

INDIVIDUALIZATION OF THE POST-TRAUMA RECOVERY PROCESS IN SPORT BY GAIT ANALYSIS – A CASE STUDY RESEARCH

G. IONESCU¹ D. V. CAIMAC²
E.T. AVRAMESCU¹ M. ZĂVĂLEANU¹

Abstract: *After trauma, it is important for a sportsman to return to the competition as soon as possible and at the highest functional level so most sport injuries require individualized rehabilitation approaches. In this context the development of a tool to analyze the functional progress of recovery process is becoming essential. In sports and rehabilitation the number and complexity of evaluation methods have increased dramatically, with the integration of non-invasive interdisciplinary investigation techniques. Our paper presents a case study regarding the correlations between the biomechanical parameters obtained by RSSCAN gait analysis before and after the application of an individualized kinetotherapeutic program. The main purpose was to demonstrate how the proposed method can be used like assessment and follow up tool permitting to individualize the frequency, intensity, time and type of rehabilitation exercises. By these innovative approaches we hope to increase the success rate in the trauma recovery and the improvement of the sports performance.*

Key words: *sports injury, sports rehabilitation, plantar pressure, individualised approaches*

1. Introduction

In sports and rehabilitation area the number and complexity of the evaluation methods have increased dramatically with integration of non-invasive interdisciplinary investigation techniques.

In order to further estimate the efficiency of a kinetic program the gait functional

analysis is less used commonly in clinical practice. At the same time, the analysis of gait is limited if it does not allow the physical therapist to choose between possible alternative interventions or a prediction of the results [1], [2], [5], [7].

Different studies report a high frequency of injuries, not only during leisure activities, but especially in performance sports.

¹University of Craiova, Faculty of Physical Education and Sport.

²University of Medicine and Pharmacology Craiova.

The highest incidence of sport trauma is related to the lower limb. In this context the need to determine the risk factors in producing these traumas but also to develop a tool for monitoring the functional progress in the recovery process becomes crucial.

Most of the times this progress cannot be assessed just by clinical usual tests and scales. If we aim to facilitate the prescription and recovery objectives, exercises and techniques it is necessary to develop tests characterized by simplicity, objectivity, reproducibility, low costs, and simple to use.

However, due to the multifunctional character and the complex structures of the foot, the role of the ankle-foot complex in terms of the interaction with the ground during movement is difficult to analyse [4]. The function of the foot during gait is widely used to evaluate the magnitude of forces acting, timing of motor unit function, walking abnormalities for presurgical assessment and treatment follow-ups [6].

Plantar pressure measurements provide direct and objective information on how various foot structures interact with the ground and provide a real opportunity to characterize the functional aspects of the ankle-foot complex during walking. [1], [2], [5], [7].

Pressure platforms provide the specific location of pressures as they appear under foot in gait dynamics, and information obtained from such pressure measurements is important in gait and posture research for diagnose in glower limb problems, designing sports shoes or

various plantar corrections, biomechanics and sports injury prevention, objectification of the process of recovery from sports injuries and other applications.

The combination of all these data together provides a more exhaustive, detailed and accurate view of foot loading during activities than traditional measurement systems alone do [4].

In the present study we focused on the correlations between the biomechanical parameters obtained through the computational analysis of gait by using the Footscan Scientific Version pressure platform, RSscan International before and after the application of an individualized kinetotherapeutic program.

In this way our research was mainly based on the hypothesis that the static and dynamic gait study with the RSSCAN platform will allow quantification of the recovery process. More, we consider that the correct evaluation of the gait during recovery intervention and establishment of the objectives of the therapeutic program based on clear data and objective biomechanical functional parameters ensure a better tracking of the process efficiency.

2. Materials and Methods

Our study was based on data acquisition and gait analysis by the use of the plantar pressure distribution system Footscan Scientific Version, RSscan International, with a length of 0.5 m for a female handball player, aged 27 that suffered a knee injury (Table 1- a,b,c).

Correspondence between the traumatic pathology recorded and the protocols used

Table 1

The type / location of the trauma (a)	Observations (b)	Orthopaedic treatment (c)	Elements of individualisation (d)	3 months rehabilitation protocol after scan evaluation
grade II / III sprain at the right knee	Grade III lesion of internal posterior meniscus horn	Surgery for anterior cruciate ligament	Proprioceptive circuit exercise: half squat, straight lunge, side lunge, and one-legged balance exercise 3 sets/ 10 times/ set/ session	<ul style="list-style-type: none"> – stretching for patient specific muscle imbalances, – low velocity progressing to higher velocity control exercises multi-plane activities, – specific balance exercises, – hip and core strengthening, – strength and control drills movements – core strengthening – stationary bike

The biomechanical measurements, the functional evaluation and the application of the therapeutic protocol were performed within the University of Craiova Research Centre for Human Motricity.

2.1. Gait assessment protocol

The pressure data's were collected by a single contact of the foot with the platform. Walking with support was not allowed. The walking speed was the one allowed by the related pathology. We perform 3 consecutive measurements until the walk was performed at a speed of between 600-800 ms.

The measurements were considered valid after familiarizing of the subject with the platform and if they meet the following criteria: (1) a common pattern of heel application, (2) the existence of a similarity of values for 2 measurements.

The frequency of planting pressure sampling was 200Hz.

The evaluations were performed before the application of the physical therapeutic protocol (initial test/ T_i) and at the end of

the period estimated as necessary for recovery (final test/ T_f).

The following parameters were recorded for the subject:

- Maximum force - maxF (N)
- Impulse - I (Ns / cm)
- Load rate - load rate- LR (N / cm.s)
- Contact area -contact area- CA (cm²)
- Contact percentage (%) of the active area in the support phase - % C
- Maximum pressure - Max P (N / cm²), respectively the force applied to the sensors level (max. F/peak sense or area).

The method was used to compare the biomechanical parameters recorded for the left/right plantar regions but also in compared with the medial and lateral parts of the foot.

The analysis of the given parameters in relation to the type of pathology allowed us the individualization of the standard rehabilitation procedure for the given pathology (Table 1 –d, e).

3. Rehabilitation Protocol

The evaluation of the plantar pressure started when the subject reaches the

phase III after the surgery orthopaedic treatment, when she was allowed to walk freely (at 3 months after surgery).

The rehabilitation protocol included only kinetic therapy with a 3 months duration, with a frequency of sessions of 3 per week, with sessions lasting 30 minutes for the first week.

After the first month, the time increase with 10 minutes each week until we get to 60 minutes. According to the recorded biomechanical parameters the standard rehabilitation protocol was completed with advanced exercises to restore proprioception (20 min per session).

The progress was quantified by comparison of the recorded parameters before and after the application of individualized therapeutic protocol followed by the automatic processing, graphic and analytical analysis.

For an optimal interpretation of the recorded data we establish a reference data set (normative study) by a previous research that recorded the above-mentioned biomechanical parameters in a number of 102 athletes with no known lower limb pathology and no known walking changes (control group - Table 2).

4. Results and Discussions

By comparing the recorded values for the two plantar regions it is observed that the subject presents a walking asymmetry. This aspect can also be noticed from the inequality of contact time between the two plantar regions (940 ms for the left foot versus 1000 ms for the right foot).

From the analysis of the data included in **Table 3** it is observed that, for the lower right limb (LRL), the one with traumatic pathology, most values exceed the maximum of the series (21 values out of

the 40 registered), 12 values exceed the average, and 3 are below the minimum.

The increased values were recorded mainly for the maximum force, impulse and loading rate parameters for most of the investigated anatomical areas and correlate with the lower walking speed for the opposite lower limb.

- For the **lower left limb**, there are 16 values that exceed the maximum of the series, 9 values that exceed the average, and 5 values are below the minimum.

- For the parameter **maximum force**, all values corresponding to LLR are above the maximum limit of the normative group. Exceptions are metatarsals 4 and 5, because the foot is in slight pronation (increased force at the level of the medial heel against the lateral heel). However, these values also exceed the average.

-For the parameter **loading rate**, it is observed that the loading is high for the metatarsal area for both plantar regions (values above the maximum normative). For the right foot, these values are also present at the level of the fingers 2-5.

This is explained by the fact that, due to the pain, the initial contact with the heel is avoided when the lower limb (knee) is in full extension, and the entire body weight will thus *loaded* at the forefoot.

Bernstein shows that patients with knee pain seams to keep the knee extended or in a slightly bent position (especially if there is present an increase joint fluid) and the normal flexion-extension-flexion cycle in the support phase is absent or attenuated. [3]

For the parameter **impulse** values above the normative maxima can be observed at the level of the metatarsals and the medial heel at the leg corresponding to the affected knee.

Table 2

The values of the biomechanical parameters registered with the RScan platform for the subject compared to the average, minimum and maximum values calculated for a control group

Parameter Unity of measure	Max F N			Upload rate N/s			Impulse Ns			Contact area cm ²		
	max	media	min	Case	max	media	min	Case	max	media	min	Case
Left foot												
Hallux	235.9	199.6071	128.8	356.3	1.65	0.761786	0.19	1.34	61.1	40.61786	33	76.8
Toes 2-5	68.6	36.27353	18.6	0	0.56	0.232059	0.04	0	14.3	7.485294	4.2	0
Meta 1	145.8	72.36129	28.5	112.6	0.69	0.572581	0.06	0.83	74.5	57.89677	39.7	28.6
Meta 2	258.7	201.8361	169.2	151.7	0.8	0.584722	0.22	0.93	64.9	48.04722	48.4	44.1
Meta 3	231.7	174.1294	99.2	179.5	0.91	0.591471	0.27	0.98	68.4	50.54118	36.5	56.6
Meta 4	212.2	121.5472	72.3	156.6	0.74	0.396111	0.12	0.77	67.3	56.01667	32.2	44.8
Meta 5	82.8	65.30303	15.6	57.9	0.43	0.447273	0.16	0.36	69.5	45.35152	35.8	13.1
Mid foot	220	178.8	115.1	223.5	5.09	1.948387	0.57	3.95	70.1	55.7	39.5	40.2
Hellmedial	338.4	288.4357	223.7	504.8	15.04	9.680714	8.85	11.65	81.3	73.41429	56.7	83.3
Hell Lateral	326.1	270.9189	223.4	296.6	12.83	10.47541	7.64	22.27	89.9	69.02973	58.3	54.4
Right foot												
Hallux	231.8	183.6676	123.4	0	1.44	0.612353	0.15	0	68.6	40.00588	32	0
Toes 2-5	73.2	37.64516	12.3	246.8	0.83	0.241935	0.04	1.09	13.9	6.777419	4.5	57.4
Meta 1	157.7	89.10606	39.6	237.8	0.95	0.585152	0.12	1.93	72.4	47.10606	36.6	72.6
Meta 2	267.1	207.573	151.8	289.4	0.86	0.598108	0.27	1.81	70.6	54.48108	48.6	102.8
Meta 3	248.8	187.4472	76.5	252.6	0.91	0.576944	0.24	1.49	68.6	54.01944	40.9	94.5
Meta 4	201.6	104.9545	55.3	184	1.1	0.371818	0.13	1.15	79.2	52.83333	36.7	61.3
Meta 5	87.5	40.16071	18.2	58.8	0.57	0.488214	0.05	0.59	66.5	46.32857	41.9	13.5
Mid foot	233.6	173.6735	124.5	243.7	2.66	1.927353	0.24	2.1	71.8	56.15588	38.2	37.6

*Value over average *Value above maximum *Value under minim

Table 3

Comparative between biomechanical parameters on anatomical areas and case for the two tests

Parameter Unity of measure	Max F N			Impulse Ns			Upload rate N/s			Contact area cm ²		
	T initial	T final	Average value	T initial	T final	Average value	T initial	T final	Average value	T initial	T final	Average value
Left foot	356.3	200,1	199.6071	1.34	1,32	0.761786	76.8	52,5	40.61786	10.1	15,2	17.44286
Hallux	0	20,1	36.27353	0	0,28	0.232059	0	6,3	7.485294	0.8	12,6	12.31765
Toes 2-5	112.6	122,4	72.36129	0.83	0,62	0.572581	28.6	37,4	57.89677	13.9	13,9	10.47419
Meta 1	151.7	155,8	201.8361	0.93	0,72	0.584722	44.1	44,1	48.04722	12.4	12,4	10.30833
Meta 2	179.5	174,3	174.1294	0.98	0,91	0.591471	56.6	54,5	50.54118	9.4	9,2	8.508824
Meta 3	156.6	156,1	121.5472	0.77	0,71	0.396111	44.8	49,2	56.01667	10.1	10,1	8.958333
Meta 4	57.9	59,3	65.30303	0.36	0,39	0.447273	13.1	43,2	45.35152	13.9	13,9	11.74242
Meta 5	223.5	194,6	178.8	3.95	3,92	1.948387	40.2	47,5	55.7	42.4	42,4	35.49677
Mid foot	504.8	254,2	288.4357	11.65	10,61	9.680714	83.3	76,5	73.41429	20.2	20,2	16.81429
Hell medial	296.6	296,9	270.9189	22.27	12,22	10.47541	54.4	64,6	69.02973	17.6	17,6	14.17297
Hell Lateral	0	153,2	183.6676	0	0,87	0.612353	0	39,4	40.00588	0	17	17.01471
Right foot	246.8	66,9	37.64516	1.09	1,21	0.241935	57.4	8,4	6.777419	27.8	13,9	12.64194
Hallux	237.8	145,3	89.10606	1.93	0,91	0.585152	72.6	56,1	47.10606	21	11,3	12.82121
Toes 2-5	289.4	214,5	207.573	1.81	0,85	0.598108	102.8	62,2	54.48108	14.6	14,1	12.19459
Meta 1	252.6	211,2	187.4472	1.49	0,88	0.576944	94.5	64,45	54.01944	10.5	11,4	9.830556
Meta 2	184	182,8	104.9545	1.15	1,02	0.371818	61.3	61,1	52.83333	11.2	11,9	9.684848
Meta 3	58.8	64,1	40.16071	0.59	0,51	0.488214	13.5	54,5	46.32857	10.1	10,3	10.08929
Meta 4	243.7	198,5	173.6735	2.1	2,19	1.927353	37.6	45,2	56.15588	45.4	40,2	33.84118
Meta 5	539.8	299,2	280.2118	12.46	12,41	9.286471	90.7	81,3	72.23824	21	20,2	17.62059
Mid foot	475.7	305,1	277.9286	7.98	14,45	9.601429	79.6	68,2	69.56571	19.1	16,1	15.14571
Hell medial												
Hell Lateral												

*Value over average *Value above maximum *Value under minim

Considering that the impulse mode is translated by loading (or weight bearing) of a certain area. That is the time when pressure is exerted on that area. The results can be explained in the context of the previous statement (avoiding the initial contact with the heel), correlated with the faster walking speed for the lower right limb.

The parameter **contact area** has several values above the normative maximum at the level of the leg without traumatic pathology (heel, middle leg, metatarsus 1-2).

For the right leg the values above the normative maximum were registered at the level of the fingers 2-5, metatarsus 1, mid foot and lateral heel. *This is due to the fact that, in order to avoid the amplification of the joint compression forces, there is a tendency to minimize the contact of the foot with the ground on the affected side.* However, we mention that for this leg the

values corresponding to the other anatomical areas were above average.

By comparing the contact area values for the medial heel and the lateral heel, an asymmetry is observed for both plantar regions, explained due to a defective balance in walking.

The global analysis of the values registered for the **right limb** indicates that there is a tendency to develop a higher force in the heel region, because, reflexively, the subject is trying to increase the support base, an aspect that is not observed even at the middle of the foot region.

From figure 1, it can be observed that the line of the pressure centre intersects the axis of the foot with the left-right oscillations. This means a certain form of instability. For all these reasons, it was recommended to introduce in the physical therapy protocol some exercises of proprioceptive re-education.

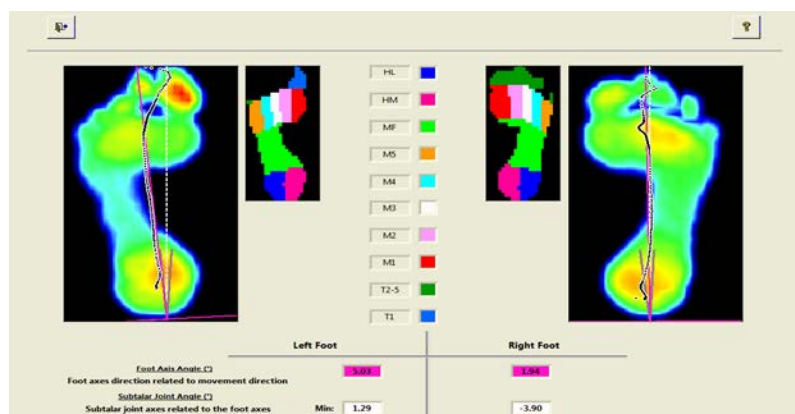


Fig.1. Comparative gait analysis for left/right foot

Also the analysis of the angle of the foot indicates values below the normal limit for the right foot, which means a slight outward rotation -exorotation.

5. Conclusions

The conclusions resulting from the analysis and interpretation of the results

of the actual research can be summarised as follows:

- The study of gait with the Rsscan platform allows objectively quantifying the recovery process. It is possible to analyse the initial data (input) for the purpose of comparison with the data obtained after applying the appropriate

therapeutic treatments (output), thus allowing quantifying the functional deficits related to the pathology of the lower limb.

This counts as a reliable and non-invasive system allowing to perform functional evaluations and to plan the individualised physical therapeutic strategies with the objective assessment of the treatment results in the pathologies that affect the movement capacity (gait).

The comparative analysis of the recorded values before and after the application of the physical therapy protocols allowed the objective tracking of the progress:

- The comparative analysis of the contact time for the two tests indicated an improvement of the values for the analysed subject, with differences between the two tests.

- The comparative analysis of the foot angles for the two tests indicated an improvement of the pathological values. This was achieved by introducing exercises in the recovery program for the exorotation of the foot (positive angle over 12 degrees) or for endorotation (negative angle).

- The comparative analysis for the biomechanical parameters: 1) maximum force, 2) loading rate, 3) impulse, 4) contact area obtained for the two tests indicated a net improvement of the values of the biomechanical parameters for the values above and below the minimum recorded at the initial testing. The values above average increased at the final test.

The general conclusion is that the use of individualized protocols according to the analysis of the biomechanical parameters that can emphasize the particularities of case contributes to the increase of the efficiency of applied rehabilitation physical therapies.

Acknowledgement: All authors equally contributed to the design, implementation of the research and writing the article manuscript. Email of correspondence author: taina_mistico@yahoo.com

References

1. Alexander, I.J., Chao, E.Y.S., Johnson, K.A.: *The assessment of dynamic foot-to-ground contact forces and plantar pressure distribution: a review of the evolution of current techniques and clinical applications*. In: *Foot&Ankle International*, 1990; 11 (3), p. 152-167.
2. Bennett, P.J., Duplock, L.R.: *Pressure distribution beneath the human foot*. *Journal of the American Podiatric Medical Association* 1993, 83 (12), p.674-678.
3. Bernstein, J.: *Meniscal Tears of the Knee*. In: *The physician and Sports medicine*, vol. 8, no. 3, March 2000.
4. Giacomozzi, C., Macellari, V., Leardini, A., Benedetti, M.G.: *Integrated pressure-force kinematics measuring system for the characterisation of plantar foot loading during locomotion*. In: *Med. Biol. Eng. Comp.* 2000, 38, p. 156-163.
5. Harrison, A.J., Folland, J.P.: *Investigation of gait protocols for plantar pressure measurement of non-pathological subjects using a dynamic pedobarograph*. In: *Gait&Posture*, 1997, 6, p. 50-55.
6. Nandikolla, V. K., Bochen, R., Meza, S., Garcia, A.: *Experimental Gait Analysis to Study Stress Distribution of the Human Foot*. In: *Journal of medical engineering*, 2017, 3432074. doi:10.1155/2017/3432074
7. Orlin, M.N., McPoil, T.G.: *Plantar pressure assessment*. In: *Phys Ther.* 2000, 80, p. 399-409.