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Incidence and effect of leg length discrepancy following total hip arthroplasty

D.J. Beard [a,*], J. Palan [a], J.G. Andrew [b], J. Nolan [c], D.W. Murray [a],

EPOS Study Group

[a] Nuffield Department of Orthopaedic Surgery, University of Oxford, Nuffield Orthopaedic Centre, Oxford OX3 7LD, UK
[b] Ysbyty Gwynedd District Hospital, Penrhosgarnedd, Bangor, UK
[c] Norfolk and Norwich University Hospital, Norwich, UK

Abstract

Objectives The clinical importance of a leg length discrepancy (LLD) following total hip arthroplasty (THA) remains controversial. This study was undertaken to determine the effects of LLD on clinical outcomes at up to 3 years follow-up.
Design and setting Prospective, multicentre study.
Participants Nine hundred and eighty-seven cases of primary THA, categorised into two main groups: the NoLLD group (LLD of less than 10 mm) and the LLD group (LLD of 10 mm or more).
Main outcome measures The primary outcome measure was the change in Oxford Hip Score (ΔOHS) at up to 3 years follow-up. Secondary outcome measures were length of operating time and hospital stay, and revision and dislocation rates. Potential predisposing factors for LLD, including body mass index, age and type of anaesthesia employed, were examined.
Results At 3 years, the LLD group had a significantly worse ΔOHS [22.0; 95% confidence interval (CI) 20.5 to 23.5] compared with the NoLLD group (23.8; 95% CI 23.1 to 24.5) ($P = 0.034$). There were no significant differences in revision ($P = 0.389$) or dislocation ($P = 0.220$) rates between the two groups. Use of an epidural was associated with a decreased incidence of developing an LLD of 10 mm ($P = 0.004$).
Conclusion A postoperative LLD of 10 mm or more leads to poorer functional outcomes. Further studies are needed to assess the impact of an LLD on clinical outcomes in the longer term.

Keywords: Leg length discrepancy; Arthroplasty, hip; Dislocation; Revision; Oxford Hip Score

Introduction

Leg length discrepancy (LLD) has been well described as a common complication following total hip arthroplasty (THA) [1,2]. The presence of LLD has been associated with back pain [3,4], increased risk of nerve injury [5] and dislocation [6], poor patient satisfaction [7] and the need for revision surgery [8]. It has been cited as a major cause of litigation following THA [9]. In the literature, there is continuing debate about the importance of LLD and its clinical effect. A recent paper by Konyves and Bannister [10] concluded that patients with an LLD (longer leg length on operated side) had a worse functional outcome compared with patients who did not have an LLD. However, a study by White and Dougall [11] showed no statistical association between LLD and patient satisfaction and outcome. However, in both of these studies, the cohort size was small and single centred.

Objectives

The aim of this study was to determine the clinical effects of LLD following THA using the change in the Oxford Hip Score (ΔOHS) as a primary outcome measure.

* Corresponding author. Tel.: +44 1865 227454; fax: +44 1865 227671.
E-mail address: david.beard@orthopaedic-surgery.oxford.ac.uk (D.J. Beard).

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Design and setting

This was a prospective non-randomised multicentre study involving seven centres.

Participants

In total, 987 THAs were examined in this study, involving consultant and non-consultant surgeons and utilising two different surgical approaches (anterolateral and posterior). The diagnosis in every case was that of primary osteoarthritis and all were unilateral hips. None of the patients had undergone previous surgery to the hip. In all cases, a cemented Exeter femoral stem (Stryker Howmedica Osteonics, Mahwah, New Jersey, USA) was used with various acetabular components.

The true leg length was measured in millimetres (mm) using a direct tape measure method, with the patient in a supine position, from the anterior superior iliac spine to the medial malleolus of the operated side and non-operated side [12–14]. The LLD was calculated as the difference between the two measurements. The patients were categorised into two main groups: the NoLLD group, with an LLD of less than 10 mm ($n = 794$); and the LLD group, with an LLD of 10 mm or more ($n = 193$). A subgroup analysis was also performed on a small number of patients ($n = 55$) who had a severe LLD of 20 mm of more.

The mean LLD was 0.7 mm [standard deviation (SD) ± 1.8] and 14.9 mm (SD ± 7.4) in the NoLLD group and the LLD group, respectively. In the subgroup of patients with an LLD of 20 mm or more, the mean LLD was 24.7 mm (SD ± 2.1). The overall mean LLD in the series was 3.5 mm. The LLD was assessed to determine whether the effect of the discrepancy was to lengthen or shorten the affected leg. In the NoLLD group, 417 patients had equal leg lengths. Within this group, there were 110 patients with a minor LLD of less than 10 mm, of which 49 patients (45%) had a shortening of the operated leg and 61 patients (56%) had a lengthening of the operated leg. In the LLD group, 75 cases of LLD of 10 mm or more (39%) were shorter and 118 cases (61%) were longer ($P < 0.001$, Chi-squared test). Within the LLD group, the mean length of leg shortening was −13.9 mm and the mean length of leg lengthening was +15.6 mm.

Patient demographics are shown in Table 1. There were 293 men and 498 women in the NoLLD group, and 69 men and 123 women in the LLD group. Patients in the NoLLD group were younger than those in the LLD group ($P = 0.014$). There was no significant difference in the mean body mass index of the two groups ($P = 0.135$). The Charnley categories for each group of patients were not significantly different ($P = 0.865$). Category A describes unilateral hip disease, Category B describes bilateral hip disease and Category C describes multiple joint involvement which limits walking ability [15] (Table 1).

Main outcome measures

The OHS was used as a well-validated method [16,17] of assessing clinical outcomes on a patient-centred basis. The OHS is scored from 12 (best) to 60 (worst) and consists of 12 questions, each marked from one (best) to five (worst). Pre- and postoperative OHSs were collected and the change in OHS (ΔOHS) was calculated at 3 months, 1 year and 3 years. The OHS was also analysed as separate question components to identify if there were particular functional activities or symptoms which affected those patients with an LLD. Secondary outcome measures included the mean length of operating time and hospital stay, and revision and dislocation rates for each of the LLD groups. The type of anaesthetic used for each patient was recorded to assess if there was an association between the type of anaesthetic used and LLD. This was either a general anaesthetic, spinal anaesthesia or an epidural.

Statistics

For the outcome measures, analysis of variance and Tukey's Post Hoc test were used to compare differences in data between the groups. Categorical and frequency data were analysed using Chi-squared and Fisher's Exact tests, and the α-level of significance was defined as less than 5% ($P \leq 0.05$).

Table 1
Demographics and preoperative data for the two study groups

	Total no. of total hip arthroplasties	*n*	NoLLD group (LLD of less than 10 mm)	*n*	LLD group (LLD of 10 mm or more)	*P*-value
Gender (total)	983	791		192		0.803
Men			293		69	
Women			498		123	
Mean age at operation (years) ± +1 SD	985	792	69.4 ± 8.5	193	71.1 ± 8.5	0.014
Mean body mass index (kg/m^2) ± +1 SD	936	752	27.6 ± 5.0	184	27.0 ± 4.3	0.135
Charnley category	939	754		185		0.865
A			502		122	
B			141		33	
C			111		30	

LLD, leg length discrepancy; SD, standard deviation.

Data from Questions 1 and 9 of the OHS were analysed using the non-parametric Kruskal–Wallis test. Statistical Package for the Social Sciences Version 12.0.1 (SPSS Inc, Chicago, IL, USA) was employed for statistical analysis of the data.

Results

Primary outcome measure

There was no difference in the preoperative OHS between the NoLLD group and the LLD group ($P = 0.885$). The mean preoperative OHS was 43.4 in the NoLLD group (LLD of less than 10 mm) and 43.3 in the LLD group (LLD of 10 mm or more). The outcomes did not differ between the two groups until 3 years. The clinical benefit of surgery as determined by the ΔOHS was not significantly different between the groups at 3 months ($P = 0.537$) or 1 year ($P = 0.086$) after surgery (Table 2). However, at 3 years following THA, a statistically significant difference in the ΔOHS between the groups was seen, with the NoLLD group showing the greater improvement in ΔOHS ($P = 0.034$) (Fig. 1). The absolute OHS (Table 2) at 3 years was also significantly different between the groups: 19.3 for the NoLLD group and 21.1 for the LLD group ($P = 0.022$).

A subgroup analysis of the LLD group was performed whereby patients with an LLD of 20 mm or more were also assessed in terms of their OHS and ΔOHS. This minority group of patients had a significantly higher preoperative OHS (45.6) compared with patients in the LLD group with an LLD of 10 to <20 mm (OHS = 42.3) ($P = 0.017$), indicating worse pain and functional symptoms prior to surgery. At 3 years, this group of patients achieved a considerable benefit from surgery as evidenced by their ΔOHS of 24.6.

The effect of shortening and lengthening of the operated leg side was evaluated within the LLD group. There was no difference in ΔOHS at 3 months ($P = 0.568$), 1 year ($P = 0.591$) or 3 years ($P = 0.498$) when comparing a shorter LLD with a longer LLD (Table 3).

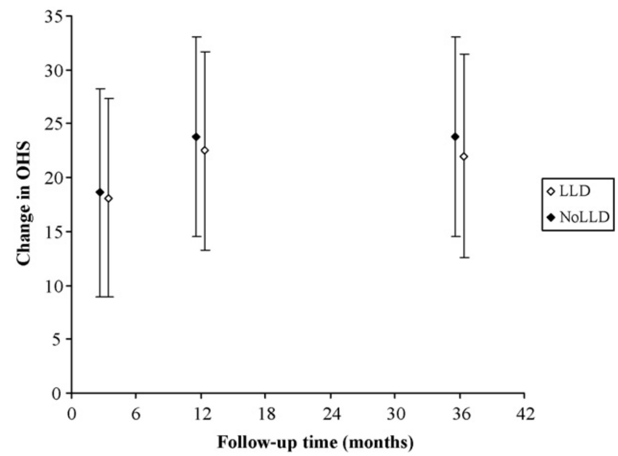

Fig. 1. Change in Oxford Hip Score (OHS) at 3, 12 and 36 months follow-up in the two study groups. Error bars represent standard deviation (+1SD).

The individual components of the OHS questionnaire were analysed. In particular, emphasis was placed on Questions 1 and 9 which dealt specifically with pain and limping, respectively. Questions 1 and 9 were scored from one to five points (one point being the best score, five points being the worst score). Patients with an LLD of 20 mm or more scored highest (worst) preoperatively for Question 1 compared with the other patients ($P = 0.03$), indicating that patients who had a severe postoperative LLD had significantly more pain associated with their arthritic hip prior to their operation. After surgery, this difference in pain was no longer significant ($P = 0.654$).

With regards to limping, there were no significant differences in the scoring for Question 9 preoperatively between the NoLLD group and the LLD group, including the subgroup of patients with an LLD of 20 mm or more ($P = 0.584$). However, differences emerged after surgery, with the LLD group, especially the patients with an LLD

Table 2
Mean absolute pre- and postoperative Oxford Hip Scores (OHSs) and change in OHS (ΔOHS) in the two study groups at up to 3 years follow-up

	Total no. of total hip arthroplasties	NoLLD group (LLD of less than 10 mm)			LLD group (LLD of 10 mm or more)			*P*-value[c]
		n	Mean	95% CI	*n*	Mean	95% CI	
Preoperative OHS	987	794	43.4	42.8 to 43.9	193	43.3	42.2 to 44.3	0.885
Mean absolute OHS[a]								
3 months	861	691	24.7	24.1 to 25.2	170	25.2	24.1 to 26.2	0.423
1 year	946	758	19.4	18.9 to 20.0	188	20.8	19.6 to 21.9	0.041
3 years	814	661	19.3	18.7 to 19.9	153	21.1	19.6 to 22.5	0.022
Mean ΔOHS[b]								
3 months	861	691	18.6	17.9 to 19.4	170	18.1	16.7 to 19.5	0.537
1 year	946	758	23.8	23.2 to 24.5	188	22.5	21.2 to 23.9	0.086
3 years	814	661	23.8	23.1 to 24.5	153	22.0	20.5 to 23.5	0.034

LLD, leg length discrepancy; CI, confidence intervals.
[a] Absolute OHS: 12 (best) to 60 (worst).
[b] ΔOHS: 0 (worst) to 48 (best).
[c] *P*-value calculated using analysis of variance.

Table 3
Mean change in Oxford Hip Score (ΔOHS) in the leg length discrepancy (LLD) group, at up to 3 years follow-up, comparing a shorter and longer LLD

	Total no. of total hip arthroplasties	Shorter LLD			Longer LLD			*P*-value[b]
		n	Mean	95% CI	*n*	Mean	95% CI	
Mean ΔOHS[a]								
3 months	170	68	18.6	16.3 to 20.9	102	17.8	16.0 to 19.6	0.568
1 year	188	73	22.1	19.9 to 24.3	115	22.8	21.3 to 24.5	0.591
3 years	153	57	21.4	18.9 to 23.9	96	22.4	20.5 to 24.3	0.498

CI, confidence intervals.
[a] ΔOHS: 0 (worst) to 48 (best).
[b] *P*-value calculated using analysis of variance.

of 20 mm or more, scoring worse for Question 9 compared with the NoLLD group ($P = 0.001$).

Secondary outcome measures

The percentage of patients in each of the three groups needing revision surgery was analysed. In the NoLLD group, six of 794 cases [relative frequency (RF) = 1%] needed revision, and in the LLD group, three of 193 cases were revised (RF = 2%; $P = 0.389$). There was no significant difference in dislocation rate between the groups (NoLLD group: RF = 2%, 16/794 cases; LLD group: RF = 1%, 1/193 cases; $P = 0.220$). The mean length of operating time for the two groups was significantly different ($P = 0.038$), as was the length of hospital stay ($P = 0.006$). The NoLLD group had a longer mean operating time (89.9 minutes) and a shorter length of hospital stay (9.0 days) compared with the LLD group (mean operating time 84.9 minutes, length of hospital stay 10.6 days).

Use of an epidural was associated with a decreased incidence of having an LLD greater than 10 mm ($P = 0.004$). A higher percentage of patients in the NoLLD group (29%, 229/793 cases) received an epidural and had an LLD of less than 10 mm, whereas in the LLD group, the percentage was 19% (36/193 cases). No significant differences were associated with a general ($P = 0.307$) or spinal ($P = 0.225$) anaesthetic and an LLD of 10 mm or more.

Discussion

LLD has been reported in the literature as being a common finding following primary THA, although there is a lack of consensus about what constitutes a clinically significant postoperative inequality [18]. The vast majority of these patients have an LLD of less than 10 mm; in one series, 97% of patients undergoing THA had an LLD of less than 10 mm, with a mean LLD of 1 mm [19]. In another study, Turula *et al.* [14] found that LLD varied from −20 (shortened leg) to +15 mm (lengthened leg) with a mean of 2.8 mm. In a consecutive series of 100 patients, Ranawat and Rodriguez [20] demonstrated that the mean LLD was 3.4 mm (range −10 to 18 mm). In the present series, the relative frequency of patients with an LLD of less than 10 mm was 80%, with an overall mean LLD of 3.5 mm. The incidence of an LLD of 20 mm or more was 6% (55/987 cases). Such a pronounced discrepancy has been described in the literature as being poorly tolerated by patients [21].

This study has demonstrated that having an LLD of 10 mm or more is associated with having a significantly poorer outcome in terms of the clinical benefit of surgery (ΔOHS) compared with patients who either have equal leg lengths or an LLD of less than 10 mm. Whether such a difference in ΔOHS is clinically important is more difficult to assess. Murray *et al.* have described a two-point change in ΔOHS as being the minimum clinical change perceived by patients as meaningful and which may lead to changes in clinical practice [22].

There was no difference in ΔOHS at 3 years when a shorter LLD was compared with a longer LLD. It is surprising to note that those patients in the LLD group who had an LLD of 20 mm or more still gained a considerable benefit from having a THA and had a greater ΔOHS at 3 years compared with patients who had an LLD of 10 to <20 mm. The reason for this is unclear. It may be because such patients had particularly severe pain symptoms from their diseased hip, and therefore the benefit of surgery is especially pronounced in terms of improved OHS outcomes and the reduction of pain.

Patients with an LLD of 20 mm or more had a significantly higher score preoperatively for Question 1 of the OHS questionnaire (indicating worse pain symptoms) compared with the other groups, yet achieved a comparable score to the other groups at 3 years follow-up. This suggests that surgery alleviated their pain to such an extent that even with an LLD of 20 mm or more, the analgesic effect of surgery was such as to offset the symptoms of significant LLD. It should also be remembered that the sample size in this group was small and that this may affect the meaning of statistical tests of significance [23]. A power analysis was performed in this subgroup of patients and the sample size was insufficient to detect a two-point difference in OHS. As such, some caution is advised when interpreting the significance of the results in this select group of patients.

Limping appeared to be more of a problem in patients with an LLD of 10 mm or more. Preoperatively, patients in all three groups had a similar incidence of limping; however, 3 years after surgery, patients with an LLD of 10 mm or more had twice the incidence of limping compared with patients with an LLD of less than 10 mm. Clearly, the presence of an LLD of 10 mm of more is, perhaps not surprisingly, associated with the presence of a limp.

The use of an epidural was associated with a decreased risk of having an LLD of 10 mm or more. It is postulated that the reasoning for this relates to the degree of motor blockade achieved using an epidural compared with the other anaesthetic techniques. LLD is thought to be related to myofascial tension, which may be difficult to assess during surgery, under a general anaesthetic, as the muscles are fully relaxed [6]. An epidural provides a less potent muscle relaxant effect compared with a spinal or general anaesthetic [24], and the patient's muscles are in a more 'physiologically' normal state. In turn, this may lead to greater accuracy in assessing intra-operative leg lengths and hence minimise the risk of developing a substantial LLD [25].

This study did not demonstrate any significant differences in revision or dislocation rates between the groups. In terms of dislocation, this finding is supported by experimental evidence examining the potential dislocating forces around the hip joint. Gait analysis work by Brand and Yack [26], on the effects of an LLD on the forces at the hip joint, concluded that there are no substantial changes in hip forces for most types of LLD seen after THA. The present results contradict those of other studies which have demonstrated an association between LLD and dislocation rates [27,28], which is thought to be due to changes in the myofascial tension affecting the stability of the hip prosthesis [29].

It is important to differentiate between an apparent and a true LLD as the success of various treatment options will be different. An apparent or functional LLD can occur as a result of a fixed spinal deformity (lumbosacral scoliosis), contractures of periarticular hip muscles including tensor fascia lata, gluteus minimus and medius, and the presence of pelvic obliquity [20]. An apparent LLD can be treated with aggressive physiotherapy in the form of stretching exercises, manual massage and soft tissue mobilisation techniques occasionally supplemented with steroid or Botox injections [30]. Most cases of an apparent LLD following THA resolve with time and physiotherapy, although a small subset of patients may require a shoe lift, heel lift or, as a last resort, surgical soft tissue releases or revision arthroplasty [20].

A true LLD is an anatomical deficit and occurs as a result of component malpositioning following THA. Either the acetabular cup is implanted too distally (shifting the centre of the hip joint and causing the leg to migrate distally) or too long a femoral component is used [13]. In such cases, physiotherapy has a much more limited role as no amount of rehabilitation will correct the discrepancy. By and large, the majority of treatments remain non-operative and involve the use of shoe or heel lifts to the shorter leg. Shoe lifts have been used in patients with an LLD of less than 10 mm, and are non-invasive, inexpensive and can be prepared and adjusted by trained physiotherapists [31]. Occasionally, because of persistent pain and impaired function, failure of non-operative therapy or if there is gross instability of the hip replacement, revision surgery is required [13].

There are some potential limitations to this study. Firstly, the measurement of leg length was performed by clinical measurement and not radiological measurements. Such imaging techniques, although considered the gold standard in measuring LLD accurately, are limited by their costs, time consumption and patient exposure to radiation [32], and clinical methods involving the tape measure method of determining LLD have been shown to be valid in the clinical setting [12,25]. Secondly, although this is a large and prospective study by design, it did have some incomplete data and there is always the potential that those patients lost to follow-up may have different characteristics. However, demographic data suggest that such patients had no particular differences and the number was small.

In conclusion, an LLD of more than 10 mm does appear to diminish the benefits of THA significantly in terms of ΔOHS. Whether this difference in OHS is clinically important, from a patient's perspective, remains less clear. Care should therefore be taken to minimise LLD intra-operatively in order to maximise the clinical benefits of THA for the patient. Further studies are needed into the longer-term effects of an LLD following hip arthroplasty.

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References

[1] Williams O, Fitzpatrick R, Hajat S, Reeves BC, Stimpson A, Morris RW, *et al.* Mortality, morbidity, and 1-year outcomes of primary elective total hip arthroplasty. J Arthroplasty 2002;17:165–71.

[2] Williamson JA, Reckling FW. Limb length discrepancy and related problems following total hip joint replacement. Clin Orthop Relat Res 1978:135–8.

[3] Friberg O. Clinical symptoms and biomechanics of lumbar spine and hip joint in leg length inequality. Spine 1983;8:643–51.

[4] Giles LG, Taylor JR. Low-back pain associated with leg length inequality. Spine 1981;6:510–21.

[5] Pritchett JW. Nerve injury and limb lengthening after hip replacement: treatment by shortening. Clin Orthop Relat Res 2004:168–71.

[6] Woo RY, Morrey BF. Dislocations after total hip arthroplasty. J Bone Joint Surg Am 1982;64:1295–306.
[7] Maloney WJ, Keeney JA. Leg length discrepancy after total hip arthroplasty. J Arthroplasty 2004;19(Suppl. 1):108–10.
[8] Austin MS, Hozack WJ, Sharkey PF, Rothman RH. Stability and leg length equality in total hip arthroplasty. J Arthroplasty 2003;18(Suppl. 1):88–90.
[9] Attarian DE, Vail TP. Medicolegal aspects of hip and knee arthroplasty. Clin Orthop Relat Res 2005:72–6.
[10] Konyves A, Bannister GC. The importance of leg length discrepancy after total hip arthroplasty. J Bone Joint Surg Br 2005;87:155–7.
[11] White TO, Dougall TW. Arthroplasty of the hip. Leg length is not important. J Bone Joint Surg Br 2002;84:335–8.
[12] Beattie P, Isaacson K, Riddle DL, Rothstein JM. Validity of derived measurements of leg-length differences obtained by use of a tape measure. Phys Ther 1990;70:150–7.
[13] Parvizi J, Sharkey PF, Bissett GA, Rothman RH, Hozack WJ. Surgical treatment of limb-length discrepancy following total hip arthroplasty. J Bone Joint Surg Am 2003;85-A:2310–7.
[14] Turula KB, Friberg O, Lindholm TS, Tallroth K, Vankka E. Leg length inequality after total hip arthroplasty. Clin Orthop Relat Res 1986:163–8.
[15] Garellick G, Malchau H, Herberts P. Specific or general health outcome measures in the evaluation of total hip replacement. A comparison between the Harris hip score and the Nottingham Health Profile. J Bone Joint Surg Br 1998;80:600–6.
[16] Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. J Bone Joint Surg Br 1996;78:185–90.
[17] Dawson J, Fitzpatrick R, Murray D, Carr A. Comparison of measures to assess outcomes in total hip replacement surgery. Qual Health Care 1996;5:81–8.
[18] Abraham WD, Dimon III JH. Leg length discrepancy in total hip arthroplasty. Orthop Clin North Am 1992;23:201–9.
[19] Woolson ST, Hartford JM, Sawyer A. Results of a method of leg-length equalization for patients undergoing primary total hip replacement. J Arthroplasty 1999;14:159–64.
[20] Ranawat CS, Rodriguez JA. Functional leg-length inequality following total hip arthroplasty. J Arthroplasty 1997;12:359–64.
[21] Gross RH. Leg length discrepancy: how much is too much? Orthopedics 1978;1:307–10.
[22] Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ, *et al.* The use of the Oxford hip and knee scores. J Bone Joint Surg Br 2007;89:1010–4.
[23] Royall RM. The effect of sample size on the meaning of significance tests. Am Statist 1986;40:313–5.
[24] Holmstrom B, Laugaland K, Rawal N, Hallberg S. Combined spinal epidural block versus spinal and epidural block for orthopaedic surgery. Can J Anaesth 1993;40:601–6.
[25] Jasty M, Webster W, Harris W. Management of limb length inequality during total hip replacement. Clin Orthop Relat Res 1996;333:165–71.
[26] Brand RA, Yack HJ. Effects of leg length discrepancies on the forces at the hip joint. Clin Orthop Relat Res 1996;333:172–80.
[27] Callaghan JJ, Heithoff BE, Goetz DD, Sullivan PM, Pedersen DR, Johnston RC. Prevention of dislocation after hip arthroplasty: lessons from long-term followup. Clin Orthop Relat Res 2001;393:157–62.
[28] Coventry MB. Late dislocations in patients with Charnley total hip arthroplasty. J Bone Joint Surg Am 1985;67:832–41.
[29] Padgett DE, Warashina H. The unstable total hip replacement. Clin Orthop Relat Res 2004;420:72–9.
[30] Bhave A, Mont M, Tennis S, Nickey M, Starr R, Etienne G. Functional problems and treatment solutions after total hip and knee joint arthroplasty. J Bone Joint Surg Am 2005;87(Suppl. 2):9–21.
[31] Defrin R, Ben Benyamin S, Aldubi RD, Pick CG. Conservative correction of leg-length discrepancies of 10 mm or less for the relief of chronic low back pain. Arch Phys Med Rehabil 2005;86:2075–80.
[32] Gurney B. Leg length discrepancy. Gait Posture 2002;15:195–206.