Gait temporospatial parameters: assessment tools for post-surgical recovery in patient with different anatomo-topographic types of lumbar disc herniation

Cristina Tacu[1], N Ianovici[2], Elena Rezus[3], I.S. Stratulat[4], Silvia Nicoleta Miu[5]

[1]Rheumatology, University of Medicine and Pharmacy "Gr.T. Popa" Iasi, Ph D candidate
[2]Neurosurgery, University of Medicine and Pharmacy "Gr.T. Popa" Iasi
[3]Rheumatology, University of Medicine and Pharmacy "Gr.T. Popa" Iasi
[4]Functional dental rehabilitation, University of Medicine and Pharmacy "Gr.T. Popa" Iasi
[5]Precision Mechanics Department, University of Polytechnic, Bucharest

Abstract

The development in technology and informatics in the last decades enables integrated analysis of biomechanical and clinical data and facilitates the understanding of relations between human gait characteristic and different medical conditions of a patient. The aim of the study was to demonstrate the importance of gait temporospatial parameters analysis [opposite foot off, opposite foot contact, foot off, cadence, step length, walking speed, step time, step width, stride length, stride time] to quantify the response to surgical treatment for patients with lumbar disc herniation related to the anatomotopographic type of disc herniation. The study was prospective, with consecutive selection of subjects according to eligibility criteria, using a control group. The number of subjects was 64: 41 patients [61% with extensive lumbar disc hernia, 22% with paracentral lumbar disc hernia and 17% with intraforaminal lumbar disc herniation] and 23 healthy subjects. The flowchart had 2 visits: presurgical evaluation and postsurgical evaluation. The patients were evaluated clinically, imagistically and biomechanically. The biomechanical evaluation was performed with VICON MX optical motion capture system. Data of interest were temporospatial parameters of gait: opposite foot off, opposite foot contact, foot off, cadence, step length, walking speed, step time, step width, stride length, stride time. Specific statistic techniques were used in order to confirm the results. The most consistent response in terms of normalization of gait temprospatial parameters are to be observed in patients with intraforaminal herniation, followed by patients with paracentral disc herniation. The gait temprospatial parameters of patients with extensive lumbar disc herniation responded the least in terms of normalization.

Keywords: gait, lumbar disc herniation, presurgical, postsurgical

Introduction

The development in technology and informatics in the last decades enables integrated analysis of biomechanical and clinical data and facilitates the understanding of relations between human gait characteristic and different medical conditions of a patient.

Technological applications in the study of human gait provide medical specialists with accurate data that broaden the spectrum of information, data that they could not achieve through simple clinical observation.

There are numerous studies that analyze gait from both kinematical and kinetic points of view and focus on a wide range of neurological pathologies [1, 2, 3, 4] orthopedics pathologies [5, 6], rheumatology pathologies [7, 8], nutritional diseases [9, 10] and thus provided data used in current practice.

The study of human gait in relation to spine pathology represents a topic of great interest for medical researchers, given the socio-economic impact that this type of pathology generates [11, 12].

Aim of this study is to demonstrate the importance of gait temporospatial parameters analysis [opposite foot off, opposite foot contact, foot off, cadence, step length, walking speed, step time, step width, stride length, stride time] in the assessment of patient recovery after surgical treatment, related to different anatomotopographic types of lumbar disc herniation.

Material and methods

Study protocol

The study was prospective, with consecutive selection of patients according to eligibility criteria, using a control group. Number of subjects was 64: 41 patients and 23 subjects without clinical symptoms who represented the control group. The average (+/- standard deviation) age, mass and height of the patients were 41.1 years old (+/-10), 69.8 Kg (+/- 7.3), and 167.5 cm (+/- 6.8). The average (+/- standard deviation) age, mass and height of the subjects from control group were 38,1 years old (+/- 7.8), 64.2 kg (+/- 6.5), 168.2 cm (+/- 8.9).

Within the group of patients, the anatomotopographic types of lumbar disc herniation cases were divided as follows: 61% extensive herniated disc type, 22% paracentral herniated disc type and 17% intraforaminal type.

The study flowchart covered the following steps: patient selection (1-2 days), the preoperative evaluation visit - 2 weeks prior to surgery (clinical, biomechanical and imagistic) and the postoperative monitoring visit - one month after surgery (clinical and biomechanical evaluation).

The procedures during patient selection included: signing the informed consent before the beginning of any study procedure (ICF was approved by the Ethical Commission of The Rehabilitation Hospital in Iaşi) and checking patient eligibility according to inclusion and exclusion criteria.

Inclusion criteria were: age above 18 when signing the ICF, mechanical low back pain unilaterally irradiated on radicular territory of L5/S1 +/- neurological signs corresponding to the radicular condition [without motor deficit], slowly resolving clinical phenomena with a duration of at

least 4 weeks, documenting the presence of disc hernia through CT or MRI, their independent walking ability.

Exclusion criteria were: no systemic disease with relevant influence on walking ability, no orthopedic surgeries, conditions which are taken into account during the "red flags" screening and generate low back pain, motor deficit corresponding to radicular pain L5/S1, counter indications in CT or MRI exploring, presence of the biological syndrome of inflammation.

The biomechanical evaluation was performed inside the biomechanics and motion analysis laboratory belonging to the University of Medicine and Pharmacy "Gr.T. Popa" Iaşi, using the VICON advanced optical motion capture system

The imagistic evaluation was performed using CT or IRM in order to demonstrate the existence of lumbar disc herniation and to classify the anatomotopographic type of hernia: paracentral, extensive or intraforaminal.

Methods

Material: selected patient group and the control group, lumbar spine images (computed tomography and nuclear magnetic resonance imaging), patients' clinical exploration data files and VICON optical motion capture system. The biomechanical evaluation included the following steps: preparing the room, preparing the patient (placing the retroreflexive markers on the points of interest according to VICON work protocol), real-time digital translation of retroreflexive markers and reconstruction of their three-dimensional coordinates according to the two-dimensional video images. The study focused on temporospatial parameters: opposite foot off, opposite foot contact, foot off, cadence [step frequency], step length, walking speed, step time, step width, stride length, stride time.

Statistical processing

Primary processing, namely the systematization of data by grouping and centralizing, led to the formation of a primary indicators database. Data were loaded and processed using statistical functions in Excel, EpiInfo and SPSS. The following statistical methods were applied: the ANOVA test, the t-student test and the χ^2 test.

Results and discussion

After statistical processing of gait temporospatial parameters monitored one month after surgery for patients with extensive herniated disc the following issues are extensively outlined:

1. Average values of opposite foot off, opposite foot contact, foot off, double support time, step time, stride time parameters decreased significantly from a statistical point of view;

2. Average values of cadence, step length, speed, step width and stride length parameters increased significantly from a statistical point of view.

A significant improvement of gait temporospatial parameters after surgery can be observed in the extensive herniated disc group, but differences from the control group remain highly statistically significant (Table 1).

Table 1

Statistical differences of average values of gait temporal-spatial parameters monitored for the patients with extensive herniated disc

Parameter	Extensive Herniated Disc Group				Control Group vs. Postsurgical Extensive Herniated Disc Group		
	Presurgically	Postsurgically	t	p	Reference values	t	p
Foot strike [%]	0	0	-	-	-	-	-
Opposite foot off [%]	20.50±4.71	17.00±7.10	2.27	**p<0.05**	9.69±2.38	6.20	**p<0.001**
Opposite foot contact [%]	49.56±1.33	46.70±5.30	2.30	**p<0.05**	43.01±4.66	2.93	**p<0.05**
Foot off [%]	68.84±5.28	64.70±8.40	2.34	**p<0.05**	58.91±1.82	4.38	**p<0.001**
Cadence [step/min]	71.26±16.11	77.30±4.56	2.34	**p<0.05**	98.23±4.20	18.20	**p<0.001**
Double support time[s]	0.77±0.42	0.60±0.23	2.20	**p<0.05**	0.42±0.14	3.97	**p<0.001**
Step length [m]	0.39±0.08	0.43±0.07	2.21	**p<0.05**	0.60±0.04	12.64	**p<0.001**
Walking speed [m/s]	0.47±0.20	0.59±0.13	3.06	**p<0.01**	1.08±0.12	15.42	**p<0.001**
Step time [s]	0.90±0.29	0.72±0.24	2.83	**p<0.01**	0.42±0.39	3.37	**p<0.002**
Step width [m]	0.17±0.06	0.20±0.05	2.27	**p<0.05**	0.24±0.04	3.56	**p<0.001**
Stride length [m]	0.78±0.17	0.90±0.19	2.69	**p<0.01**	1.33±0.10	12.14	**p<0.001**
Stride time [s]	1.76±0.55	1.41±0.45	2.92	**p<0.01**	1.23±0.05	2.62	**p<0.05**

Parameter improvement percentage for the group with extensive herniated disc changed as follows (Figure 1):

- opposite foot off, 111.6% higher presurgically and 75.4% higher postsurgically than the value recorded in the control group; the decrease of average values after surgical treatment was 36.1%;
- opposite foot contact, 15.2% higher presurgically and 8.6% higher postsurgically than the value recorded in the control group; a decrease of 6.6% after surgical treatment;
- foot off, 16.9% higher presurgically and 9.8% higher postsurgically, with a decrease of 7% after surgical treatment;
- cadence, 27.5% lower presurgically and 21.3% postsurgically as compared to the control group; the postsurgical increase of cadence was of 6.1%;
- double support time was presurgically 83.3% higher and postsurgically 42.9% higher than that of the control group; the decrease of the average values after surgical treatment was 40.5%;
- step length, 35% lower presurgically and 28.3% lower postsurgically as compared to the control group; the postsurgical values increase was 6.7%;
- walking speed, 56.6% lower presurgically and 45.4% lower postsurgically as compared to the control group; the postsurgical increase compared to presurgical value was 11.1%;
- step time, 114.3% higher presurgically and 71.4% higher postsurgically as compared to the control group; but the decrease of average values after surgery was 42.9%;
- step width, 29.2% lower presurgically and 16.7% lower postsurgically as compared to the control group; the postsurgical increase was 12.5%;
- stride length, 41.4% lower

presurgically and 32.3% lower postsurgically as compared to the control group; it improved postsurgically by 9%;

- stride time, 44.7% higher presurgically and 14.6% higher postsurgically as compared to the control group; the decrease of average values after surgery was 30.1%.

For the paracentral herniated disc patients, the postsurgical evaluation shows significant differences for all parameters, closer to the reference values of the control group: opposite foot contact, step time, step width (Table 2).

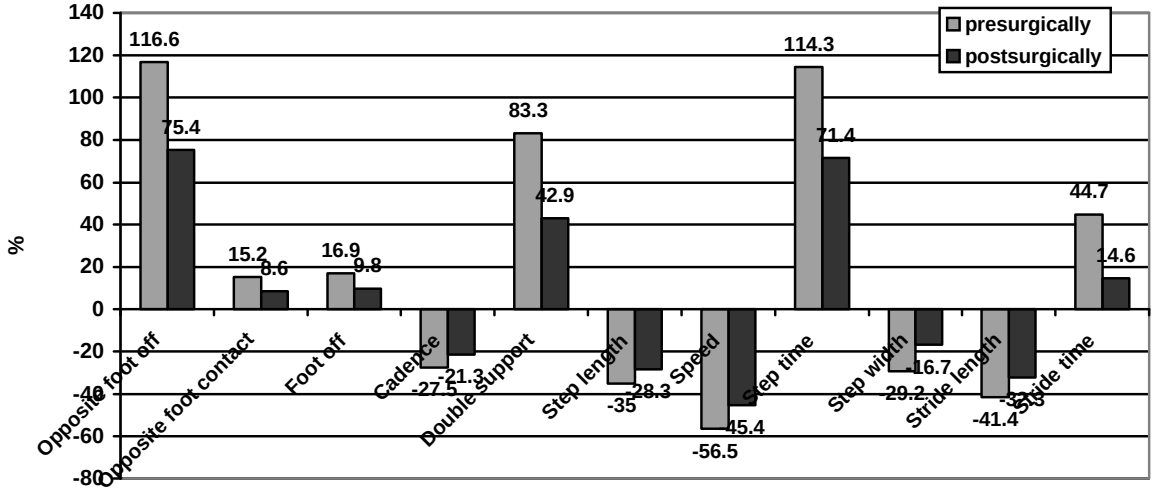

Figure 1 Percentage evolution of gait temporospatial parameters for the patients with extensive herniated disc group

Table 2

Statistical differences of average values of parameters monitored for the patients with paracentral herniated disc

Parameter	Paracentral herniated disc group				Control Group vs. Postsurgical Paracentral Herniated Disc Group		
	presurgically	postsurgically	t	p	Reference values	t	p
Foot strike [%]	0	0	-	-	-	-	-
Opposite foot off [%]	22.78±6.28	13.50±5.99	3.20	**p<0.01**	9.69±2.38	2.12	**p<0.05**
Opposite foot contact [%]	50.53±2.46	45.20±6.12	2.20	**p<0.05**	43.01±4.66	1.09	p>0.05
Foot off [%]	70.01±3.22	66.10±4.15	2.14	**p<0.05**	58.91±1.82	5.72	**p<0.001**
Cadence [step/min]	67.48±12.19	87.11±10.15	3.77	**p<0.002**	98.23±4.20	3.64	**p<0.001**
Double support time [s]	0.81±0.31	0.56±0.13	2.45	**p<0.05**	0.42±0.14	2.94	**p<0.01**
Step length [m]	0.36±0.08	0.48±0.09	2.92	**p<0.01**	0.60±0.04	4.40	**p<0.001**
Walking speed [m/s]	0.40±0.16	0.88±0.32	3.71	**p<0.002**	1.08±0.12	2.09	**p<0.05**
Step time [s]	0.92±0.17	0.62±0.20	3.33	**p<0.01**	0.42±0.39	2.01	p>0.05
Step width [m]	0.17±0.04	0.22±0.05	2.26	**p<0.05**	0.24±0.04	1.20	p>0.05
Stride length [m]	0.69±0.19	0.93±0.22	2.41	**p<0.05**	1.33±0.10	5.98	**p<0.001**
Stride time [s]	1.85±0.33	1.44±0.32	2.66	**p<0.05**	1.23±0.05	2.26	**p<0.05**

Parameter improvement percentage for the group with paracentral herniated disc changed as follows (Figure 2):

- opposite foot off, 135.1% higher presurgically and 39.3% higher postsurgically as compared to the control group, the decrease of average values after surgery was 95.8%;
- opposite foot contact, 17.5% higher presurgically and 5.1% higher postsurgically as compared to the control group, with a decrease of 12.4% after surgery;
- foot off, 18.8% higher presurgically and 12.2% higher postsurgically as compared to the control group, with a decrease of 6.6% after surgery;
- cadence, 31.3% lower presurgically and 11.3% postsurgically, as compared to the control group; the increase of cadence postsurgically compared to presurgically was 20%;
- double support time, 92.9% higher presurgically and 33.3% higher postsurgically as compared to the control group, the decrease of the average values was 59.5%;
- step length, 40% lower presurgically and 20% postsurgically as compared to the control group; the increase was 20%;
- walking speed, 63% lower presurgically and 18.5% postsurgically as compared to the control group; the increase was 44.4%;
- step time, 119% higher presurgically and 47.6% postsurgically as compared to the control group; the decrease of the average values postsurgically was 71.4%;
- step width, 29.2% lower presurgically and 8.3% postsurgically as compared to the control group; the postsurgical increase was 20.8%;
- stride length, 48.1% lower presurgically and 30.1% postsurgically as compared to the control group; the postsurgical improvement was 18%;
- stride time, presurgically 50.4% higher and 17.1% postsurgically as compared to the control group; the decrease of average values after surgical treatment was 33.3%.

The postsurgical evaluation of intrafornaminal disc hernia patients revealed significant differences of all parameters, close to the reference values of the control group: opposite foot off, foot off, double support, step length, step time, step width, stride length (Table 3).

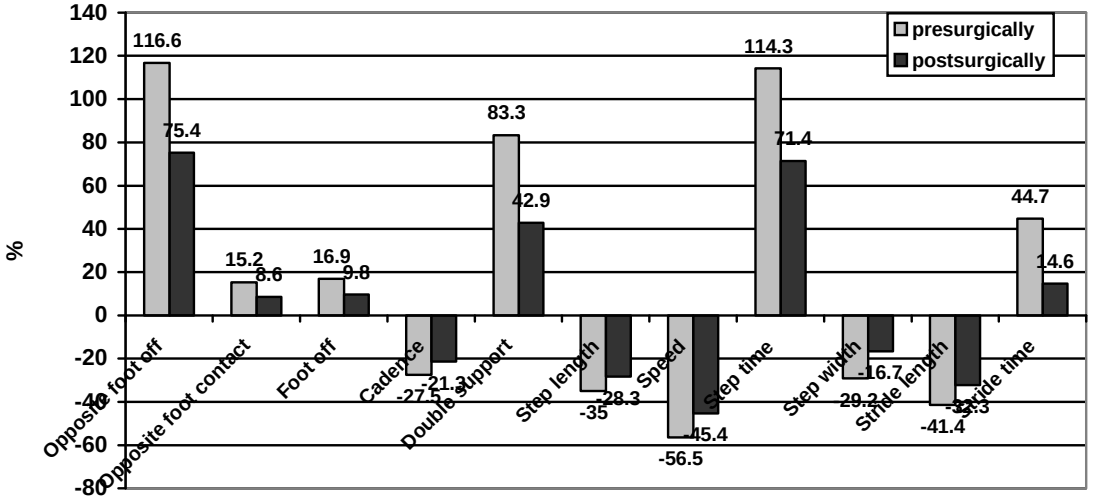

Figure 2 Percentage evolution of gait temporospatial parameters for the patients with paracentral herniated disc group

Table 3

Statistical differences of average values of parameters monitored for the patients with intraforaminal herniated disc

Parameter	Intraforaminal disc hernia group				Control Group vs. Postsurgical Intraforaminal Herniated Disc Group		
	presugically	postsurgically	t	p	Reference values	t	p
Foot strike [%]	0	0	-	-	-	-	-
Opposite foot off [%]	18.79±3.65	10.22±2.55	6.55	**p<0.001**	9.69±2.38	0.67	p>0.05
Opposite foot contact [%]	50.08±1.48	46.12±2.58	3.81	**p<0.002**	43.01±4.66	2.48	**p<0.05**
Foot off [%]	68.72±4.18	59.10±4.22	5.09	**p<0.001**	58.91±1.82	0.19	p>0.05
Cadence [step/min]	74.97±8.42	85.25±6.53	3.21	**p<0.01**	98.23±4.20	7.63	**p<0.001**
Double support time [s]	0.62±0.21	0.46±0.05	2.95	**p<0.01**	0.42±0.14	1.13	p>0.05
Step length [m]	0.43±0.07	0.58±0.08	4.33	**p<0.001**	0.60±0.04	1.04	p>0.05
Walking speed [m/s]	0.53±0.12	0.88±0.27	3.30	**p<0.01**	1.08±0.12	3.16	**p<0.01**
Step time [s]	0.81±0.11	0.52±0.17	4.17	**p<0.001**	0.42±0.39	0.99	p>0.05
Step width [m]	0.17±0.05	0.22±0.03	3.01	**p<0.01**	0.24±0.04	1.73	p>0.05
Stride length [m]	0.84±0.13	1.28±0.35	3.24	**p<0.01**	1.33±0.10	0.65	p>0.05
Stride time [s]	1.63±0.21	1.39±0.14	3.27	**p<0.01**	1.23±0.05	5.06	**p<0.001**

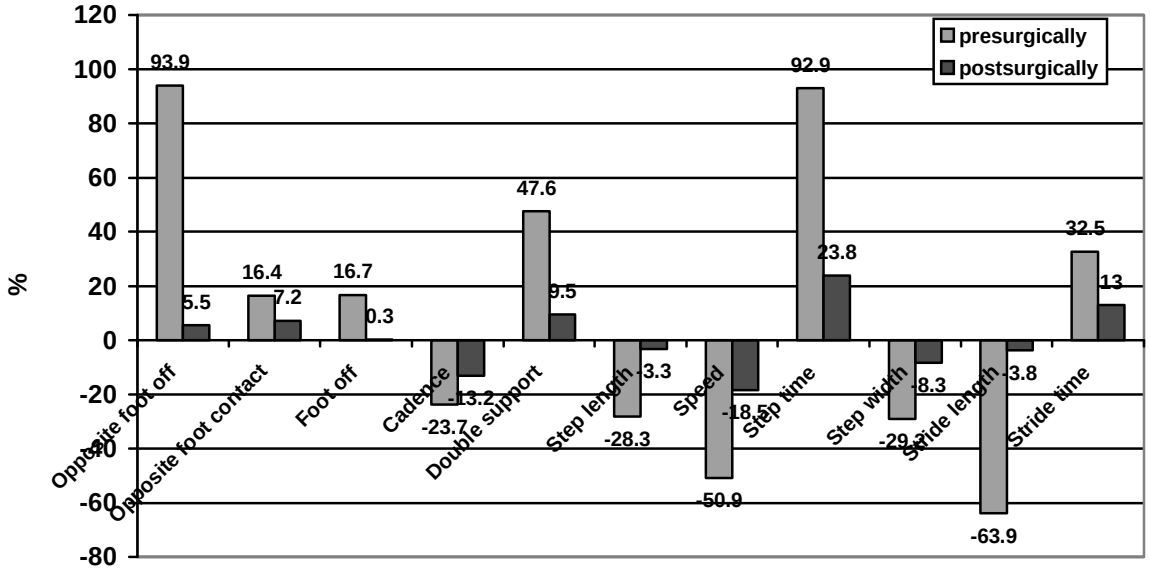

Figure 3 Percentage evolution of gait temporospatial parameters for the patients with intraforaminal herniated disc group

Parameter improvement percentage for the group with intraforaminal herniated disc changed as follows (Figure 3):

- opposite foot off, 93.9% higher presugically and 5.5% higher postsurgically than the values recorded for the control group; the decrease of average values after surgical treatment was 88.4%;
- opposite foot contact, 16.4% higher presurgically and 7.2% higher postsurgically than the values recorded in the control group; a decrease of 9.2% after surgical

treatment as compared to the control group.

- foot off, 16.7% higher presurgically and 0.3% higher postsurgically, with a decrease of 16.3% after surgical treatment;
- cadence, 23.7% lower presurgically and 13.2% postsurgically as compared to the control group; the cadence postsurgical increase was 10.5%;
- double support, 47.6% higher presurgically and 9.5% higher postsurgically than the value recorded in the control group; the decrease of average values postsurgically was 38.1%;
- step length, 28.3% lower presurgically and 3.3% postsurgically as compared to the control group; the postsurgical increase was 25%;
- walking speed, 50.9% lower presurgically and 18.5% postsurgically as compared to the control group; the postsurgical increase was of walking speed was 32.4%;
- step time, 92.8% higher presurgically and 23.8% postsurgically as compared to control group; the average values decrease after surgical treatment was 69%;
- step width, 29.2% lower presurgically and 8,3% postsurgically as compared to the control group; the postsurgical increase of step width was 20.8%;
- stride length, 63.9% lower presurgically and 3.8% postsurgically as compared to the control group; the postsurgical improvement was 60.2%;
- stride time, 32.5% higher presurgically and 13% postsurgically as compared to the control group; the postsurgical decrease of average values was 19.5%.

Conclusions

Different types of anatomotopographic lumbar disc hernia are accompanied by different degrees of gait impairment.

Gait temporospatial parameters can be used in the assessment of postsurgical gait recovery.

Surgical intervention for lumbar disc hernia is effective, although there is residual gait impairment.

The most consistent response in terms of improvement of gait temprospatial parameters are to be observed in patients with intraforaminal lumbar disc hernia, followed by patients with paracentral lumbar disc hernia.

The gait temprospatial parameters of patients with extensive lumbar disc hernia responded the least in terms of improvement of gait temprospatial parameters.

Acknowlegment

The present study was possible due to the logistic support of the Center for the Study and Therapy of Pain, University of Medicine and Pharmacy “Gr.T. Popa” Iaşi.

References

1.Holden MK, Gill KM, Magliozzi MR, Gait assessment for neurologically impaired patients. Phys Ther, 1986. 66: 530-1539.

2.Knutsson E, Richards C, Different types of disturbed motor control in gait of hemiparetic patients. Brain, 1979.102: 405-430.

3.Wall JC, Turnbull GI, Gait asymmetries in residual hemiplegia. Arch Phys Med Rehabil, 1986. 67: 550-553.

4.Brandstater ME, de Bruin H, Gowland C, Clark BM, Hemiplegic gait: analysis of temporal variables. Arch Phys Med Rehabil, 1983. 64: 583-590.

5.Lieberman JR, Dorey F, Shekelle P et al. Differences between patients and physicians' evaluations of outcome after total hip arthroplasty. J. Bone Joint Surg Am, 1996. 78(6): 835-838.

6.Mattsson E., Olsson E., & Brostörm, L.A., Assessment of walking before and after unicompartmental knee arthroplasty. Scand J Rehabil Med., 1990. 22: 45-50.
7.Messier SP, Loeser RF, & Hoover JL, Osteoarthritis of the knee: effects on gait, strength and flexibility. Arch Phys Med Rehabil., 1992. 57: 571-577.
8.Woodburn J, Nelson KM, Lohmann Siegel K, Kepple TM, Gerber LH, Multisegment foot motion during gait: proof of concept in rheumatoid arthritis. J Rheumatol, 2004. 31: 918-1945.
9.Courtemanche R, Teasdale N, Boucher P, Fleury M, Lajoie Y, Bard C, Gait problems in diabetic neuropathic patients. Arch Phys Med Rehabil, 1996. 77: 849-855.
10.Yavuzer G, Yetkin I, Toruner FB, Koca N, Bolukbasi N: Gait deviations of patients with diabetes mellitus: Looking beyond peripheral neuropathy. Eura Medicophys, 2006. 42: 127-133.
11.Morag E, Hurwitz DE, Andriacchi TP, Hickey M, Andersson GB, Abnormalities in muscle function during gait in relation to the level of lumbar disc herniation. Spine, 2000. 25 (7): 829-833.
12.Russwurm H, Bjerkreim I, Ronglan E, Lumbar Intervertebral Disc Herniation in the Young. Acta Orthopaedica, 1978. 49(2): 158 – 163.