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CASE REPORT

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Biomechanical disorders of foot in multiple sclerosis

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Abstract

Multiple sclerosis (MS) has a multifactorial etiology located at the interaction point of environmental factors – nutritional, geographic, infectious, etc. – with genetic factors, which confers susceptibility to disease or alters its development. This research presents a case study focused on complex assessment of a patient using clinical and functional assessment, biomechanical gait evaluation using RSScan force plate. Biomechanical parameters (contact area, load, impulse, force, pressure, foot balance) are the parameters that we obtain after force plate measurements. Analyzing the results of the functional assessment, it is found an anatomical functional abnormality with a tendency to increase. Biomechanical tests show an asymmetric gait due to the impact of neurological disorders generated in the proprioceptive system. Global analysis of values (surface contact, pressure, force, load, impulse, active contact area) indicates the fact that there is a tendency to develop a higher pressure in the anterior-medial region of the plant in an attempt to maintain balance. It is a tendency to increase the active contact area in the forefoot region; this increase is explained by the body tendency to develop compensatory mechanisms to maintain balance.

Keywords: biomechanics, assessment, gait, balance.

Introduction

Multiple sclerosis (MS) is a chronic, often progressive disease, characterized by inflammation processes in the central nervous system and demyelination in axonal region [1, 2].

MS has a multifactorial etiology, located at the interaction point of environmental factors – nutritional, geographic, infectious, etc. – with genetic factors, which confers susceptibility to disease or alters its development; all this, together with post-genomic changes, lead to heterogeneous expression from the clinical, histological and genetic points of view [3].

Studies of magnetic resonance (MRI) show that axonal damage occurs in the first phase of the disease. In this first phase, the remyelination potential is maximum [4]. Therefore, early diagnosis would have valuable results, both in prevention and recovery. If the disease is diagnosed in early stage, current immunomodulatory therapies are very effective, albeit limited. The initiation of these therapies is influenced by the difficulty in administering drugs, their side effects and very expensive costs [5].

Clinically, MS is divided into four forms: clinically safe MS, clinically safe MS in conjunction with specific laboratory testing, clinically probable MS, clinically probable MS in conjunction with specific laboratory testing [6].

MS assessment is based on:

▪ Clinical functional evaluation using sensorial and motor scales (clinical and biomechanical), instrumental methods and temporary assessment tests to evaluate motor performance [7]. Any scale is based on scores obtained by adding the records and quotations of each item of the scale. Total score allows classification of the patients from the functional point of view (between normal, independent and fully dependent).

▪ Paraclinical evaluation including tests, in which a special attention is given to blood tests, nuclear magnetic resonance (MRI), cerebro-spinal fluid examination and evaluation of evoked potentials [8].

Patient and Methods

Male patient, aged 43 years, diagnosed with MS [9] from the age of 28 years, shows fatigue, impaired balance and gait, tremor of bilateral lower limbs, without having the family medical history of MS components; in personal pathological records presented an appendectomy 10 years ago. Anamnesis was followed by a clinical and functional assessment involving:

1. Clinical evaluation: complete neurological examination (muscle strength, presence of pyramidal signs, evaluation of gait disturbance and sensorial disorders and the presence of cerebellar signs, assessment of visual and auditory acuity) [10–13].

Following these assessments, we observed a decrease in muscle force (F=3), the presence of pyramidal signs highlighted by bilateral motor deficit in the lower limbs, sensory disturbances such as hyperesthesia, ataxic

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gait with no changes in visual and auditory acuity. Evolutionary stage is of primary chronic progressive multiple sclerosis.

2. Functional evaluation was achieved conform to Hamilton scales, ADL, Kurtz, and Scale Score of movement capacity, Impairment Scale, Disabilities, Handicap (IDH) [14–16].

3. Biomechanical gait evaluation was performed using a platform for force distribution and plantar pressure distribution FootScan Scientific Version planting, RSScan International, Olen, Belgium, able to perform measurements with a frequency of 500 Hz in 2D and record the complete action of both plants. The platform was used to record the pressure distribution values in the lower limb at ground contact. The plant applied on the platform measures local pressure at full contact with the ground at high frequency, the operational substrate is represented by the total impact force measured at the level of a sensor matrix on a known surface [17].

RSScan force platform makes the gait analysis in terms of ground reaction force and the pressure developed during gait. The values are expressed in [N] for force and [N/cm^2] for pressure. These measurements allow the study of the lower limb during gait, with or without assistive means. Data analysis includes: information about pressure distribution at plantar level, depending on time, force distribution in each plantar region, depending on time, load values in each region, the contact surface which is active (in direct contact with the platform surface, which stimulates the platform sensors), limbs axis and subtalar angle, limb balance in antero-posterior and frontal planes, pressure center position.

Both plants were recorded during two gait cycles, paying attention to alternative placement of the right/left lower limb.

In the present study, we grouped the eight stages of gait into three stages, namely: ground attack phase – the initial contact heel; midstance phase, in which the middle region of the plant is involved, and propulsion phase, in which the load is higher in the metatarsals; this stage depends on the way the tibial-tarsal control is achieved.

The parameters studied were:

▪ The maximum pressure recorded in the study area (P): maxP [N/cm^2];

▪ The maximum force recorded for the studied area (F): maxF [N];

▪ Impulse, I [Ns/cm]: the total load of the assessed region;

▪ Loading rate measured in the region, load rate, LR [N/cms]: the upload speed in the assessed region;

▪ Contact area, CA [cm^2]: the area corresponding to each evaluated area;

▪ Contact percentage [%] of the active surface during the stance phase: %C;

▪ Pressure distribution during gait relative to the sustaining surface;

▪ Graphs of foot balance: heel rotation, foot balance, load in the metatarsal area, which provides information about foot stability during gait.

Paraclinical evaluation used MRI [18] and found focal degenerative lesions.

Results

The results obtained by functional assessment are presented in Table 1.

Table 1 – *Results of functional assessment*

Scales	Results
Hamilton score	7 (absence of depression)
ADL score	8 points
Kurtz score	5 (medium severe disability)
Movement capacity	Moves 100 m without any aid
IDH classification	Severe disability

Biomechanical evaluation included analysis of the parameters in the following regions: lateral heel, medial heel, midfoot and toes 2–5; the results are presented in Table 2.

Table 2 – *Results of biomechanical assessment*

Analyzed parameters			Assessed areas			
			Toe 2–5	***Mid leg***	***Medial heel***	***Lateral heel***
Contact area	P	Left	86	61	57	56
		Right	72	85	66	71
	F	Left	133.8	60.5	6.9	10.3
		Right	73	87	72	73
Pressure/ Maximum force	P	Left	3.6	1.9	14.4	11.3
		Right	5.5	8.5	1.4	4.5
	F	Left	75.9	94	270.2	181.8
		Right	62	539.5	19.8	65.7
Load	P	Left	0.01	0.01	0.21	0.05
		Right	0.01	0.02	0.01	0.01
	F	Left	0.14	0.43	3.70	0.78
		Right	0.12	0.96	0.07	0.19
Impulse	P	Left	1.9	0.8	6.6	4.3
		Right	2.4	4.8	0.6	1.9
	F	Left	41.1	37.7	122.7	68.6
		Right	26.9	304.9	9.3	27.1
Active contact region	P	Left	21.4	49.1	18.8	16.1
		Right	11.2	63.4	14.6	14.6
	F	Left	21.4	49.1	18.8	16.1
		Right	11.2	63.4	14.6	14.6

Anatomical and functional parameters of the leg recorded the following aspects:

1. Distribution of the pressure center was assessed depending on the plantar axis; there was a distribution in medial plantar region, bilaterally (Figure 1).

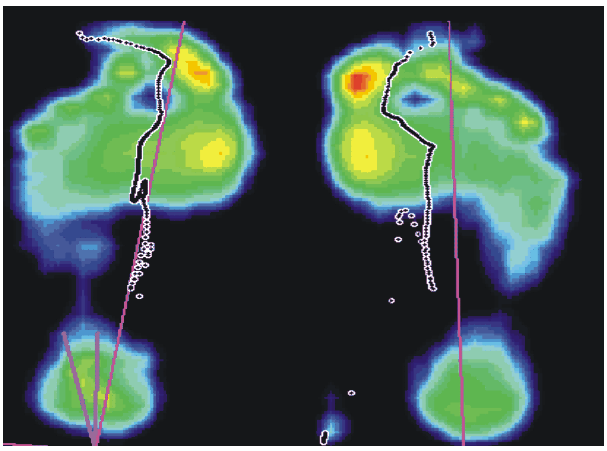

Figure 1 – *Distribution of the pressure center.*

2. Heel rotation: during a gait cycle, there is a tendency towards negative values from 0^0 to 20^0 for the left leg. In the right leg, we observe values of 0^0 during the ground attack phase and negative values up to -38^0, negative values signifying an endorotation (Figure 2).

3. Foot balance: we notice an evolution of the left foot from 0^0 to 30^0, the maximum value during the propulsion phase; in the right foot the positive values were up to 124^0, value reached during the propulsion phase (Figure 3).

4. Load in metatarsal region: it is constant in the left foot, while in the right foot it is constant only during the contact phase and part of the midstance phase, recording a load decrease in the final part of midstance phase and during propulsion phase.

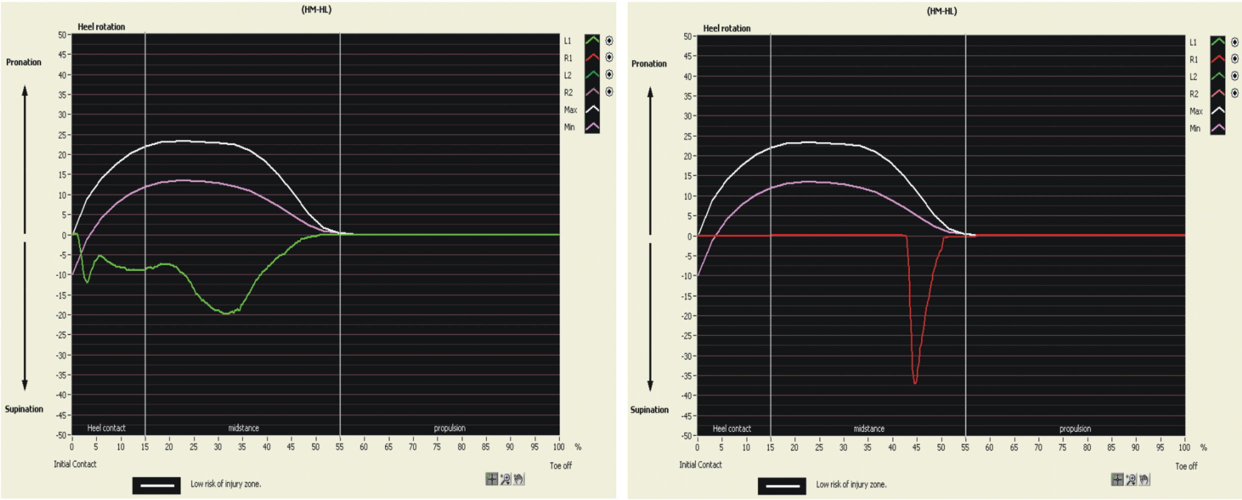

Figure 2 – ***Heel rotation.***

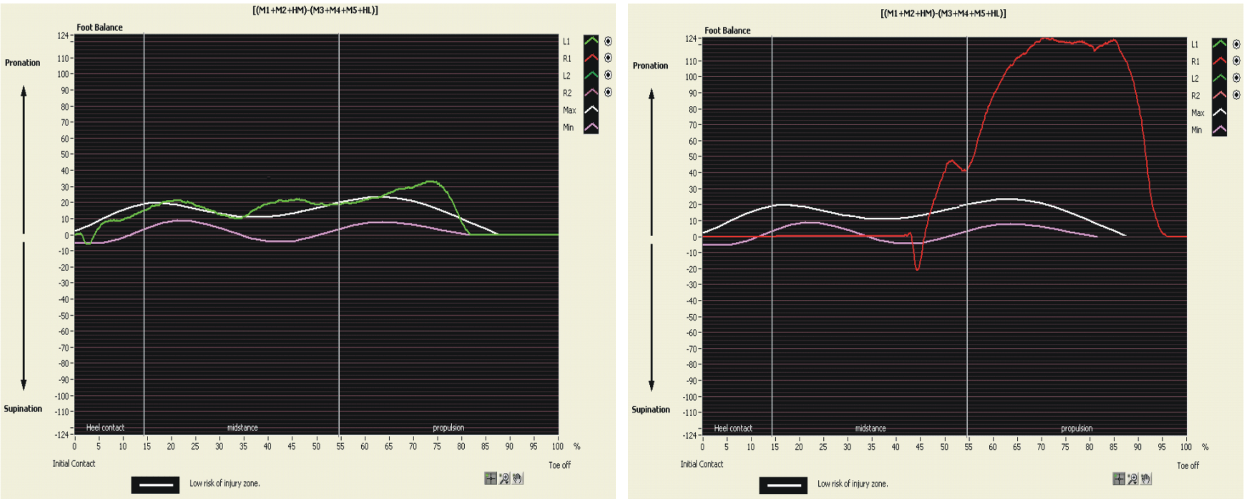

Figure 3 – ***Foot balance.***

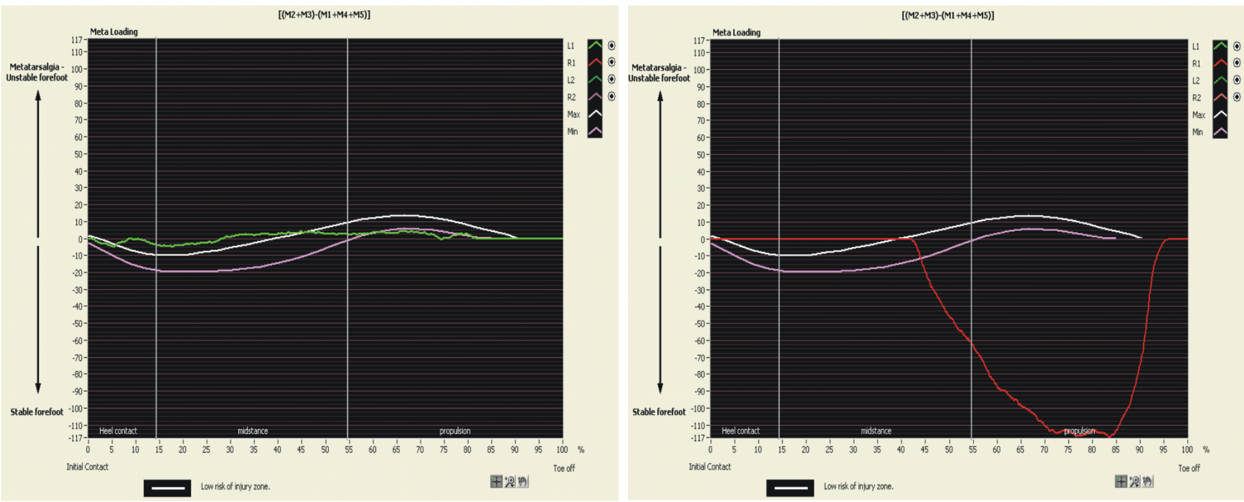

Figure 4 – ***Loading in metatarsal region.***

Discussion

Analyzing the results of the functional assessment, it is found an anatomical functional abnormality with a tendency to increase; this aspect is supported by the values of ADL scale, which indicate the patient's inability to carry out daily activities. The value 5 on Kurtz scale highlights a poor clinical and functional condition of the patient and the tendency of a progressive disease. Evaluation of gait [19] and motor performance by the use of biomechanical tests shows an asymmetric gait due to the impact of neurological disorders generated in the proprioceptive system; this aspect is highlighted by Fjeldstad C *et al*. as well [5]. In the context of these findings, one of the biomechanical parameters assessed – the contact area – shows differences between right and left limb, which are also evident in the expression of maximum and minimum values; all this leads to an increasing tendency of this area as a compensatory means to maintain balance [20].

The impulse correlated with the movement speed had high values due to the poor motor control; the aspect is noted by Kelleher KJ *et al.* [21] who observed the decrease in plantar flexion and propulsion force based on a dynamic EMG gait test [22].

Maximum pressure values are recorded in the left leg.

Global analysis of values (surface contact, pressure, force, load, impulse, active contact area) indicates the fact that there is a tendency to develop a higher pressure in the anterior-medial region of the plant in an attempt to maintain balance.

Regarding the analysis of the morphofunctional parameters, we found the following:

▪ Heel rotation: there is a complete output of the minimum risk area with a pronation of up to -20^0 for the left limb in the first two phases and a return to neutral position during the propulsion phase. In the right leg, there is a much higher supination -38^0 in the midstance phase to return to neutral position during the propulsion phase.

▪ Balance foot: there is a point near the minimum risk area for Phase 1 and 2 and an increased pronation up to 124^0 during the propulsion phase in the right limb.

▪ Load in the metatarsal area: there is a load in the left limb in neutral position while the right limb is stable during the propulsion and midstance phases.

▪ Distribution of the pressure center: there is a bilateral distribution to the metatarsals 1 and toes 1, sharper in the right foot, which means that the gravity center tends to project to the anterior side.

Conclusions

Corroboration of clinical and functional data with the biomechanical results indicate high values of loading and an elevated pulse, a marked right-left asymmetry in all phases of gait, aspects justified by reducing propulsion force of the foot during gait. There is a tendency to increase the active contact area in the forefoot region; this increase is explained by the body tendency to develop compensatory mechanisms to maintain balance. Analysis of maximum pressure and force in the metatarsals 1 and toes 1 shows the onset of certain compensatory mechanisms to solve balance disorders and orientation disorders of ground reaction force to normalize the gait; these compensatory mechanisms are, in fact, adaptive mechanisms.

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