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Morphofunctional aspects of lower limb in multiple sclerosis

M. C. NEAMŢU[1)], LIGIA RUSU[2)], M. MARIN[3)], TAINA AVRAMESCU[2)], P. F. RUSU[3)], OANA MARIA NEAMŢU[2)], MARIA IANCĂU[4)]

[1)]*Department of Pathologic Physiology, University of Medicine and Pharmacy of Craiova*

[2)]*Department of Sports Medicine and Kinesiology*

[3)]*Department of Applied Mechanics*

University of Craiova

[4)]*Department of Physiology, University of Medicine and Pharmacy of Craiova*

Abstract

Gait, as an expression of the locomotive system, needs a complex biomechanical analysis, which allows the description of multiple sclerosis (MS) specific patterns, MS patients having a polymorphism of motion patterns. The studied group consisted of 13 MS patients with gait disorders, average age of the group was of 36 years. The evaluation of the subjects comprises: clinical evaluation (anamnesis, neurological examination), paraclinical evaluation (MRI), functional evaluation, neuro-physiologic evaluation and biomechanical evaluation. Biomechanical examination was completed using the force and pressure-measuring platform of plantar pressure distribution Footscan Scientific Version, RSscan. The studied parameters were: contact area, active contact area, heel rotation, foot balance, foot angle. The evaluated zones during a gait cycle were: the heel, medial foot, antefoot. Although the analysis of contact area in the lateral foot did not show any significant differences between the right and the left foot, it nonetheless underlined a major difference in the expression of maximum and minimum values, which meant that MS patients with clinically detectable gait disorders had a tendency to increase contact area to maintain balance. Examining the foot positions in relation to the movement direction and to the foot vertical axis, we noticed the existence of certain elements indicating an orientation tendency of the foot. This tendency had to be related to neutral position (corresponding to anatomical position) of the foot. We also noticed a foot deviation in abduction, associated with visible pronation and decrease of the contact area corresponding to medial plantar zone.

***Keywords*:** gait, morphofunctional parameters, biomechanical parameters, evaluation.

Introduction

Each patient with multiple sclerosis (MS) presents a wide range of lesion types [1], which involves a polymorphism of the gait patterns due to many pathologic mechanisms and etiologies. This demonstrates the existence of heterogeneous syndromes with consequences on the therapeutic approach.

Gait, as an expression of the locomotor system, needs a complex biomechanical assessment [2, 3], which allows the description of MS specific patterns and facilitates certain programmes of gait disorders prophylaxis and rehabilitation [4] at MS patients [5].

The gait cycle is comprised of stance (approximately 60%) and swing phases (approximately 40%). The stance phase is divided into more stages: loading, median stance and heel rising while the swing phase comprises initial and terminal swing. There are two short moments of double stance when both feet contact the ground, allowing weight transfer from the rear foot to the front foot. The body weight is sustained by a single limb approximately 80% of the gait cycle.

Kinetic variables are highly important in gait analysis; they are calculated using force plates and kinematic data. These are: *vertical and horizontal ground reaction forces (GRF)* (Newtons per kilogram), *the moment of force* produced at the joint level (Newton-meters per kilogram), *the power* transferred between the body segments (watt) and *mechanic energy* of the body segments (Jouli). *The moments of force* represent the final product of the forces in the ligaments and of friction forces, which modify the rotation angle at the joint level. The moments can be interpreted as resultants of muscle forces.

Patients and Methods

The purpose of this paper is to present morpho-functional limb aspects during gait at MS patients.

The research was carried out in compliance with the principles of ethics, the Declaration of Helsinki and the Law No. 206/2004.

The studied group consisted of 13 MS patients with clinically detectable gait disorders, out of whom seven men and six women. Average age of the group was of 36 years.

From the clinical point of view, the patients had two flares: positive MS diagnosis and gait capacity. There were excluded both the patients with spasticity level above 2 on Ashworth scale, who presented severe balance disorders during gait and orthostatic and the patients whose data were incomplete and did not allow evaluation.

The evaluation of the subjects comprises: clinical evaluation (anamnesis, neurological examination), paraclinical evaluation (MRI), functional evaluation, neurophysiologic evaluation and biomechanical evaluation.

Biomechanical examination was completed using the force-measuring platform of plantar pressure distribution Footscan Scientific Version, RSscan International, Olen, Belgium, which can measure at a frequency of 500 Hz in 2D and record the complete action of both heels. RSscan system uses a force platform of 0.5×0.4 m, equipped with pressure sensors to measure the ground reaction force resulted at the heel contact with the stance surface. The platform is laid on a 6 m surface, which is long enough to record a normal gait (Figure 1).

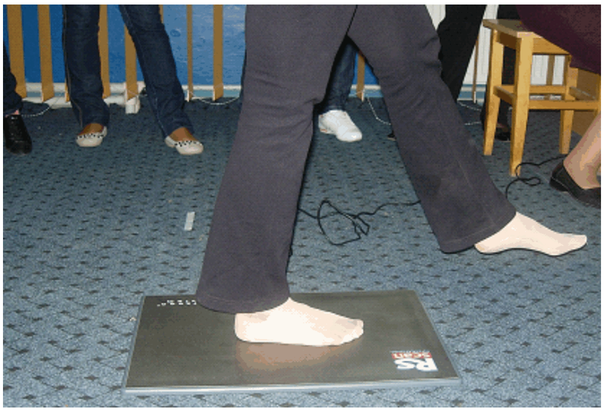

Figure 1 – ***Using the pressure plate off the stride.***

The measures were completed in dynamics during a full gait cycle at comfortable walking speed. Out of the eight gait stages, we chose three stages: heel strike or initial contact; midstance, when midfoot intervenes; and propulsion stage or pre-swing, when the loading is mainly at metatarsal level. This last stage depends on the way cnemial-tarsal control is done.

The plantar analyzed zones were lateral heel (LH), medial heel (MH), midfoot (MF) and rarefoot corresponding to metatarsals.

The data obtained were processed by RSscan software. The results are in accordance with anthropometric parameters: height, weight, foot size, age.

The registered parameters are: pressure parameters, force and balance [6]:

▪ Maximum pressure recorded in the measured zone: Max P [N/cm^2];

▪ Maximum force recorded in the measured zone: Max F [N];

▪ Impulse – I [Ns/cm]: represents total load of the studied zone;

▪ Load rate – LR [N/cm×s], in the studied zone: represents the load speed in the studied zone;

▪ Contact area – CA [cm^2]: represents the area corresponding to each studied zone;

▪ Contact percentage [%] of the active area during stance – %C: offers information of the percentage of total active area, corresponding to the studied moment, respectively, the percentage of contact time in comparison with balance complete phase.

We considered that contact area and contact active area are the most significant parameters from morpho-functional point of view. The data obtained and the graphic representations were statistically processed by general mathematical software package (Microsoft Excel) or by specific statistic programs (the program of academic usage, Minitab 15 or the package distributed by WHO, Epi2000).

The calculation and statistical analyses in Microsoft Excel were processed by predefinite functions, Data Analysis Module, XLSTAT and WinSTAT.

Results

Biomechanical evaluation of the gait by pressure platform RSscan allowed us to divide the patients into three categories: patients with normal symmetric gait, patients with abnormal symmetric gait and patients with asymmetric gait. These aspects are shown in Figure 2 and Table 1.

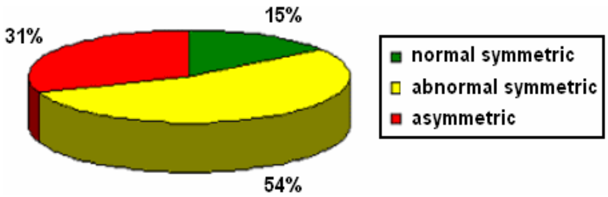

Figure 2 – ***Graphic representation of MS patients in terms of foot symmetry.***

Table 1 – ***Distribution of MS patients in terms of foot symmetry***

Symmetry type	No. of subjects
Normal symmetric	2
Abnormal symmetric	7
Asymmetric	4

Contact area recorded average values for both feet depending on the pressure (Figure 3) and force (Figure 4).

Mean value of contact area in the lateral heel of the right foot was of 71.38 cm^2, and of the left foot of 65 cm^2.

At the level of medial heels, we also noticed higher mean values in the right lower limb – of 72.03 cm^2, comparatively with 71.07cm^2 in the left lower limb.

In the midfoot, we recorded a mean contact area of 66.46 cm^2 in the right limb and of 78.61 cm^2 in the left one.

The last gait phase we studied corresponded to the metatarsal zone 2–5; this area showed a mean contact area of 56.76 cm^2 in the right lower limb and of 59.92 cm^2 in the left lower limb.

Active contact area is a parameter connected to contact area but which depicts the way in which the plantar area studied exerts pressure on the sensors of pressure and force plate, determining thus the ground reaction force. Our recording is shown in Figures 5 and 6.

The values recorded in the lateral heels were of 16.8% in the right lower limb and of 15.86% in the left lower limb.

In the medial heel zone, we recorded values of 15.86% in the right lower limb and of 18.68% in the left lower limb.

In the medial heel, the values obtained were of 49.06% in the left lower limb and of 41.24% in the right lower limb.

In metatarsal zone 2–5, our values were of 14.62% in the right lower limb while in the left one they were much lower – of 9.75%.

The data obtained in gait analysis allowed us to evaluate the patients according to qualitative parameters such as: heel rotation, foot balance and foot angle evolution as well.

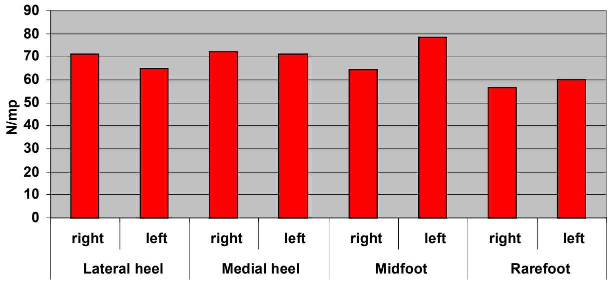

Figure 3 – ***Mean values of contact area in terms of pressure for both feet.***

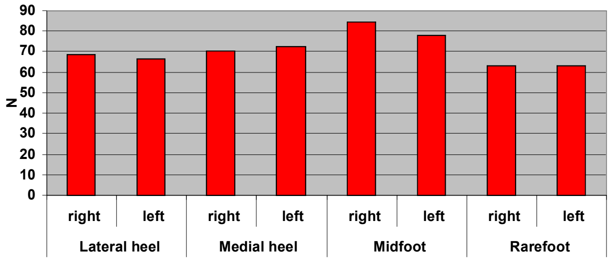

Figure 4 – ***Mean values of contact area in terms of force for both feet.***

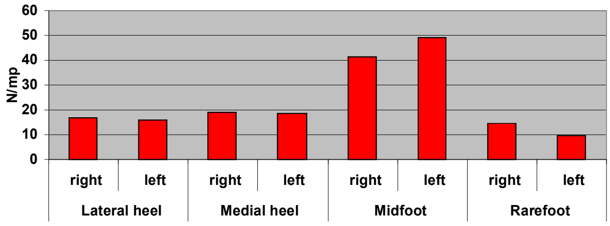

Figure 5 – ***Mean values of active contact area in terms of pressure for both feet.***

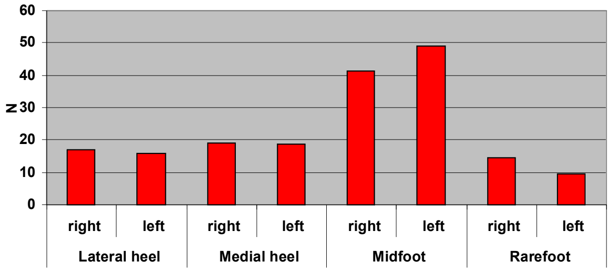

Figure 6 – ***Mean values of active contact area in terms of force for both feet.***

Heel rotation underlined a functional right–left asymmetry, in one of the lower limb supination accounted for values between 38^0 to -5^0, corresponding to the heel strike phase. We noticed a stronger pronation in the counterlateral lower limb, more stressed during semistance phase and propulsion phase; it even reached 124^0.

Foot balance showed supination in one of the lower limbs and pronation in the counterlateral limb. All the patients recorded balance limb disorders during all the gait phases studied, as well as a lack in the evolution tendency towards neutral position.

Foot angle at the MS studied patients had a mean value of 9.97 in the left lower limb apart from six patients who recorded higher values. The mean value in the right lower limb was of 9.79 except for seven patients who registered higher values. Although the mean values were quite similar, we noticed major differences right–left at each patient.

Discussion

Despite the fact that contact area analysis of lateral heel did not show significant differences between the right and the left lower limbs, it pointed out a clear difference in the expression of maximum, minimum values, which means that MS patients with detectable gait disorders needed a larger contact area as a compensatory means to maintain balance. A similar situation was recorded in the medial heel, where the values evolution indicated a tendency to enlarge the contact area. The increase of the contact area was, on the one hand, necessary due to the lack of motor control in the limb at heel strike and, on the other hand, because of the compensatory mechanisms triggered by balance disorders, mechanisms that played a role in increasing stance base.

Moreover, we could notice a functional deficit in the ankle joint complex, which prevents physiologic orientation of the force vectors from shank to foot, namely decomposition in the vertical and horizontal plans, also demonstrated by Houglum PA, in 2005 [7, 8].

Analyzing the metatarsal zone 2–5 from the point of view of contact area parameter, we realized that this zone did not represent a significant element in gait analysis [9].

Active contact area expressed the pressure distribution in stance area depending on the way in which the sensors of pressure and force plate are stimulated. This area allowed us to appreciate both the correct physiological pressure distribution namely talus, heel, navicular, cuneiforms, and the way in which the ground reaction, force is physiologically orientated, namely from lateral heel to cuboid and metatarsal II.

MS patients recorded the same value of active contact area, with a right–left asymmetry. At the same time, the interval range of minimum values is lower, while maximum values had a mean of 20% [10, 11].

Following the patients' evaluation according to qualitative parameters, namely heel rotation, we noticed an evolution of supination to pronation and again to supination in one lower limb when heel strike is performed by heel exorotation (supination), and a tendency to pass from pronation to neutral position in the other limb. These aspects could be explained by adaptive control-motor mechanisms, which tried to maintain balance [12, 13].

Foot balance referred to the general limb position, especially during the propulsion phase. Heel strike depended entirely on this phase in the next gait cycle, aspect that was connected to the tendency of heel exorotation and pronation.

All the patients recorded disorders in foot balance during all the gait phases studied, as well as the lack of evolution tendency to neutral position [14, 15].

Analyzing the limb position in contrast to gait direction and vertical foot axis we noticed that there were elements, which indicated a foot orientation tendency also analyzed in its neutral position (corresponding to anatomical position). We could see a foot deviation during abduction, due to an increased pronation and a decreased contact area corresponding to average plantar zone.

We noticed at MS patients a predominance of the cases with a tendency to evolve from endorotation to exorotation, but also cases of bilateral exorotation. These aspects were explained either by balance disorders or by the decrease of plantar contact area [16, 17].

Conclusions

The biomechanical study demonstrated that the two parameters: load and impulse had high values at MS patients; these patients displayed a significant right-left asymmetry during all the gait phases due to the lower propulsion force of the foot in stride.

We noticed that during the heel strike and in semistance the feet are in pronation, with a tendency to neutral position while in the propulsion phase.

The results obtained in heel rotation analysis were correlated with the results recorded in foot balance, namely there was a balance disorder due to the supination of one of the lower limbs and the pronation of counterlateral lower limb.

Analyzing the evolution of the foot angle, we determined negative values at the patients with asymmetric gait disorders and endorotation. This right-left asymmetry reflected the tendency to develop compensatory mechanisms to control foot balance and stability.

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Corresponding author

Marius Cristian Neamțu, MD, Department of Pathologic Physiology, University of Medicine and Pharmacy of Craiova, 2–4 Petru Rareş Street, 200349 Craiova, Romania; Phone +40757–033 888, e-mail: drcristianneamtu@yahoo.com

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