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Can patients return to high-impact physical activities after hip resurfacing? A prospective study

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Abstract
Purpose Although the resumption of low-impact sports activities is compatible with total hip arthroplasty (THA), participation in high-impact sports seems problematic, and there is no consensus as to whether it is advisable. The purpose of this article is to evaluate the quality and possibility of resuming high-impact physical activities after hip resurfacing.
Materials The study was performed in an on-going, single-surgeon, prospective series of 215 resurfacing arthroplasties (RSA). Mean follow-up was 44.1 months (range, 39.1–54.5). Clinical evaluation included the Postel-Merle d'Aubigné (PMA) score, the Oxford hip score, the Harris hip score (HHS), Devane score, and UCLA activity score. A specific questionnaire analysing sports activities was administered to each patient to assess the number and level of physical activities performed (both before the operation and at final follow-up).
Results In the series of 202 consecutive patients (215 RSA), 50 patients (55 RSA) engaged regularly in at least one high-impact activity before their operation and the onset of pain, 102 patients practised at least one intermediate-impact activity, and the 50 remaining patients undertook only low-impact activities. Harris hip score increased from 44.8 (range, 23–68) before the operation to 97.8 (range, 85–100) at the last follow-up. Mean time to sports resumption after surgery was 14.6 weeks (range, 7–29). The resumption rate was 98 % for sports of any impact level and 82 % for high-impact activities. No osteolysis or implant loosening was observed at follow-up. No revision was performed.
Conclusion In 2012, no consensus recommendations yet exist for the resumption of sports activities after RSA. Existing recommendations concern only conventional THA. We believe that RSA allows younger and more active patients to resume physical and sports activities without restriction. The rate of return to sports after RSA appears to be excellent and unequalled by conventional hip prostheses. High-impact sports seem to be compatible with hip resurfacing, although no long-term studies have analysed the impact of these activities on wear and/or aseptic loosening.

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Introduction

The resumption of low-impact sports activities is compatible with total hip arthroplasty (THA), but the effects of participation in high-impact sports are not well understood. Indeed, the resumption rate of high-impact activities frequently correlates with the surgeon and/or implant type [43]. Although patients generally report a high degree of satisfaction with THA [13, 26], they feel restricted in terms of sports participation. Sports activities that generate significant impact seem to be problematic, given the risks of dislocation, peri-prosthetic fracture, and aseptic loosening [4, 5, 20].

Since 2012, however, patients increasingly feel that maintaining high-level sports activities constitutes an important part of their quality of life [10, 45]. Furthermore, some authors believe that sports activities are not necessarily deleterious to implants [10, 12].

In this patient category, hip resurfacing arthroplasty (RSA) has been increasing in popularity since the early 2000s because of its potential benefits (biomechanical reconstruction, femoral bone stock preservation, absence of instability, large diameter effect, preservation of proprioception, etc.) [2, 15, 29, 38, 40]. After RSA, the return to low- or intermediate-impact physical activities seems to be faster and of better quality than after THA [27]. However, the resumption and possibility of high-impact physical activities have not been analysed after RSA.

The goal of this study was to evaluate the quality and possibility of resuming high-impact physical activities after RSA, in an on-going, single-surgeon, prospective series.

Materials and methods

Patient series

Between October 2007 and October 2008, 215 RSA (202 patients) were performed by an experienced senior surgeon. Contraindications to the procedure included age over 65 years for men and over 55 years for women, femoral head avascular osteonecrosis with volume exceeding one-third of the femoral head, and osteoporosis confirmed by bone densitometry.

A specific questionnaire analysing sports activities was administered to each patient to assess the number and level of physical activities performed (both before the operation and at final follow-up). These activities were divided into three groups with various impact levels (low, intermediate, or high), as classified by Clifford and Mallon [8]. The protocol was approved by the research ethics and scientific evaluation committees of our institution. In the series of 202 consecutive patients (215 RSA), 50 patients (55 RSA) engaged regularly in at least one high-impact activity before their operation and the onset of pain, 102 patients practised at least one intermediate-impact activity, and the 50 remaining patients undertook only low-impact activities. Our study analysed the 50 patients (55 RSA) who participated in high-impact activities before surgery: 45 were male (50 RSA) and five were female (five RSA). A total of 26 RSA were performed on the patients' right side, and 29 on the left side. Mean age at the time of surgery was 51.5 years (range, 30.8–64.8), and mean body mass index (BMI) was 23.7 kg/m^2 (range, 21.7–33.6). Pre-operative aetiologies are detailed in Table 1.

Surgical technique

The RSA prosthesis used was the Conserve Plus® implant (Wright Medical Technology, Inc., Arlington, TN, USA). All procedures were performed by an experienced surgeon and the same surgical technique was employed each time [16]. All procedures were conducted under general anaesthesia with the patient in the lateral decubitus position and taking an external posterior approach. The external rotators were detached eight millimetres from the femur, while the lower quarter of the quadratus femoris muscle was preserved. Posterior capsulotomy was performed to permit hip dislocation. Femoral instrumentation permitted optimal positioning of the femoral stem axis to optimise the anterior head–neck ratio [16]. Once the femoral head was prepared, all osteophytes were removed from the acetabular cavity to prevent the cam effect. Then, the acetabular cup was impacted and the femoral implant cemented. After verification of good joint congruence and intra-operative testing of stability and the cam effect, the external rotators and gluteus maximus muscles were reattached.

Full weight bearing was immediately permitted and patients stood up the day after the procedure. They started walking again with the help of two crutches. Mean length of hospital stay was 6.1 days (range, four to eight). A physiotherapist monitored functional recovery three times per week for one month. Unrestricted sports activities were permitted by the sixth week after postoperative follow-up.

Table 1 Pre-operative aetiologies of patients performing high-impact sports

Aetiologies	Number of hips, N=55
Primary coxarthrosis	15 (27.3 %)
Femoro-acetabular conflict	20 (36.4 %)
Post-traumatic coxarthrosis	1 (1.8 %)
Dysplasia	3 (5.5 %)
Avascular osteonecrosis	16 (29 %)

Data collection

Patients were seen at follow-up at six weeks, six months, and then annually. Range of motion was measured during the clinical examination, with patients performing the hop test and checked for Trendelenburg's sign. Clinical evaluation included the Postel-Merle d'Aubigné (PMA) score, the Oxford hip score, the Harris hip score (HHS), Devane score, and UCLA activity score.

Patients were asked to report the amount of time they devoted to sports per week (under two hours, two to four hours, four to seven hours or over seven hours), the presence of any specific symptoms while engaged in sports (pain, stiffness, muscle weakness, etc.), and the resulting use of analgesics or anti-inflammatory agents.

Antero-posterior radiographs of the pelvis were taken with the legs positioned in 15° of internal rotation. The radiographs were rejected if the coccyx was not centred on the pubic symphysis and was not located within two to four centimetres proximal to it. This ensured proper positioning of the pelvis in both the frontal and sagittal planes [41].

The selected radiographs were scanned (VXR-12, VIDAR Systems Corporation, Herndon, VA, USA) and analysed with Imagika™ software (View Tech, Jersey City, NJ, USA) for valid and reliable values of hip joint biomechanical parameters [17].

Femoral neck-shaft angle was measured on postoperative radiographs, as was the angle between the resurfacing femoral prosthesis axis and the anatomical axis of the femoral shaft (femoral component axis-shaft angle). Pre-operative

Table 2 Distribution of sports performed before and after surgery

Sport	Pre-operative	Postoperative	Difference
Jogging	40	38	−5 %
Soccer	9	11	+22 %
Tennis	7	4	−43 %
Basketball	3	2	−33 %
Martial arts	2	2	0 %
Squash	5	2	−60 %
Handball	1	2	+50 %
Surfing	1	2	+50 %
High-impact dance	4	4	−25 %
Rugby	1	1	0 %

femoral shaft/neck angle (CC'D) angle, cup inclination and heterotopic ossification were also assessed.

Statistical analysis

Statistical analysis was performed with SPSS® 15.0 software (SPSS, Inc., Chicago, IL, USA) software. The Wilcoxon Z-test was used for paired samples and ordinal variables, Cochran's Q test for paired samples and binary variables, and Student's *t*-test for continuous variables and paired samples. The significance threshold was $p<0.05$ for all statistical analyses.

Results

Mean follow-up time was 44.1 months (range, 39.1–54.5). No revision arthroplasty was performed, and no dislocation or infection complications occurred.

Of the 50 patients participating in high-impact sports before the operation, 48 (96 %) reported that they were satisfied or very satisfied with the procedure, and only one patient was dissatisfied. All patients had to modify or stop their high-impact sports activities pre-operatively because of pain and discomfort.

At clinical review, only one patient had stopped all kinds of sports activities. Mean time to sports resumption after surgery was 14.6 weeks (range, seven–29). Eight patients no longer participated in high-impact sports at the last follow-up, yielding an 82 % rate of return to high-impact activities.

Pre-operatively, the mean number of sports that patients participated in was four (range, one to seven), and the weekly time spent participating in sports was 3.2 hours (range, 1–8) (Table 2). At the last follow-up, the mean number of activities performed was 3.6 (range, 1–8), which was not significantly different from pre-operative values ($p=0.08$). Similarly, there was no significant difference between time spent participating in sports pre-operatively and at last follow-up ($p=0.07$), with a mean weekly duration of 2.9 hours (range, 2–9). It must be noted that, in this series, physical activity participation (whatever the impact level) was 98 %.

The series was sub-divided into patients older than and younger than 50 years (28 and 27 patients, respectively). Patients older than 50 years significantly decreased their number of activities (Table 3). Other data (time spent participating in sports, number of activities) showed no significant differences between the pre-operative period and at final follow-up.

Five patients (10 %) reported feeling apprehensive while engaged in sports after the procedure, two patients (4 %) felt they had not regained their earlier flexibility, and two others (4 %) complained of muscular weakness. No patients took any analgesics.

Improvement of joint amplitude was significant for all sectors of mobility (Table 4). Mean pre-operative flexion was 91.2° (range, 75–130), which increased to 118.2° (range, 95–130) at follow-up ($p<0.001$), while mean extension increased from 2.4° (range, –10 to 10) to 11.4° (range, 0–30) ($p<0.001$). The nine cases of pre-operative hip flexion deformity (>10°) had completely resolved on follow-up. The mean pre-operative hop test score of 2.6 (range, 0–10) increased to 8.8 (range, 5–10) ($p<0.001$) at follow-up.

Mean PMA score was 11.1 (range, 7–15) pre-operatively and 17.8 (range, 16–18) at follow-up ($p<0.001$). HHS improved significantly ($p<0.001$), from 44.8 (range, 23–68) pre-operatively to 97.8 (range, 85–100) at follow-up. Mean Devane score increased significantly ($p<0.001$), from 3.6 (range, 2–5) pre-operatively to 4.6 (range, 3–5) post-operatively. UCLA activity score improved significantly ($p<0.001$), from 6.6 (range, 4–10) pre-operatively to 9.1 (range, 8–10) at follow-up. Significant differences were also noted in PMA, HHS and Devane scores of subgroups older than and younger than 50 years (Table 5).

Radiological analysis revealed mean pre-operative CCD angle of 134.2° (range, 125–144). At follow-up, the mean

Table 3 Average amount of time devoted weekly to sports and number of sports practiced by the entire cohort and by subgroups more or less than 50 years of age

Variable	All patients			Patients younger than 50 years			Patients older than 50 years		
	Before	After	*p*	Before	After	*p*	Before	After	*p*
Time devoted to sports	3.2	2.9	0.471	3.18	3.11	0.602	2.74	2.70	0.769
Number of sports	4.0	3.6	0.423	3.89	4.04	0.620	4.19	3.26	0.003

Table 4 Joint amplitude in pre-operative period and at last follow-up

Measure	Pre-operative	Postoperative	*p*
Total	139.3°(90/220)	221.6° (160/265)	<0.001
Flexion	91.2° (75/130)	118.2° (95/130)	<0.001
Extension	2.4° (−15/10)	14° (0/30)	<0.001
Abduction	29.9° (15/40)	33.6° (15/45)	<0.001
Adduction	22.1° (0/40)	34.5° (10/45)	<0.001
External rotation	16.9° (0/30)	29.1° (10/40)	<0.001
Internal rotation	1.6° (−20/30)	26.5° (10/40)	<0.001

central stem axis was 141.3° (range, 130–154) and mean acetabular inclination was 43.9° (range, 35–50). There were four cases of heterotopic ossification (7.3 %), three of Brooker class 1, and one of Brooker class 2. No osteolysis or implant loosening was found at follow-up.

Discussion

Functional ability after hip arthroplasty has become increasingly important since 2012 [38]. Current implants and surgical techniques must respond to growing demands from patients who want to resume their normal sports activities. Among active and athletic patients, hard-hard bearing (metal-on-metal or ceramic-on-ceramic) can help to reduce the risk of wear and loosening [14, 21], while polyethylene wears more quickly, reducing implant survival rate [33]. In addition, the recent development of large-diameter prosthetic heads (equivalent to femoral head diameter) has significantly curtailed dislocation rates and allowed unrestricted movements necessary for participation in sports activities [9, 12]. However, resumption of high-impact sports after hip arthroplasty implantation has been seldom analysed in the literature, despite growing demand [28, 43].

Follow-up in our study was relatively short, but the resumption of sports activities generally occurs during the first six–12 months after surgery [23], with no real subsequent changes. Although the number of patients included in this study (50 out of 202 cases) may appear small, it represents the proportion of people engaged in high-impact sports in the general population.

Recommendations for resuming sports after THA have evolved along with manufacturing techniques for implants, which now have lower wear rates than ever before. In 2007, Klein et al. [23] published a survey of 549 surgeons belonging to the Hip Society and the American Association of Hip and Knee Surgeons, to establish consensus recommendations. Impact level was determined according to the same classification as in our study [8]. All high-impact activities, but also tennis and snowboarding, were contraindicated after THA. More than 60 % of surgeons gave their consent for patients to resume their activities between three and six months after the procedure, and only ten percent authorised their patients to engage in a sport within the first three months. We, on the other hand, believe that the return to sports should not be limited by time. Indeed, in our experience, patients should return to sports as soon as they wish to do so. Time to recovery varies, but usually corresponds to the acquisition of good monopodal postural stability and locking of the hip, which occurs around the second month after surgery [40].

The patient and surgeon decide when the patient can resume sports activities [26]. In our series, patients were able to return to their activities as soon as they wished (after a minimum of six weeks). We ascertained that mean time to sports resumption was about three months (14.6 weeks), a finding supported by data from other series [3, 7, 28, 32, 33]. In the series reported by Naal et al., 50 % of patients resumed their sports activities within the first three months, and 90 % in less than six months [32]. The resumption timeframe in the series studied by Banerjee et al. [3] was less than three months for 90 % of patients. As noted in other recent series [18, 26], we have not determined whether age has a negative influence on number of activities and time spent participating in them. It seems, however, that with age, patients stabilise the amount of time devoted to physical activities by selecting and reducing the number of sports they participate in. The number of activities resumed is high in all RSA series, with a mean number of 4.6 sports reported by Naal et al. [32] and 3.2 by Banerjee et al. [3].

The 98 % rate of return to sports of any impact level observed in our series is consistent with data in the literature, which rates between 87 % and 98 % being recorded [3, 28, 33]. This rate is significantly lower in conventional hip arthroplasty series. Indeed, older series reported 52–56 % rates of return to sports after THA [11, 20, 36]. More recent THA series showed high rates (up to 83 %, according to

Table 5 PMA, HHS and Devane functional scores of the entire cohort and of subgroups more or less than 50 years of age

Functional measure	All patients			Patients younger than 50 years			Patients older than 50 years		
	Before	After	*p*	Before	After	*p*	Before	After	*p*
PMA	11.1	17.8	*p*<0.001	11.28	17.89	*p*<0.001	10.85	17.67	*p*<0.001
HHS	44.8	97.8	*p*<0.001	45.2	99.0	*p*<0.001	44.29	96.59	*p*<0.001
Devane	3.6	4.6	*p*<0.001	3.6	4.7	*p*<0.005	3.51	4.55	*p*<0.001

Chatterji et al. [7]) but always lower than in hip resurfacing series [35]. The 82 % rate of high-impact activity resumption appears to be very satisfactory, although no comparison can be found in the literature.

Very few studies have compared the resumption of sports activities after RSA and THA. Lavigne et al. [27] conducted a prospective randomised study of 194 patients, comparing RSA to THA. At follow-up, the activity score was significantly higher in the RSA group. Similarly, there was a significant difference between the mean UCLA score of 7.1 in the RSA group and 6.3 in the THA group. Wylde et al. [44] obtained better results in patients who had undergone resurfacing compared to THA. However, the absence of randomisation resulted in a population difference, with the RSA group being clearly younger. Indeed, the rate of sports resumption was 49.6 % in the RSA group, whose mean age was 52.2 years, and 25.7 % in the conventional arthroplasty group, whose mean age was 68.2 years. Therefore, age seems to have been a determining factor in patient selection and results of the series. The corollary is that RSA is more appropriate for younger patients (under 65 years old), who are more active and participate in several sports.

In our series, range of motion at follow-up was very satisfactory and contributed to the resumption of daily and physical activities in good conditions. The mean flexion observed in our study was close to the threshold value of 120° required for patient satisfaction and the resumption of daily and sports activities [22, 34]. There is also a correlation between flexion and sports performance, clinical function scores, climbing stairs, and putting on shoes [6, 26]. Since significant pre-operative hip mobility was a risk factor for dislocation [25], a large-diameter implant was proposed for patients whose combined flexion, adduction, and internal rotation exceeded 115°. With THA, the chance of having another instability episode remained high in young and active patients. At ten years, the cumulative risk of dislocation after THA varied from 3 % to 12 %, depending on femoral head diameter, [4] while it was quite low (almost zero) after RSA [2, 24].

In our series, participation in high-impact sports did not increase short-term complications. Similarly, Amstutz et al. [2] reported that among active RSA patients under 50 years of age, the medium-term survival rate for implants was identical to that of the older group. Also, no aseptic loosening was seen at five-year follow-up, and the femoral revision rate for aseptic loosening and neck fracture was 2.8 %. Treacy et al. [42] reported a survival rate of 98.8 % over ten years among patients with RSA whose mean age at implantation was 52 years. In a series of 58 tennis players with conventional replacement (75 THAs), Mont et al. [30] encountered a revision rate of 4 % within eight years.

Resumption of sports is strongly correlated with muscular function, which requires perfect biomechanical reconstruction and compliance with the abductor muscles. Automatic biomechanical hip reconstruction after RSA allowed us to observe a walking pattern identical to that of a natural, non-osteoarthritic hip [39]. Mont et al. [31] noted that this walking pattern was severely compromised in THA patients, who expend more energy during cyclical movements and whose maximum walking and running speeds are substantially lower than those of RSA patients. The preservation of femoral bone stock, femoral neck mechanoreceptors, femoral offset, and femoral lever arm permit better reconstruction of the anatomy after RSA than after THA [5, 29].

Conclusion

Sports recommendations after THA [19] have evolved between 2001 and 2007, allowing more physical activities. This evolution is due to better understanding of the causes of wear and the development of more effective bearings [37]. In 2012, no consensus recommendations yet exist for the resumption of sports activities after RSA. Existing recommendations concern only conventional THA. We believe that RSA allows younger and more active patients to resume physical and sports activities without restriction. The absence of medium-term wear, the good bone quality of RSA patients, and implant stability engender very satisfactory functional recovery, without loosening over the medium term [1].

We found that the rates of return were 98 % for sports of any impact level and 82 % for high-impact activities. These rates are excellent and are unequalled by THA. High-impact sports seem to be compatible with RSA, although no long-term studies have analysed the impact of these activities on wear and/or aseptic loosening [38].

References

1. Amstutz HC, Ball ST, Le Duff MJ et al (2007) Resurfacing THA for patients younger than 50 year: results of 2- to 9-year followup. Clin Orthop Relat Res 460:159–164
2. Amstutz HC, Le Duff MJ, Johnson AJ (2012) Socket position determines hip resurfacing 10-year survivorship. Clin Orthop Relat 470:3127–3133. doi:10.1007/s11999-012-2347-y
3. Banerjee M, Bouillon B, Banerjee C (2009) Sports activity after total hip resurfacing. Am J Sports Med 38:1229–1236
4. Berry DJ, von Knoch M, Schleck CD et al (2005) Effect of femoral head diameter and operative approach on risk of dislocation after primary total hip arthroplasty. J Bone Joint Surg Am 87:2456–2463
5. Bradbury N, Borton B, Spoo G et al (1998) Participation in sports after total knee replacement. Am J Sports Med 26:530–535
6. Bryant MJ, Kernohan WG, Nixon JR et al (1993) A statistical analysis of hip scores. J Bone Joint Surg Br 75:705–709
7. Chatterji U, Ashworth MJ, Lewis PL et al (2004) Effect of total hip arthroplasty on recreational and sporting activity. ANZ J Surg 74:446–449

8. Clifford PE, Mallon WJ (2005) Sports after total joint replacement. Clin Sports Med 24:175–186
9. Courpied JP, Caton JH (2011) Total hip arthroplasty state of the art for the 21st century. Int Orthop 35:149–150
10. Dorey FJ, Amstutz HC (2002) The need to account for patient activity when evaluating the results of total hip arthroplasty with survivorship analysis. J Bone Joint Surg Am 84:709–710
11. Dubs L, Gschwend N, Munzinger U (1983) Sport after total hip arthroplasty. Arch Orthop Trauma Surg 101:161–169
12. Fouilleron N, Wavreille G, Endjah N, Girard J (2012) Running activity after hip resurfacing arthroplasty: a prospective study. Am J Sports Med 40:889–894
13. Garellick G, Malchau H, Herberts P et al (1998) Life expectancy and cost utility after total hip replacement. Clin Orthop Relat Res 346:141–151
14. Girard J, Bocquet D, Autissier G et al (2011) Metal-on-metal hip arthroplasty in patients 30 years of age or younger. J Bone Joint Surg Am 92:2419–2426
15. Girard J, Lavigne M, Vendittoli PA et al (2006) Biomechanical reconstruction of the hip joint: a randomized study comparing total hip resurfacing and total hip arthroplasty. J Bone Joint Surg Br 86:721–726
16. Girard J, Krantz N, Bocquet D et al (2012) Femoral head to neck offset after hip resurfacing is critical for range of motion. Clin Biomech 27:165–169
17. Girard J, Touraine D, Soenen M et al (2005) Measurement of head penetration on digitalized radiographs: reproducibility and accuracy. Rev Chir Orthop Reparatrice Appar Mot 91:137–142
18. Gschwend N, Frei T, Morscher E et al (2000) Alpine and cross-country skiing after total hip replacement: 2 cohorts of 50 patients each, one active, the other inactive in skiing, followed for 5–10 years. Acta Orthopaedica 71:243–249
19. Healy WL, Iorio R, Lemos MJ (2001) Athletic activity after joint replacement. Am J Sports Med 29:377–388
20. Huch K, Muller KA, Sturmer T et al (2005) Sports activities 5 years after total knee or hip arthroplasty: the Ulm osteoarthritis study. Ann Rheum Dis 64:1715–1720
21. Jeffers JR, Walter WL (2012) Ceramic-on-ceramic bearings in hip arthroplasty: state of the art and the future. J Bone Joint Surg Br 94:735–745
22. Johnston RC, Smidt GL (1970) Hip motion measurements for selected activities of daily living. Clin Orthop Relat Res 72:205–215
23. Klein GR, Levine BR, Hozack WJ et al (2007) Return to athletic activity after total hip arthroplasty. Consensus guidelines based on a survey of the Hip Society and American Association of Hip and Knee Surgeons. J Arthroplasty 22:171–175
24. Krantz N, Miletic B, Migaud H et al (2012) Hip resurfacing in patients under 30 years old: an attractive option for young and active patients. Int Orthop 236(9):1789–1794
25. Krenzel BA, Berend ME, Malinzak RA et al (2010) High preoperative range of motion is a significant risk factor for dislocation in primary total hip arthroplasty. J Arthroplasty 25:31–35
26. Laupacis A, Bourne R, Rorabeck C et al (2002) Comparison of total hip arthroplasty performed with and without cement: a randomized trial. J Bone Joint Surg Am 84:1823–1828
27. Lavigne M, Masse V, Girard J et al (2008) Return to sport after hip resurfacing or total hip arthroplasty: a randomized study. Rev Chir Orthop Reparatrice Appar Mot 94:361–367
28. Le Duff MJ, Amstutz HC (2012) The relationship of sporting activity and implant survivorship after hip resurfacing. J Bone Joint Surg Am 94:911–918
29. McMinn DJW, Daniel J, Ziaee H, Pradhan C (2011) Indications and results of hip resurfacing. Int Orthop 35:231–237
30. Mont MA, LaPorte DM, Mullick T et al (1999) Tennis after total hip arthroplasty. Am J Sports Med 27:60–64
31. Mont MA, Seyler TM, Ragland PS et al (2007) Gait analysis of patients with resurfacing hip arthroplasty compared with hip osteoarthritis and standard total hip arthroplasty. J Arthroplasty 22:100–108
32. Naal FD, Maffiuletti NA, Munzinger U et al (2007) Sports after hip resurfacing arthroplasty. Am J Sports Med 35:705–711
33. Narvani AA, Tsiridis E, Nwaboku HC et al (2006) Sporting activity following Birmingham hip resurfacing. Int J Sports Med 27:505–507
34. Odding E, Valkenburg HA, Algra D et al (1996) The association of abnormalities on physical examination of the hip and knee with locomotor disability in the Rotterdam study. Br J Rheumatol 35:884–890
35. Ollivier M, Frey S, Parratte S et al (2012) Does impact sport activity influence total hip arthroplasty durability? Clin Orthop Relat Res 470:3060–3066. doi:10.1007/s11999-012-2362-z
36. Ritter MA, Meding JB (1987) Total hip arthroplasty. Can the patient play sports again? Orthopedics 10:1447–1452
37. Schmalzried TP (2005) Metal-on-metal resurfacing arthroplasty: no way under the sun!–in opposition. J Arthroplasty 20(4 Suppl 2):70–71
38. Schuh R, Neumann D, Rauf R et al (2012) Revision rate of Birmingham hip resurfacing arthroplasty: comparison of published literature and arthroplasty register data. Int Orthop 36:1349–1354
39. Shii Y, Tojo T, Terajima K et al (1999) Intracapsular components do not change hip proprioception. J Bone Joint Surg Br 81:345–348
40. Szymanski C, Thouvarecq R, Dujardin F et al (2012) Functional performance after hip resurfacing or total hip replacement: a comparative assessment with non-operated subjects. Orthop Traumatol Surg Res 98(1):1–7
41. Tannast M, Zheng G, Anderegg C et al (2005) Tilt and rotation correction of acetabular version on pelvic radiographs. Clin Orthop Relat Res 438:182–190
42. Treacy RB, McBryde CW, Shears E et al (2011) Birmingham hip resurfacing: a minimum follow-up of 10 years. J Bone Joint Surg Br 93:27–33
43. Williams DH, Greidanus NV, Masri BA et al (2012) Predictors of participation in sports after hip and knee arthroplasty. Clin Orthop Relat Res 470:555–561
44. Wylde V, Blom A, Dieppe P et al (2008) Return to sport after joint replacement. J Bone Joint Surg Br 90:920–923
45. Yun AG (2006) Sports after total hip replacement. Clin Sports Med 25:359–364