabilitation processes monitoring, as the only solution noticed in the medical devices market. It would also be recommended for practical usage in clinics and local / regional laboratories.

The automatic conclusion making units are also very encouraging that are under development at present.

BIBLIOGRAPHY

[1] ZBROJKIEWICZ J.S., PIECHA J.:Parkinson disease examination using walk disturbances characteristics. Journal of Medical Informatics & Technologies. Vol. 3, pp: MI-134 – MI-142. ISSN 1642-6037, 2002.), pp.105-116.

[2] DRUŻBICKI M., KWOLEK A., RUSEK W.: Wykorzystanie platformy z komputerową synalizacją i rejestracją do ćwiczeń równowagi i oceny postępu rehabilitacji chorych z niedowładem połowiczym po udarze mózgu. Wydawnictwo Instytutu Gosp. Sur. Min. i Energią. PAN, Kraków 2001, 37- 42 (in polish).

[3] KWOLEK A., DRUŻBICKI M.: Wykorzystanie platformy do ćwiczeń równowagi z zastosowaniem biologicznego sprzężenia zwrotnego u chorych po udarze mózgu. Fizjoterapia 1999, 7, 3, 3-6 (in polish).

[4] ZBROJKIEWICZ. J, PIECHA J, .JARZĄBEK-STĘPNIAK A : Some abnormalities in gait pattern detected in patients with acute sciatic neuralgia using PSW system. Proc. Int. Conf. "KOSYR'01, pp. 29-36

[5] KWOLEK A., ZUBER A.: Charakterystyka chodu osób z niedowładem połowiczym po udarze mózgu. Neurologia - Neurochirurgia. 2002-36-2-337-347 (in polish).

[6] KWOLEK A., Wróbel B.: Problemy rehabilitacji chorych z niedowładem połowiczym obustronnym po udarze mózgu. Post. Reh. 1995, 9, 3, 31-37. (in polish)

[7] ZBROJKIEWICZ J., PAWEŁCZYK P., JARZĄBEK-STĘPNIAK A. The hemiparetic patient's motor disturbances and the PSW options evaluation. Journal of Medical Informatics & Technologies. Vol. 5/2000, pp:BI 45-50, ISBN 83-909517-2-7.

[8] ZYGUŁA J., PIECHA J., GAŹDZIK T. i wsp.: Zaawansowany system pomiarowy obciążeń statycznych i dynamicznych dla diagnostyki schorzeń ortopedycznych. "Chirurgia Narządów Ruchu i Ortopedia Polska", vol. LXI 1996 - suplement 3B pp.118-124 (in polish)

[9] LEWIT K. Leczenie manualne zaburzeń czynności narządu ruchu. PZWL Warszawa 1984 (in polish).

[10] ZBROJKIEWICZ J., JARZĄBEK- STĘPNIAK A: Analiza zaburzeń chodu u pacjentów ze spastycznym niedowładem połowiczym po udarze mózgowym przy użyciu systemu komputerowego PSW. Proc. Krakowskie Sympozjum Udarowe 29- 30 Sept. 2000 ,Przegląd Lek (Medical Revue - Supplement, 2/2000, val. 57, pp.2 (in polish)

[11] ZBROJKIEWICZ, J,. PIECHA J,. PAWEŁCZYK P., JARZĄBEK- STĘPNIAK A:Evaluation of motor disturbances in hemiparetic patients using Parotec System for Windows Proc. Int. Conf. "Medical Informatics & Technologies" (MIT'02) Ustroń-Jaszowiec, pp. 45- 50.