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GAIT ANALYSIS OF PATIENTS WITH OSTEOARTHRITIS OF THE HIP JOINT

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Abstract. *Patients with osteoarthritis of the hip joint suffer from pain and functional impairment of the hip over a long period of time. Although different functional scores are widely used to assess improvement after surgery, the patients' responses are often subjective and the disparities between the patients' and doctors' evaluations can be significant. Therefore, objective and quantified data from gait analysis could be useful. Patients may adapt their gait in response to pain, deformity or laxity in the joints of the lower extremities. It is difficult to identify objective parameters for assessing joint function when evaluating the outcome of orthopaedic procedures, especially endoprosthetic hip replacement. A clinical gait analysis enables movement parameters to be quantified. Spatial and temporal gait parameters have clinical relevance in the assessment of motor pathologies, particularly in orthopaedics. The aim of this study is to determine how selected gait parameters may change as a result of coxarthritis. A total of 11 patients with severe unilateral osteoarthritis of the hip and 21 healthy elderly subjects without any history of lower extremity joint pathology were examined at self-selected speeds. Gait analysis was performed using an ultrasound-based Zebris system with a 19-point biomechanical model. From the spatial coordinates of the investigated antropometrical points, the kinematical data (step length, step width, knee, hip and pelvic angles) was calculated. The difference in step width and step length between the two sides is not significant. Significant statistical differences in joint angles were observed between the non-affected and affected limbs. In this research, spatial gait parameters did not show significant asymmetry, although all the patients had unilateral hip diseases. This may occur when the patient walks with short steps or when compensatory movements of other joints are involved. Asymmetry was observed in the range of hip motion as well as knee motion. The maximum hip flexion and extension on the affected side were inversely correlated with the maximum hip extension and flexion on the non-affected side. Therefore, it was suggested that the increased motion of the opposite hip was a compensatory function. The study showed that the increased pelvic obliquity directly*

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correlated with the range of hip flexion. When the range of hip motion is decreased, it might be expected that increased pelvic obliquity would occur as a compensation. The present study detected an influence of the decreased range of affected hip motion on the ipsilateral knee as a decreased range of knee joint motion.

The results indicate a generally poor functional outcome, even though asymmetrical loading was observed. Major limitations in physical function were detected.

Key words: *gait analysis, 3D kinematics, kinetics, hip osteoarthritis*

INTRODUCTION

Gait analysis can be used for evaluating improvements after an intervention to improve walking. Comprehensive gait analysis usually includes kinematics, kinetics and electromyography and this complex information can only be obtained in a specialized laboratory (Kocsis, 2004). Kinematics, kinetics, and electromyography are fundamental for the purpose of characterising gait patterns and their underlying mechanisms. Complex gait analysis presents itself as a possible tool for the evaluation of the rehabilitation process after orthopaedic surgery, such as an ACL reconstruction (Knoll, 2004) or during the analysis of different sports movements (Kiss, 2004).

However, simplified analyses using spatio-temporal parameters, for example, can also be clinically valuable. One application of simplified gait analysis could be in the field of hip or knee arthroplasty. Patients with coxarthritis suffer from pain and functional impairment of the hip over a long period of time. Although different functional scores are widely used to assess the improvement after surgery, the patients' *responses* are often subjective and the disparities between the patients' and doctors' evaluations can be significant (Liebermann et al., 1996). Therefore, objective and quantified data from a gait analysis could be useful.

Patients may adapt their gait in response to pain, deformity or laxity in the joints of the lower extremities. Patients with hip osteoarthritis often adapt an antalgic type of gait as their disease progresses. It is unknown whether gait adaptation is mainly related to the severity of the disease, pain, muscle weakness, or limitations in a range of passive motions. Furthermore, adaptations protecting the hip may influence the mobility of the lower back and the other joints of the lower extremities. The objective is to analyse the resulting changes in functional gait patterns in patients with unilateral osteoarthritis of the hip.

MATERIALS AND METHODS

Patients

The study was carried out on a group of 21 healthy elderly people and a group of eleven patients with severe unilateral hip osteoarthritis.

The group of healthy subjects consisted of 9 women (61.8 years ± 7.51 years, 72.3 ± 8.34 kg and 1.68 ± 0.23 m) and 12 men (61.15 years ± 9.14 years, 77.23 kg ± 13.12 kg, 1.74 m ± 0.22 m). The group of patients consisted of 7 women (62.7 years ± 2.91 years, 68.8 ± 9.44 kg and 1.69 ± 0.11 m) and 4 men (71.8 years ± 7.51 years, 72.3 kg ± 8.34 kg and 1.75 m ± 0.19m) with unilateral osteoarthritis of the hip, and they were all included in a prospective longitudinal study. Each subject provided informed consent before participation and signed a consent form approved by the Hungarian Human Subjects Compliance Committee.

In previous research, patients were evaluated by the Harris Hip Score, as well as the Womack Osteoarthritis Scale and the Short Form Healthy Survey (SF-36) (Bullinger, 1996).

The average Harris Hip Score of healthy elderly people was 98.9 points (± 1.1), the average SF-36 score was 97.6 (± 2.4) and the average Womack Score 96.7 points (± 3.3). All of the subjects had excellent results for all three measurements (~100 point). Subjects were not limited in their normal daily or recreational activities.

The average Harris Hip Score of the patients was 51.3 points (± 15.2), the average SF-36 Score 45.6 (± 12.4) and the average of the Womack Score 31.3 (± 3.4). All of the patients had poor results (<70 points). All patients were seriously limited in their activities due to the pain for more than one year.

Method

Objective functional evaluation was based on a three-dimensional gait analysis. Evaluation in the gait laboratory lasted about one hour and included the recording of lower extremities kinematics and kinetics.

Fig. 1. Arrangement of measurement

Spatial coordinates for the determination of kinematic data were collected using an ultrasound-based Zebris CMS-HS system (ZEBRIS, Medizintechnik GmbH, Germany) in the Biomechanical Laboratory of the Department of Applied Mechanics at the Budapest University of Technology and Economics. The measuring head with three sensors was positioned behind the individual and the five ultrasound triplets with three active markers on each were placed on the sacrum, left and right thighs, and left and right calves (Figure 1). The data obtained from the measuring system recording the active markers allowed for the determination of coordinates of optional anatomical points of the lower limbs. The measuring method was developed by Kocsis (2004). The biomechanical model developed by Knoll et al (2004) was chosen for our investigation. The spatial coordinates were recorded at a frequency of 100Hz. At the same time, the ground forces were measured at 1000 Hz. The patients were asked to walk at their natural, freely chosen speed and cadence on a motorized and instrumented 330 mm × 1430 mm treadmill with a built-in force plate (Bonte Zwolle B.V, Austria). Walking on the treadmill can initially be an unfamiliar experience, which in turn may influence the parameters measured. Therefore, measurements should start after six minutes of familiarization time (Alton et al., 1998; Matsas et al., 2000). Kinematic data was collected for six gait cycles.

The assessed kinematic parameters are the following:

- Temporal and spatial parameters: stance, swing and double stance phase in percent of the gait cycle; step length, step width (in centimetres); cadence (steps per minute)
- Angular parameters: knee, hip and pelvic angles, presented by Kocsis and Beda (2001);
- Force parameters: first peak force (F1) in the early stance phase and second peak force (F2) in the late stance phase (in percent of body weight).

The parameters above are calculated by a software package presented first in (Jurak and Kocsis, 2002).

Statistical analysis

The data processing and statistical analyses were performed using an MS Excel based software of our own development. In the case of each examined subject, we calculated the average and the standard deviation of the kinematic and kinetics parameters calculated from the measurement results of the recorded motion cycles, and this data was further processed.

The biomechanical properties of individuals belonging to a given group and those of various groups were statistically analyzed using the MS Excel Analysis ToolPak software. The uniformity of standard deviations was checked by an F-test; the significance levels of the difference between the average values of identical parameters were determined by a t-test, by applying a symmetrical critical range. A two-sample t-test was applied when comparing the results for healthy people and patients with osteoarthritis. It is assumed that the gait parameters of the healthy group and the patients with osteoarthritis or gait parameters determined at different gait speeds should be different, and that the results present a statistically significant differences if $p < 0.05$.

The correlation coeficient was used to determine the relationship of the results of the Womack score, which represents two levels of osteoarthritis and of kinematical parameters obtained on the treadmill.

RESULTS

The fastest healthy subject walked on the treadmill at a speed of 3.50 km/h, and the slowest at 1.80 km/h.The average maximum speed of the healthy subjects was 3.12 km/h. The fastest patient walked on the treadmill at a speed of 3.0 km/h, and the slowest at 0.5 km/h, the average maximum speed of the patients is 2.12 km/h. The difference between the averages is significant ($p<0.002$).

Table 1 presents a summary of the comparison of healthy subjects and the patients with osteoarthritis of the hip by means of selected spatial-temporal parameters (step length, step width and duration of swing phase). No significant, statistical differences were observed between the dominant and non-dominant limbs for the healthy control group ($p>0.17$). Furthermore, the step length with the OA limb (25.5 ± 12.4 cm) was shorter compared to the contralateral limb (29.4 ± 19.4 cm), but the difference is not significant ($p>0.07$). The correlation coefficient between the step length and the Womack score is $p>0.87$. The step length of the patients is significantly shorter compared to the step length of the healthy subjects (the dominant side is 33.99 ± 12.70 cm, the non-dominant side 36.32 ± 12.05 cm) ($p<0.009$).

Table 1. Results of temporal and spatial parameters in patients with osteoarthritis of the hip and in control subjects

Parameter		Patients	Controls
Cadence [steps per minute]		150.5 ±12.3	96.42 ±18.35
Step length [cm]	Patients: OA side Control: non-dominant side	25.5 ±12.4	33.99 ±12.70
	Patients: contralateral side Control: dominant side	29.4 ±19.4	36.32 ±12.05
Step width [cm]	Patients: OA side Control: non-dominant side	21.3 ± 6.8	22.74 ±3.86
	Patients: contralateral side Control: dominant side	19.1 ± 3.5	21.97 ±6.09
Double support phase [% of gait cycle]		37.4 ± 7.8	13.47 ±3.43
Swing phase [% of gait cycle]	Patients: OA side Control: non-dominant side	28.3 ± 4.2	36.86 ±4.97
	Patients: contralateral side Control: dominant side	34.5 ± 8.9	39.93 ±2.58

Table 2 presents a summary of the comparison of joint kinematics between the healthy subjects and the group of subjects with coxarthritis. No significant, statistical differences were observed between the dominant and non-dominant limbs for the group of healthy elderly people ($p>0.19$). Significant, statistical differences were observed between the non-affected and affected limbs for the group of patients with hip osteoarthritis ($p>0.009$). Significant differences were observed between the group of healthy subjects and the group of subjects with coxarthritis ($p<0.001$) if we compared the joint kinematics parameters of the non-dominant side of the healthy subjects to the non-affected side of the patients and the non-dominant side of the healthy subjects to the affected side of the patients.

Table 3 presents a summary of comparisons between the healthy subjects and the group of subjects with coxarthritis for the kinetics results. No significant, statistical differences were observed between the dominant and non-dominant limbs for the group of healthy elderly people ($p>0.34$). Significant, statistical differences were observed between the non-affected and affected limbs for the group of patients with osteoarthritis ($p>0.02$). Significant differences were observed between the group of healthy subjects and the group of subjects with coxarthritis ($p<0.0009$).

The correlation coefficient was $p>0.76$, if the results of the Womack score and biomechanical parameters are compared.

Table 2. Results of angular parameters in patients with osteoarthritis of the hip and in control subjects

Parameter		Patients	Controls
Hip flexion [degree]			
range	Patients: OA side Control: non-dominant side	20.6 ± 11.3	49.30 ± 13.3
	Patients: contralateral side Control: dominant side	47.9 ± 7.1	51.20 ± 13.5
maximum	Patients: OA side Control: non-dominant side	23.9 ± 10.6	24.67 ± 8.5
	Patients: contralateral side Control: dominant side	39.5 ± 11.3	41.30 ± 9.1
minimum	Patients: OA side Control: non-dominant side	3.1 ± 12.8	−9.63 ± 3.89
	Patients: contralateral side Control: dominant side	−7.9 ± 7.8	−9.91 ± 5.78
Pelvic rotation [degree]			
range		9.1 ± 4.7	5.22 ± 1.69
maximum		6.2 ± 4.0	6.37 ± 1.30
minimum		−2.9 ± 5.1	1.26 ± 1.15
Pelvic obliquity [degree]			
range		5.9 ± 2.1	3.12 ± 1.87
maximum		6.3 ± 3.3	3.97 ± 1.55
minimum		0.4 ± 3.8	0.85 ± 0.85
Knee flexion [degree]			
range	Patients: OA side Control: non-dominant side	41.1 ± 11.2	39.45 ± 3.1
	Patients: contralateral side Control: dominant side	49.2 ± 8.8	41.15 ± 2.9
first peak	Patients: OA side Control: non-dominant side	12.3 ± 13.4	17.83 ± 2.36
	Patients: contralateral side Control: dominant side	21.3 ± 12.0	19.77 ± 2.94
second peak	Patients: OA side Control: non-dominant side	43.9 ± 19.7	49.44 ± 3.78
	Patients: contralateral side Control: dominant side	59.3 ± 12.9	50.67 ± 2.58
minimum	Patients: OA side Control: non-dominant side	2.8 ± 9.0	9.80 ± 2.88
	Patients: contralateral side Control: dominant side	10.1 ± 15.8	10.08 ± 2.08

Table 3. The results of force parameters in patients with osteoarthritis of the hip and in control subjects

Parameter		Patients	Controls
F1 first peak in the early stance phase [% of body weight]	Patients: OA side Control: non-dominant side	101.3 ± 1.6	142 ± 1.3
	Patients: contralateral side Control: dominant side	99.6 ± 0.7	137 ± 1.0
F2 second peak in the late stance phase [% of body weight]	Patients: OA side Control: non-dominant side	100.5 ± 0.9	136 ± 0.8
	Patients: contralateral side Control: dominant side	102.6 ± 1.4	123 ± 1.1

DISCUSSION

The aim of this study was to analyse the resulting changes in functional gait patterns in patients with unilateral osteoarthritis of the hip.

It was previously reported that the greatest improvements to gait symmetry, both temporal and spatial gait parameters (step length, time of stance and double support phase), occurred in the osteoarthritis of the hip (Murray et al., 1979). In this research, the spatial gait parameters did not show significant asymmetry, although all the patients had unilateral hip diseases. In such a situation, this may occur when the patient walks with short steps or when compensatory movements of other joints are involved (Wall et al., 1981). In our group, the range of hip joint movements on the affected side was 20.6 º, which was of the same order as in other studies (Long et al., 1993; Murray et al., 1979). On the other hand, the walking speed is slower and the step length is shorter, and the cadence is higher compared with other studies (Long et al., 1993; Murray et al., 1979). Thus, it seems that compensatory movements of the contralateral joint may have contributed greatly in our group.

Our study may be the first to clarify the movement relationship between an impaired hip and other joints such as the knee and the pelvis. Asymmetry was observed in the range of hip motion, maximum hip flexion, maximum hip extension, as well as knee motion. The maximum hip flexion and extension on the affected side were inversely correlated with the maximum hip extension and flexion on the non-affected side. Therefore, it was suggested that the increased motion of the opposite hip was a compensatory function.

However, synchronous movements of the hip and pelvis were also previously reported in healthy people (Crosbie and Vachalalthiti, 1979), so it is inadequate to consider this link to simply be a compensatory mechanism. The study showed that the increased pelvic obliquity was directly correlated with the range of hip flexion. When the range of hip motion is decreased, it might be expected that increased pelvic obliquity would occur as compensation. It seems that the range of pelvic rotation was not involved, even in the case of our patients with unilateral coxarthritis.

On the other hand, other asymmetric motions in the pelvis and the knee may show compensatory movements for decreased hip motion. The present study detected an influence of the decreased range of affected hip motion on the ipsilateral knee as a decreased range of knee joint motion.

CONCLUSION

Asymmetry of the range of hip motion was observed in patients with unilateral coxarthropathy during free level walking. The results suggest that compensatory mechanisms greatly involved the other joints. The results indicate a generally poor functional outcome even though an asymmetrical loading was observed. Major limitations in physical function were detected.

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ANALIZA HODA KOD PACIJENATA SA OSTEOARTRITISOM ZGLOBA KUKA

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Pacijenti sa osteoartritisom zgloba kuka osećaju bolove i imaju fukcionlno oštećenje kukova tokom dugog vremenskog perioda. Iako su različiti funkcionalni skorovi u širokoj primeni kako bi se procenilo poboljšanje nakon operacije odgovori pacijenata su često subjektivni i razlike izmedju procena pacijenata i lekara su značajne. Stoga objektivni i verifikovani podaci dobijeni analizom hoda mogu biti od velike koristi. Pacijenti mogu adaptirati svoj hod u odnosu na jačinu bola, deformitet ili labavost zglobova u donjim ekstremitetima. Teško je odrediti objektivne parametre za procenu funkcije zglobova kada se procenjuju rezultati ortopedskih zahvata, a naročito kada je u pitanju endoprostetička zamena kuka. Klinička analiza hoda omogućava kvantifikaciju parametara. Prostorni i vremenski parametri hoda imaju kliničku vrednost u proceni patologije motornog aparata, a naročito u ortopediji. Cilj ove studije je da odredi na koji se način selektovani parametri hoda mogu da promene kao rezultat koksartritisa. Ispitivano je ukupno 11 pacijenata sa *teskim stepenom unilateralnog osteoartritisa kuka i 21 zdrava starija osoba bez ikakve istorije patoloških oboljenja donjih ekstremiteta, sa samoizabranim brzinama hoda. Analiza hoda je uradjena pomoću zebra ultrazvučnog sistema sa biomehaničkim modelom od 19 tačaka. Iz spacijalnih koordinata istraživanih antropometrijskih faktora izračunavane su kinematičke vrednosti (dužina koraka, širina koraka, uglovi kolena, kuka i karlice). Razlika izmedju širine i dužine koraka obe populacije ispitanika nije tako značajna. Značajne statističke razlike u uglovima zglobova su pronadjene kod obolelih i zdravih udova. U našem istraživanju spacijalni parametri nisu pokazali značajnu asimetriju iako su svi pacijenti bolovali od unilateralnog oboljenja kuka. Ovo se može dogoditi kada pacijent hoda kratkim koracima ili kada su u pitanju kompenzatorni pokreti drugih zglobova. Asimetrija se javljala kod kretanja kuka kao i kretanja kolena. Maksimalna fleksija i ekstenzija kuka obolelih pacijenata je u obrnutom odnosu sa maksimalnom ekstenzijom i fleksijom kuka zdravih ispitanika. Zato se i sugeriše da je pojačano kretanje suprotnog kuka imalo kopmenzatornu ulogu. Studija je pokazala da je povećana pelvička ukošenost direktno u korelaciji sa opsegom fleksije kuka. Kada je taj opseg smanjen može se očekivati da povećana ukošenost karlice može da se javi kao kompenzacija. Ova studija je otkrila da postoji uticaj smanjenog opsega kretanja obolelog kuka na ipsilateralno koleno u obliku smanjenog opsega kretanja zgloba kolena. Rezultati ukazuju na generalno slab funkcionalni ishod čak iako je primećeno asimetrično opterećenje. Otkriveni su takodje i limitirajući faktori fizičke funkcije.*

Ključne reči: *analiza hoda, 3D kinematika, kinetika, osteoartritis kuka*