Gait & Posture 72 (2019) 46–50

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Gait analysis in patients after bilateral versus unilateral total hip arthroplasty

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ARTICLE INFO

Keywords:
Total hip arthroplasty
Gait analysis
Kinematics
Functional recovery

ABSTRACT

Background: Gait abnormalities were reported in patients after total hip arthroplasty (THA). One-stage bilateral THA was introduced for bilateral hip pathologies, showing similar clinical and surgical outcome to unilateral procedure. However, no studies analyze the gait features after bilateral THA surgery compared to unilateral THA.

Research question: Are there differences in gait characteristics between bilateral and unilateral THA patients and are there differences between these cases and asymptomatic age-matched healthy subjects?

Methods: In this prospective observational study, thirty-five patients with bilateral (n = 18) or unilateral THA (n = 17) and twenty asymptomatic age-matched volunteers were studied. Participants underwent three-dimensional gait analysis*in order to detect gait spatial-temporal and kinematic (Gait Variable Score - GVS) parameters.* Mobility (Timed Up and Go - TUG), fear of movement (Tampa Scale of Kinesiophobia - TSK) and pain during walking (Numeric Rating Scale - NRS) were also assessed. Patients were evaluated the day before surgery and at seven days, whereas healthy subjects underwent a single evaluation. ANOVA was used to assess differences between the three groups at each time-point and within-group differences in bilateral and unilateral groups.

Results: At baseline, no differences between the two groups of patients were found. As expected, their gait spatial-temporal and kinematic parameters and functional variables were impaired with respect to healthy subjects, both before and after surgery. After surgery, GVS Pelvic-TILT closer to normative values, longer stance and shorter swing phases were found in bilateral cases compared to unilateral patients. Moreover, a higher NRS score was found in bilateral patients, whereas TUG and TSK revealed no differences between the two groups of patients.

Significance: The current findings, focusing on short-term effectiveness of bilateral THA, could assist physiotherapists in selecting the best ambulation training and an appropriate rehabilitation approach immediately after surgery.

1. Introduction

Hip osteoarthritis is a common chronic disease with increasing incidence and prevalence in adult population [1]. Pain, stiffness and loss of function represent the main symptoms leading to considerable impact on daily activities and quality of life [2]. Total hip arthroplasty (THA) is an effective and definitive treatment for the end-stage of osteoarthritis, able to relieve pain and improve hip function, in order to quickly restore functional independence and quality of life [3]. Despite the satisfactory functional recovery characterizing THA, several alterations were described during daily activities of these patients. This is the case of walking, in which preoperative adaptations to pain and reduced joint mobility sometimes persist for many years after surgery [4,5]. In particular, gait spatial-temporal parameters and kinematic abnormalities were described in patients after unilateral THA, representing a risk factor for the development of inter-joint coordination problems of both lower limbs [6,7]. A systematic review of Ewen et al. showed reduced walking speed, stride length and hip flexion-extension

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https://doi.org/10.1016/j.gaitpost.2019.05.026
Received 5 February 2019; Received in revised form 6 May 2019; Accepted 14 May 2019

range of motion after unilateral THA compared to healthy asymptomatic subjects [8]. Moreover, pelvis and hip kinematic asymmetries were described between affected and non-affected sides of these patients [9]. These alterations could result from attempts by unilateral surgery patients to protect the operated limb during walking, promoting adaptations with non-operated lower limb [10].

One-stage bilateral THA was introduced for bilateral hip osteoarthritis, resulting in similar clinical and functional outcomes to unilateral THA [11]. This approach revealed not just a reduction in operative time, hospitalization and costs compared to two-stage bilateral THA, but pain and hip function were similar to the unilateral approach [12–15]. However, the functional recovery in patients after simultaneous bilateral THA was assessed only through the administration of questionnaires or in terms of hip motion without analyzing functional activities like walking [16]. Three-dimensional gait analysis represents a valid tool to assess gait features in patients before and after THA, able to identify abnormalities occurring in early postoperative phase and their long-term persistence [8,17,18]. This approach allows clinicians to quantify deviations from normality comparing THA patients with healthy subjects [19]. To date, no studies have evaluated gait features in operated bilateral patients compared to those undergoing unilateral THA. Our hypothesis is that bilateral patients could produce different gait patterns to unilateral subjects. Thus, the aim of this study was to investigate gait and functional characteristics in bilateral operated patients versus unilateral THA in perioperative phase and to compare them with asymptomatic subjects.

2. Methods

2.1. Participants

Fifty-five subjects were enrolled in the study between June 2017 and September 2018. Thirty-five were patients admitted to our Institute for bilateral (n = 18) or unilateral THA (n = 17), whereas twenty were asymptomatic age-matched volunteers. Patients satisfied the following inclusion criteria: primary cementless THA for osteoarthritis or osteonecrosis, between 45 and 65 years of age and the ability to walk for at least 50 m without aids. Exclusion criteria were: THA for severe dysplasia (Crowe III and IV), history of traumatic events, hip ankylosis or previous femoral and/or pelvic osteotomy. Patients admitted for revision surgery, with leg disparity greater than 1 cm or with concomitant neurological and/or musculoskeletal disorders able to influence motor and functional recovery were also excluded. Healthy volunteers were enrolled from among employees of the hospital and relatives of the patients and they had no history of lower limb disorders or pain in the previous year.

Patients were operated on by three orthopedic surgeons in the same Orthopedic Surgery Department, performing the same posterolateral surgical technique. After surgery, patients followed a standardized rehabilitation program characterized by two daily sessions focused on progressive resistance training and exercises aimed to improve hip range of motion (RoM) and postural stability. Training was also given in functional activities such as transfers, walking and stair climbing with crutches. The study was conducted at the Hip and Knee Orthopedic Surgery Department and at the Motion Analysis Laboratory of Humanitas Research Hospital. All patients signed an informed consent form and the study was approved by the Ethical Committee of the Institute (n. CLF17/2 of March 20, 2017).

2.2. Study design

In this prospective observational study patients were evaluated the day before surgery and then at seven days, whereas healthy volunteers underwent a single evaluation session. All participants underwent three-dimensional gait analysis. In addition, functional mobility, fear of movement during ADL and pain during walking were evaluated at each time-point. The assessments were always conducted by the same two operators (one for gait analysis and the other for functional evaluations) in the same order with a rest of 5–15 minutes between each test. Before the evaluation the assessor delivered standardized instructions to participants and the tasks were acquired with two video cameras in order to check a posteriori the correct performance execution.

2.3. Three-dimensional gait analysis

Participants were instructed to walk along a wooden walkway at comfortable speed without crutches. Twenty-two spherical retro-reflective markers (diameter 10 mm) were placed on anatomical landmarks according to the Helen Hayes marker set and anthropometric measures were collected. The assessment consisted of 10 s of standing for calibration followed by four walking tasks spaced by 30 s of rest to avoid fatigue. Data were acquired using an optical motion capture system (SMART-DX, BTS, Italy) with a sample rate of 100 Hz and then filtered with a 2 Hz low-pass filter. The Heel-strike and Toe-off events of the gait cycle were defined for each side using the markers placed on the heel and on the fifth metatarsus. Spatial-temporal parameters, Gait Profile Score (GPS) and Gait Variable Score (GVS) of pelvis, hip, knee and ankle were computed. GPS is a summary index of gait kinematics for quantifying its deviation with respect to a healthy reference population, whereas GVS consists of nine gait variables expressing joints kinematics deviations from healthy gait profile [20,21]. Smaller GPS and GVS scores index greater proximity to normality data.

2.4. Functional assessment

Functional mobility was assessed using the Timed Up and Go (TUG) test. Patients were asked to stand-up from an armchair, walk at spontaneous speed for three meters, turn, walk back to the chair and sit down. The test was repeated three times in order to eliminate any learning effect between pre-surgery and post-surgery. The performance was always timed by the same operator and only the best score was used for data analysis. Fear of movement during daily activities was also assessed through the Tampa Scale of Kinesiophobia (TSK). It consists of a 17-item self-completed questionnaire with score ranges from 17 to 64, with a high score indicating high kinesiophobia. Finally, after gait analysis participants were asked to indicate perceived pain using the Numeric Rating Scale (NRS) ranging from 0 to 10, where a high value indicates a high pain.

2.5. Statistical analysis

Categorical variables were presented as proportions, whereas continuous variables were described as mean and standard deviation. All measurements were checked for normality with the Kolmogorov-Smirnov test. Univariate ANOVA with Bonferroni adjustment for multiple comparisons was used to assess differences between the three groups at each time-point, whereas repeated measures ANOVA was used to assess within-group differences in bilateral and unilateral groups. Data were analyzed using SPSS Statistics 20.0 for Windows and the statistical level of significance was set at $\alpha = 0.05$.

3. Results

All subjects completed the tests correctly. The three groups were homogenous in term of age, weight, height and gender **(**Table1**).**

3.1. Bilateral vs unilateral

No differences were found between bilateral and unilateral groups at baseline for all measurements (Table 1). After surgery, GVS PelvicTILT closer to normative values was observed in bilateral patients. Moreover, longer stance and shorter swing phases and higher NRS score

Table 1
Demographic and baseline characteristics of patients and healthy subjects (Univariate ANOVA and Chi-Square tests). Data are shown as mean and standard deviation.

	Bilateral THA (n = 18)	Unilateral THA (n = 17)	Healthy subjects (n = 20)	p-value
Demographic variables				
Age (years)	51.60 ± 6.43	53.05 ± 6.2	55.9 ± 7.4	0.259
Weight (kg)	81.75 ± 14.82	78.35 ± 12.7	77.2 ± 10.7	0.413
Height (cm)	175.55 ± 8	171 ± 8.73	170.7 ± 8.7	0.108
Gender	16 M/2F	10 M/7F	12 M/8F	0.086
Spatial-temporal parameters				
Speed (m/s)	0.74 ± 0.18	0.77 ± 0.11	1.04 ± 0.21	< 0.001 †† §§
Cadence (step/min)	91.3 ± 10.2	93.9 ± 8.2	103.2 ± 12	< 0.001 † §§
Step Length (m)	0.47 ± 0.09	0.49 ± 0.10	0.52 ± 0.2	0.400
Stride Length (m)	0.97 ± 0.14	1 ± 0.12	1.2 ± 0.16	< 0.001 †† §§
Stance (%)	62.3 ± 2.5	60.9 ± 1.9	59.3 ± 2.7	< 0.001 §
Swing (%)	38 ± 2.5	39.3 ± 1.7	40.1 ± 2.5	0.001 §
Single-Stance (%)	38 ± 2.7	38.5 ± 1.8	40.2 ± 2.6	0.001 §
Double-Stance (%)	12.3 ± 2.4	11.7 ± 1.5	9.9 ± 2.3	< 0.001 † §§
Kinematic indexes				
GVS Pelvic-TILT	8.5 ± 5.5	10.1 ± 4.9	5.3 ± 2.4	< 0.001 † §
GVS Pelvic-ROT	4.8 ± 1.9	4.3 ± 1.5	4.6 ± 1.4	0.560
GVS Pelvic-OBL	3.7 ± 1.3	3.2 ± 1.2	2.6 ± 1.2	0.002 §
GVS Hip-FE	11.8 ± 5.9	11.5 ± 5.6	8.4 ± 3.8	0.012 §
GVS Hip-AA	5.1 ± 2.9	4.6 ± 1.7	3.9 ± 1.7	0.072
GVS Hip-IE	15.6 ± 10	12.3 ± 6.7	13.3 ± 7.9	0.354
GVS Knee-FE	11.2 ± 5.9	9.3 ± 3.5	9.1 ± 3.7	0.149
GVS Ankle-FE	9.7 ± 6.8	9.8 ± 5.4	5.8 ± 2.6	0.003 † §
GVS Ankle-IE	11 ± 6.8	8.8 ± 5.9	10.8 ± 9.9	0.628
GPS	10.6 ± 3.6	9.6 ± 2.2	7.7 ± 2.4	< 0.001 §§
Functional variables				
TUG	9.7 ± 2.2	9.7 ± 1.7	7.5 ± 1.2	< 0.001 † §
NRS	1.8 ± 2	2.3 ± 2.2	0 ± 0	< 0.001 †† §
TSK	36.4 ± 8.7	34.1 ± 7.7	17 ± 0	< 0.001 †† §§

THA: Total Hip Arthoplasty, **M**: Male, **F**: Female, **GVS**: Gait Variable Score, **GPS**: Gait Profile Score, **TUG**: Timed Up and Go, **NRS**: Numeric Rating Scale, **TSK**: Tampa Scale of Kinesiophobia, **ROT**: Roation, **OBL**: Obliquity, **FE**: Flexion-Extension, **AA**: Adduction-Abduction, **IE**: Internal rotation - External rotation. Unilateral vs Bilateral THA * $p < 0.05$ ** $p < 0.001$; Unilateral THA vs Healthy subjects † $p < 0.05$ †† $p < 0.001$; Bilateral THA vs Healthy subjects § $p < 0.05$ §§ $p < 0.001$.

Table 2
Gait spatial-temporal and kinematic parameters and functional outcome measures after surgery (Univariate ANOVA and Bonferroni post-hoc analysis). Data are shown as mean and standard deviation.

	Bilateral THA (n = 18)	Unilateral THA (n = 17)	Healthy subjects (n = 20)	p-value
Spatial-temporal parameters				
Speed (m/s)	0.49 ± 0.23	0.53 ± 0.17	1.04 ± 0.21	< **0.001** †† §§
Cadence (step/min)	81.3 ± 15.3	84 ± 14	103.2 ± 12	< **0.001** †† §§
Step Length (m)	0.33 ± 0.14	0.36 ± 0.11	0.52 ± 0.2	< **0.001** † §§
Stride Length (m)	0.7 ± 0.24	0.75 ± 0.19	1.2 ± 0.16	< **0.001** †† §§
Stance (%)	68.7 ± 6.7	64.2 ± 3.5	59.3 ± 2.7	< **0.001** * † §§
Swing (%)	31.7 ± 6.4	36 ± 3.5	40.1 ± 2.5	< **0.001** * † §§
Single-Stance (%)	31.4 ± 6.4	32.7 ± 6.2	40.2 ± 2.6	< **0.001** †† §§
Double-Stance (%)	18.9 ± 6.9	17.1 ± 6.7	9.9 ± 2.3	< **0.001** †† §§
Kinematic indexes				
GVS Pelvic-TILT	6.9 ± 3.6	9.2 ± 3.3	5.3 ± 2.4	< **0.001** * ††
GVS Pelvic-ROT	4.3 ± 1.9	5.4 ± 1.8	4.6 ± 1.4	0.083
GVS Pelvic-OBL	4.1 ± 1.1	4.1 ± 1.4	2.6 ± 1.2	< **0.001** †† §§
GVS Hip-FE	11.7 ± 4.3	14.5 ± 4.5	8.4 ± 3.8	< **0.001**†† §
GVS Hip-AA	5.2 ± 2.5	5.4 ± 3.1	3.9 ± 1.7	**0.025**
GVS Hip-IE	13.1 ± 9	17.1 ± 7.1	13.3 ± 7.9	0.228
GVS Knee-FE	12.6 ± 5.7	13.5 ± 5.6	9.1 ± 3.7	**0.002** † §
GVS Ankle-FE	11 ± 8.1	12.6 ± 5.6	5.8 ± 2.6	< **0.001** †† §
GVS Ankle-IE	7.9 ± 5.3	8.1 ± 6.4	10.8 ± 9.9	0.219
GPS	10 ± 3.9	11.4 ± 2.5	7.7 ± 2.4	< **0.001** †† §
Functional variables				
TUG	15.4 ± 5.9	13 ± 2.4	7.5 ± 1.2	< **0.001** †† §§
NRS	1.4 ± 2.1	0.35 ± 0.7	0 ± 0	**0.003** * §
TSK	26.9 ± 8.2	27.4 ± 9.8	17 ± 0	< **0.001** †† §§

THA: Total Hip Arthroplasty, **GVS**: Gait Variable Score, **GPS**: Gait Profile Score, **TUG**: Timed Up and Go, **NRS**: Numeric Rating Scale, **TSK**: Tampa Scale of Kinesiophobia, **ROT**: Roation, **OBL**: Obliquity, **FE**: Flexion-Extension, **AA**: Adduction-Abduction, **IE**: Internal rotation - External rotation. Unilateral vs Bilateral THA * $p < 0.05$ ** $p < 0.001$; Unilateral THA vs Healthy subjects † $p < 0.05$ †† $p < 0.001$; Bilateral THA vs Healthy subjects § $p < 0.05$ §§ $p < 0.001$.

were found in bilateral cases compared to unilateral patients (Table 2). Comparison with baseline showed deviations from normative data for all spatial-temporal gait parameters in both groups ($p \leq 0.001$) after surgery. Moreover, deviations from normality were found for GVS Pelvic-ROT ($p = 0.038$), GVS Knee-FE ($p = 0.008$) and GPS ($p = 0.045$) in unilateral patients, and for GVS Ankle-IE ($p = 0.020$) in bilateral cases. TUG deteriorated ($p < 0.001$), whereas TSK score improved in both groups after surgery ($p = 0.001$). Finally, NRS decreased only in unilateral patients compared to baseline ($p = 0.004$).

3.2. Patients vs healthy subjects

At baseline, all patients showed a difference with healthy subjects for speed, cadence, stride length, double stance duration, GVS Pelvic-TILT, GVS Ankle-FE and functional variables. Moreover, bilateral patients revealed stance, swing and single stance duration, GVS Pelvic-OBL, GVS Hip-FE and GPS scores less similar to normative values (Table 1). After surgery, all patients revealed differences in all spatial-temporal parameters, GVS Pelvic-OBL, GVS Hip-FE, GVS Knee-FE, GVS Ankle-FE, GPS, TUG and TSK in favor of healthy subjects. Finally, NRS showed differences only in bilateral patients (Table 2).

4. Discussion

This is the first study aimed at investigating gait and functional characteristics in patients operated for bilateral or unilateral THA in perioperative phase and compared them with healthy subjects. The main finding was that bilateral patients revealed a pelvic kinematic profile closer to normative values but temporal parameters were less similar when compared to unilateral cases. Moreover, all patients showed poorer gait spatial-temporal and kinematic parameters and functional variables than healthy age-matched subjects, both before surgery and at seven days.

At baseline, no differences were found between bilateral and unilateral patients indicating similar impairment in walking and functional abilities. After surgery, bilateral patients revealed a pelvic tilt closer to normative values than unilateral cases, whereas studies reported excessive anterior pelvic tilt during quiet standing or walking, both before and after unilateral THA [22,23]. This feature could arise from the need to compensate the operated hip joint stiffness in the sagittal plane through a hyper-mobility of the lumbosacral region [24]. Similarly, bilateral surgery restored a more physiological pelvic kinematics. The amount of pelvic tilt could influence the angle of lumbar lordosis, sustaining a relationship with the incidence of low back pain [25,26]. Moreover, bilateral patients revealed no differences for pelvic rotation from baseline to the seventh day, differently from unilateral cases, in which GVS deviated from normality.

On the contrary, bilateral THA resulted in a shorter swing and longer stance duration phases with respect to unilateral subjects. This phenomenon could depend on the reduced push-off during the pre-swing phase of the also operated contralateral limb, unlike in the case of from unilateral patients, where the stance duration on the operated side was influenced by the propulsion with the unaffected limb. The reduced propulsion use of the operated limb sometimes lasts for many years [27].

It could be reasonable to speculate that the fear of movement affecting these patients may influence the gait spatial-temporal and kinematic parameters, as kinesiophobia is associated with poor short-term functional recovery [28]. However, from our data it is not possible to prove this association, and this lack of association was similar to results of other studies evaluating this phenomenon after lower limb surgery [29].

In accordance with previous studies, gait spatial-temporal parameters and several kinematic variables showed deviations from normality after surgery in both groups of patients and were already impaired with respect to healthy asymptomatic subjects before and after surgery [8,30]. Interestingly, whereas mobility decreased due to surgery, fear of movement immediately improved after the operation, representing an example of person-centred care [28]. On the contrary, patients complaining of pain decreased after surgery only in unilateral cases. Pain can represents a determinant for ambulatory capacity, able to influence gait spatial-temporal parameters and kinematics. However in the current study pain was very low and unlikely to influence patients' walking performance, as has been seen in a previous study [31]. Moreover, the difference in pain between the two groups of patients after surgery do not reach the minimal clinically important difference estimated for these patients (2 points) [32]. It is worth noting that mobility, assessed by the TUG, was similar among all the patients.

The current results, focusing on gait analysis seven days after surgery, could help facilitate appropriate rehabilitation approaches immediately after THA surgery. Establishing the correct rehabilitation approach immediately after surgery has been gaining importance over the last few years, given that the length of stay after THA has decreased from several weeks to a few days [33]. Moreover, it is reasonable to speculate that a focused rehabilitation approach might also influence the long-term outcome [34].

However, some limitations of this study need to be underlined. First, the study included patients treated with posterolateral approach. As the surgical approach may impact on postoperative hip mechanics, our results could not be generalized to all THA patients [35]. Moreover, hip joint status of asymptomatic controls was not assessed through specific techniques, in order to avoid patient radiation exposure.

In conclusion, the hypothesis that bilateral patients produce different gait patterns from unilateral subjects was supported. In particular, bilateral patients revealed a pelvic kinematic profile closer to normative values but temporal parameters were less similar when compared to unilateral cases. From a functional point of view, the recovery after surgery is superimposable and only pain during gait is greater in bilateral patients, remaining, however, at a very low level. The current findings could assist physiotherapists in selecting the best ambulation training and an appropriate rehabilitation approach immediately after surgery.

Declaration of interest

None.

Funding

This research did not received any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

The authors thank Dr. Emanuela Morenghi for her suggestions for data analysis and Patricia Taylor for her language revision.

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