

Scientific Paper

**GAIT PARAMETERS OF PATIENTS WITH OSTEOARTHRITIS
OF THE KNEE JOINT**

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Abstract. *It is difficult to identify objective parameters for assessing joint function when evaluating the outcome of orthopaedic procedures, especially endoprosthesis replacement. Spatial and temporal parameters of gait have clinical relevance in the assessment of motor pathologies, particularly in orthopaedics. The objective of this study is to compare gait patterns in patients with unilateral osteoarthritis of the knee joint to the gait pattern of healthy control subjects. A total of 20 patients with severe unilateral osteoarthritis of the knee and 20 healthy elderly subjects without any history of lower extremity joint pathology were investigated at constant gait speeds (two km/h). The gait analysis equipment used consisted of an infinitely adjustable force-instrumented treadmill and an ultrasound-based motion analyzer system with electromyography. Our findings indicate that changes in gait parameters may occur in patients with unilateral osteoarthritis of the knee joint as compared to the gait pattern of healthy control subjects. Knee joint degeneration was compensated for in part by the pelvis and other joints in the lower limb. Reduced motion of the knee joint leads to increased pelvic motion, which should affect the natural mobility of the lumbar spine and cause pain in the lumbar region of the spine due to kinematic interaction.*

Key words: *Biomechanics, gait analysis, osteoarthritis, knee*

1. INTRODUCTION

Kinematics, kinetics, and electromyography are fundamental for characterizing gait patterns and their underlying mechanisms (Frigo et al., 1996, 9). Complex gait analysis

presents itself as a possible tool for evaluating the rehabilitation process after orthopaedic surgery (Knoll et al., 2004, 12). Patients with osteoarthritis suffer from pain and functional impairment of the knee over a long period. Although different functional scores are widely used to assess improvements after surgery, the patients' responses are often subjective and disparities between patients' and doctors' evaluations can be significant (Bullinger, 1996, 35; Liebermann et al., 1996, 28). Therefore, objective and quantified data from gait analysis could be useful.

Osteoarthritis is the most prevalent form of arthritis among the elderly. It is estimated that 10% of men and 21% of women over the age of 65 have osteoarthritis in the knee joint, in the hip joint or in both joints (Al-Zahrani and Bakheit, 2002, 24). Patients may adapt their gait in response to pain, deformity or laxity in the joints of the lower extremities. Patients with osteoarthritis of the knee joint often adapt an antalgic type of gait as their disease progresses (Murray et al., 1971, 53A). It is not known if gait adaptation is mainly related to the severity of the disease, pain, muscle weakness, or limitations in a passive range of motion (Hurwitz et al., 2000, 18; Mc Gibbon and Krebs, 2002, 29). Furthermore, adaptations protecting the knee joint may influence the motion of the lower back and other joints of the lower extremities (Andriacchi et al., 1982, 64; Gök et al., 2002, 73).

Gait measurement has been used for the analysis of the biomechanical parameters of the lower extremities of patients with knee osteoarthritis. Patients with gonarthritis have demonstrated a lower walking speed, lower cadence, shorter step length, and shorter single stance phase of the involved leg (Al-Zahrani and Bakheit, 2002, 24; Andriacchi et al., 1982, 64; Baliunas et al., 2002, 10; Chao et al., 1983, 16; Gök et al., 2002, 73; Hurwitz et al., 2000, 18; Mattson et al., 1990, 22; Weidenhielm et al., 2001, 25), while a shorter double stance phase of the involved leg has been observed when compared to the normal group (Chao et al., 1983, 16; Gök et al., 2002, 73; Weidenhielm et al., 2001, 25). Several studies have established that the range of motion of the affected joint has significantly decreased and the range of motion of other joints of the lower extremities have increased significantly in patients with gonarthritis (Al-Zahrani and Bakheit, 2002, 24; Gök et al., 2002, 73; Hurwitz et al., 2000, 18). The osteoarthritis of the knee joint significantly influenced the ground reaction force (Gök et al., 2002, 73), the muscle moments (Baliunas et al., 2002, 10; Hurwitz et al., 2000, 18; Munderman et al., 2004, 50) and muscle power (McGibbon and Krebs, 2002, 29). These studies underlined a specific aspect of advanced osteoarthritis gait. It can be assumed that the observed locomotor perturbation caused by compensatory or adaptive mechanisms comes as a result of severe osteoarthritis.

The objective is to compare gait patterns in patients with unilateral osteoarthritis of the knee to the gait patterns of healthy control subjects. We hypothesized that the biomechanical parameters were significantly influenced by osteoarthritis of the knee joint compared to the healthy control group.

2. MATERIALS AND METHODS

Subjects

The population of the healthy group consisted of 12 women and 8 men. Their age was 52-84 (68.8±9.1years), body weight was 61.3-100.3 kg (73.3±11.4kg), and height was 1.50-1.96 m (1.69±0.19). The average HSS Knee Score of the healthy elderly people was 98.9 points (± 1.1); all of the subjects had excellent results (HHS~100 points). The subjects were not limited in their normal daily or recreational activities. These subjects

had no history of osteoarthritis of the knee joint and of hip joint, knee instability or major lower extremity joint surgery. These individuals had normal strength, a full range of motion of the lower extremities and no neurological deficiencies.

The population of patients with unilateral gonarthrosis consisted of 12 women and 8 men. Their age was 45-93 (68.2 ± 7.1), body weight was 55.3-122.1 kg (71.1 ± 11.9), and mean height was 1.47-1.86 m (1.69 ± 0.11). The average HSS Knee Score of the patients with unilateral gonarthrosis was 47.9 points (± 13.6), and all of the patients had poor results (HHSK < 70 points). All of the patients were seriously limited in their activities due to pain.

The age, weight and height of the healthy subjects and patients with gonarthrosis can be compared to each other, with no significant differences ($p=0.71$; $p=0.87$; $p=0.67$ respectively). The joint function of patients with gonarthrosis is significantly poorer compared to the one of the healthy control group ($p=0.003$; $p=0.001$ respectively). Each subject provided informed consent before participation and signed a consent form approved by the Hungarian Human Subjects Compliance Committee (112/2004).

The severity of the osteoarthritis of the knee joint was determined by the Kellgren and Lawrence radiographic index (Kellgren and Lawrence, 1957, 16), a 5-point scale (0-4) on the basis of anteroposterior and Laustein X-ray projections. The Kellgren and Lawrence radiographic index of 15 patients was 4, and the Kellgren and Lawrence radiographic index of 5 patients was 3. All of the patients were classified as having severe osteoarthritis of the knee joint. It means they have large osteophytes, a marked joint space narrowing, severe sclerosis and definite bone contour deformity.

Methods

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

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 limb. The measuring method was developed by Kocsis (2002). The biomechanical model developed by Knoll et al. (2004, 12) was chosen for our study. The spatial coordinates were recorded at a frequency of 100 Hz. Simultaneously, the ground forces were measured at 1000 Hz. The patients were asked to walk at constant gait speed of 2 km/h on a motorized and instrumented 330 mm * 1430 mm treadmill with a built-in force plate (Bonté Zwolle B.V, Austria). Walking on the treadmill can initially be an unfamiliar experience, which in turn may influence the parameters being measured. Therefore, measurements are to start after six minutes of familiarization time (Alton et al., 1998, 13; Matsas et al., 2000, 11). Kinematic data were collected for six gait cycles.

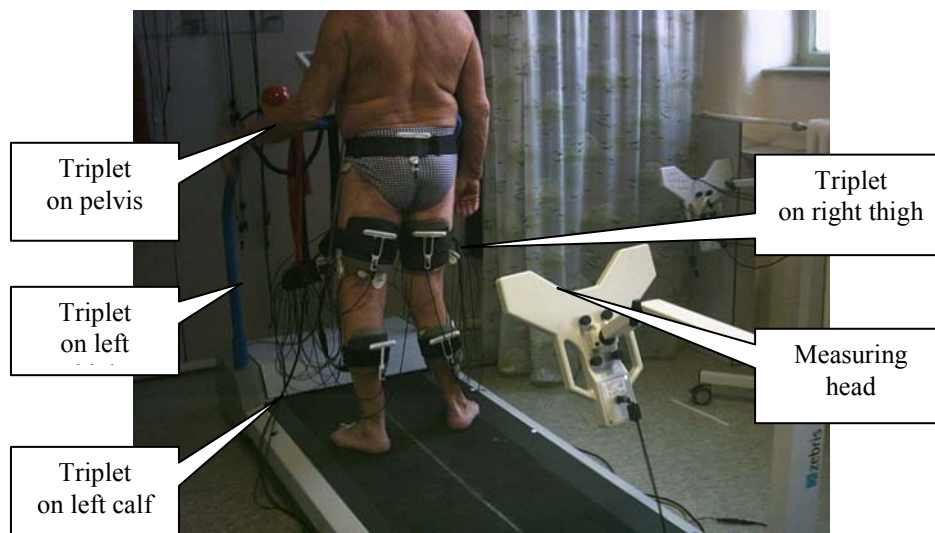


Fig. 1. Arrangement of measurements

The assessed kinematic parameters are the following:

- Temporal and spatial parameters: stance, swing and double stance phase in percent of gait cycle; step length, step width (in centimeters); cadence (steps per minute)
- Angular parameters: knee, hip and pelvic angles, presented by Kocsis and Beda (2001, 18);
- 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 were calculated by a software package presented first in (Jurak and Kocsis, 2002).

Statistical analysis

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

The biomechanical properties of individuals pertaining 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 applying a symmetrical critical range. A two-sample t-test was applied when comparing the results for healthy people and patients with osteoarthritis. It was assumed that the gait parameters of the healthy group and the patients with osteoarthritis at constant gait speeds should be different, and the results present statistically significant differences if $p < 0.05$.

3. RESULTS

All of the results are summarized in Tables 1 and 2. Significant statistical differences were observed for 13 parameters (cadence, step length, walking base, time of double support phase motion of the knee joint, motion of the hip joint at osteoarthritis side, motion of the pelvis joint –Table 1) out of 22, comparing the patients with gonarthrosis to the healthy group examined at equal gait speed. There are no statistical differences in the time of the swing phase, in unaffected hip motion, in the motion of pelvis rotation, flexion (Table 1) and in the kinetic parameters (Table 2).

Table 1. The results of spatial-temporal and angular parameters of the patients and control subjects.

Parameters	Side	Healthy	Patients
<i>Spatial-temporal parameters</i>			
Cadence (step/minutes)		94.5 ± 20.7	97.04 ± 8.1
Step length (mm)	A	999.8 ± 109.5	973.6 ± 80.9
	B	934.7 ± 110.7	903.1 ± 80.5
Walking base (mm)	A	21.7 ± 7.9	23.6 ± 6.3
	B	27.9 ± 8.7	27.8 ± 5.2
Double support phase (% of gait cycle)		20.9 ± 1.9	18.2 ± 1.7
Swing phase (percent of gait cycle)	A	33.7 ± 5.6	41.5 ± 3.3
	B	30.9 ± 5.5	31.4 ± 2.8
<i>Knee angle (degree)</i>			
ROM	A	57.5 ± 7.3	41.7 ± 8.5
	B	48.8 ± 6.1	30.7 ± 9.1
maximum	A	63.6 ± 6.3	49.8 ± 6.5
	B	56.3 ± 5.7	46.5 ± 12.3
minimum	A	6.1 ± 3.4	8.2 ± 5.4
	B	7.5 ± 3.4	15.7 ± 11.4
<i>Hip angle (degree)</i>			
ROM	A	33.6 ± 7.9	28.0 ± 9.3
	B	27.9 ± 7.1	31.9 ± 11.3
maximum	A	84.8 ± 17.6	71.9 ± 15.0
	B	82.8 ± 10.1	81.8 ± 11.2
minimum	A	51.2 ± 14.6	43.9 ± 8.1
	B	54.9 ± 17.8	43.9 ± 8.1
<i>Rotation of pelvis (degree)</i>			
ROM		5.5 ± 3.0	10.8 ± 5.6
Maximum		4.3 ± 2.8	7.1 ± 3.4
Minimum		-1.2 ± 1.1	-3.7 ± 1.5
<i>Obliquity of pelvis (degree)</i>			
ROM		4.6 ± 1.4	6.1 ± 1.7
Maximum		6.9 ± 1.7	6.7 ± 6.7
Minimum		2.3 ± 3.5	0.6 ± 2.6
<i>Flexion/extension of pelvis (degree)</i>			
ROM		5.9 ± 2.3	11.7 ± 2.8
Maximum		16.4 ± 5.8	14.2 ± 3.8
Minimum		10.5 ± 6.0	2.5 ± 4.9

Comments: side A: dominant side of the healthy people, contralateral (healthy) side of the patients
side B: nondominant side of the healthy people, affected side of the patients

Table 2. The results for the force parameters of the patients and control subjects

Parameters	Side	Healthy	Patients
F1 (percent of body weight)	A	120.3 ± 15.5	110.7 ± 8.9
	B	120.8 ± 14.9	113.9 ± 9.0
F2 (percent of body weight)	A	118.5 ± 13.4	115.9 ± 15.3
	B	116.5 ± 14.8	111.5 ± 13.2

4. DISCUSSION

The objective of the present study was to compare the gait patterns of patients with unilateral osteoarthritis of the knee joint to the gait patterns of healthy control subjects. Walking is a common functional activity of daily living. This study provides meaningful information on gait adaptations used by patients with osteoarthritis of the knee joint compared to healthy subjects. Assessment of gait changes should be helpful in the occurrence of compensatory mechanisms during the course of diseases.

In our study the cadence, step length, walking base, and the time of double support phase in patients with gonarthrosis changed significantly compared to those of the healthy subjects (Table 1). These findings are similar to those found in previous studies (Al-Zahrani and Bakheit, 2002, 24; Andriacchi et al., 1982, 64; Baliunas et al., 2002, 10; Börjesson et al., 2005, 12; Gök et al., 2002, 73; Hurwitz et al., 2000, 18; Kaufmann et al., 2001, 34; Mattson et al., 1990, 22; McGibbon and Krebs, 2002, 29; Messier et al., 1992, 57). According to Hurwitz et al. (2000, 18) the different spatial-temporal parameters were part of the adaptive mechanism to reduce pain, which is similar to the findings of McGibbon and Krebs (2002, 29).

The results of joint angle kinematics show that the minimal value of knee motion was increased, which represents a decreased knee extension; the maximal value of knee motion decreased, which means a decreased knee flexion; and the motion range of the knee joint decreased on both sides, as compared to that of the healthy subjects (Table 1). These findings were also noted by other researchers (Gök et al., 2002, 73; Kaufmann et al., 2001, 34; McGibbon and Krebs, 2002, 29; Messier et al., 1992, 57). Messier et al. (1992, 57) established that the abnormalities of the knee joint seem to reflect mechanical changes secondary to osteoarthritis rather than underlying factors involved in pathogenesis. In the case of patients with gonarthrosis, asymmetry was observed in the motion of the knee joint, due to the fact that the motion of the un-affected knee joint significantly increased compared to that of the affected joint. However, the motion of the un-affected knee joint was significantly decreased compared to the values of the dominant side of healthy subjects. Our results support the findings of Andriacchi et al. (1982, 64).

The next joint in the kinematic chain of the human body is the hip joint. It could be hypothesized that the reduced motion of the knee joint would be compensated by an increased motion of the hip joint. However, we found a decreased hip motion of the osteoarthritis side compared to the one of the healthy subjects. These findings support results from previous studies (Al-Zahrani and Bakheit, 2002, 24; Andriacchi et al., 1982, 64; Baliunas et al., 2002, 10; Börjesson et al., 2005, 12; Hurwitz et al., 2000, 18; McGibbon and Krebs, 2002, 29; Messier et al., 1992, 57) and can be attributed to a compensatory strategy which acts to prevent the knee joint with increased neuromuscular control (Childs et al., 2004, 19).

As a result of our measurement, it could be assumed that decreased knee motion was associated with increased motion occurring in the pelvis. An increase in pelvic motion obliquity was observed compared to the one of the healthy subjects (Table 2). The pelvis adaptation enabled the patient to minimize the shorter step length resulting from a reduced motion range of the knee joint (Hurwitz et al., 2000, 18) and to reduce the pain (Hurwitz et al., 2000, 18). Similarly, the findings of Whittle (1996) - the modified pelvis obliquity motion and interaction between the modified pelvis kinematics and the lumbar spine - could explain in part why pains are often noticed in patients with gonarthrosis in the HSS Knee Score.

When ground reaction forces were analyzed, we found no difference in patients with gonarthrosis compared to healthy subjects (Table 2). These results are consistent with the data reported by Gök et al. (2002, 73).

Our findings indicate that changes in gait parameters may occur in patients with unilateral osteoarthritis of the knee joint compared to the gait patterns of healthy control subjects. Knee joint degeneration was compensated for in part by the pelvis and other joints in the lower limb. Reduced motion of the knee joint leads to increased pelvic motion, which should affect the natural mobility of the lumbar spine and cause pain in the lumbar region of the spine because of the existing kinematic interaction.

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PARAMETRI HODA KOD PACIJENATA SA OSTEOARTRITISOM ZGLOBA KOLENA

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Teško je odrediti objektivne parametre za procenu funkcije pokretljivosti zglobova kada ocenjujemo rezultate ortopedskih procedura, naročito endoprostetičkih zamena. Spacijalni i temporalni parametri načina hoda imaju kliničku relevantnost u proceni patologije motoričkog aparata, naročito u ortopediji.

Cilj ovog istraživanja je da se izvrši komparacija načina hoda kod pacijenata sa unilateralnim osteoartritisom zgloba kolena i kod zdravih ispitanika. Uzorak je činilo 20 pacijenata sa ozbiljnim ostećenjima –unilateralnim osteoartritisom kolena i 20 zdravih starijih ispitanika bez ikakve istorije bolesti donjih ekstremiteta, a ispitavan je hod pri brzini od 2 km/h. Aparatura koja je korišćena sastojala se od podešive staze za šetanje sa instrumentima za merenje sile i ultrazvučnog analizatora kretanja sa elektromiografijom.

Rezultati pokazuju da se promene u načinu hodanja mogu javiti kod pacijenata sa unilateralnim osteoartritisom zgloba kolena ako se porede sa obrascima hoda zdravih kontrolnih ispitanika. Degeneracija zgloba kolena se kompenzira delimično većom pokretljivošću karlice i ostalih zglobova donjeg ekstremiteta. Smanjena pokretljivost zgloba kolena uslovljava povećanu pokretljivost pelvisa što utiče na prirodnu sposobnost kičmene moždine i što izaziva bolove u lumbalnoj regiji kičme zbog kinematičke interakcije.

Ključne reči: biomehanika, analiza hoda, osteoartritis, koleno.