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ORIGINAL ARTICLE

Functional performance after hip resurfacing or total hip replacement: A comparative assessment with non-operated subjects

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KEYWORDS
Hip resurfacing;
Proprioception;
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Hip

Summary
Introduction: Several studies reported better clinical results with total hip resurfacing than with conventional total hip replacement, including in young patients, but without comparative stabilometry assessment.
Hypothesis: Resurfacing arthroplasty provides better functional performance than conventional total hip replacement.
Objectives: To test the above hypothesis in a stabilometry study comparing balance and functional performance in patients with total hip resurfacing or conventional total hip replacement and healthy controls.
Materials and methods: Results were analyzed on three cohorts of 20 patients: healthy control subjects, with unilateral total hip replacement or unilateral total hip resurfacing. The 40 operated patients were comparable in gender, age, weight (body-mass index), date of operation and clinical results. The 20 control subjects were younger and served as reference. Balance analysis employed a force platform commonly used in stabilometry, standardizing both leg or single leg stance balance analysis. The software interpreted individual balance by measuring plantar pressure center variation during the analysis so as to contour an individual both leg or single leg area of balance (statokinesigram, in mm^2).

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Results: Balance analysis on both leg found comparable results in the control and resurfacing groups. The weight-bearing statokinesigraphic both leg balance area was greater in the hip replacement than in either of the other two groups ($p < 0.05$), and five times greater than in the resurfacing group ($p < 0.05$). The single leg weight-bearing balance results were significantly better in the resurfacing group, with a statokinesigraphic balance area half that of the hip replacement group, whether on the operated or the non-operated side ($p < 0.001$).
Discussion and conclusion: The present functional performance results confirm the advantage of resurfacing over conventional hip replacement, and help explain the excellent radioclinical results reported for total hip resurfacing.
Level of evidence: III, comparative case-control study.

Introduction

Osteoarthritis of the hip or knee is mainly frequent in the elderly but also affects young active subjects [1,2]. The most common symptom is mechanical pain, but loss of muscle force, balance and motion have also been reported [3,4]. Recent studies further showed suboptimal motor patterns and lower-limb proprioception in knee osteoarthritis [5—9].

Neurophysiological studies showed motor patterns to depend on various sense receptors, providing efficient muscle response under adaptive central nervous system control [10]. Any joint pathology such as osteoarthritis thus disturbs the motor pattern. The main joints concerned in motor pattern are the ankle (talocrural) and hip (femoroacetabular) joints [11,12]. The joint position underlying proprioception and balance is based on input from various mechanoreceptors in the joint capsule and periarticular tendons and also from deep cutaneous receptors [13—15]. Certain studies following first-generation total hip replacement reported insignificant loss of proprioceptive sensitivity in the operated hip [16,17]; i.e., hip position did not depend on the bone section or type of implant used [18]. Certain authors suggested that joint and bone receptors play a smaller role than the periarticular tendon receptors, which are conserved [18]. These older studies are being put in doubt by more recent findings according to which implant choice is not without importance, resurfacing restoring a motor pattern closer to that of the native hip than does conventional total hip replacement [19—21].

The present study compared mono- and bipedal balance, and thus motor pattern, in three cohorts: with healthy hip, total hip replacement and total hip resurfacing.

Patients and methods

Cohorts and matching

Three cohorts of 20 patients were formed. The control cohort (considered ''ideal'') comprised 20 patients free of hip or spinal pathology, with strictly normal neurologic and ENT examination (Table 1). There were 10 males and 10 females; mean age, 31.2 ± 7 years (range, 24—53 yrs); mean weight, 72.2 ± 13.1 kg (range, 53—94 kg); mean height, 176 ± 10.2 cm (range, 161—190 cm); mean body-mass index (BMI), 23.4 ± 2.9 kg/m^2 (range, 18.5—31.1 kg/m^2).

The second cohort of 20 patients comprised 12 males and eight females who had undergone hip resurfacing implantation (DynaMoM, Tornier™) performed by a single senior surgeon (JG) during the year 2008. Mean follow-up was 15.5 ± 2.3 months (range, 12—20 months). The procedure and posterolateral approach were strictly identical in all cases. All had perfectly normal hip examination and excellent Postel-Merle-d'Aubigné (PMA) scores [22] (≥ 17 points). Mean age was 54.1 ± 7.6 years (33—64 yrs); mean weight, 79.5 ± 4.24 kg (53—115 kg); mean height, 172 ± 8.6 cm (156—185 cm); and mean BMI, 26.9 ± 4.77 kg/m^2 (21.8—42.8 kg/m^2).

The third cohort (10 male, 10 female) had been operated on in Lille University Hospital Center (France) by a single senior surgeon (JG) during the year 2008, with a mean follow-up of 15.3 ± 2.6 months (range, 12—21 months). Twelve had osteonecrosis and eight osteoarthritis of the hip; all received the same hip replacement: a Zweillmuller™ (Zimmer™) cementless stem with Allofit™ (Zimmer™) cementless impacted cup; the friction couple was metal—metal, with 28 mm femoral head diameter whatever the patient's bone fragment sizes: i.e., a ''small diameter'' friction couple. PMA scores were excellent (≥ 17). Mean age was 61.2 ± 11.6 years (32—73 yrs); mean weight, 71.6 ± 12.3 kg (53—89 kg); mean height, 171 ± 7.8 cm (158—189 cm); and mean BMI, 24.5 ± 3 kg/m^2 (18—28.8 kg/m^2).

The control subjects were significantly younger, serving as reference ($p < 0.05$). Preoperative data in the other two cohorts were comparable for age, gender and preoperative PMA score ($p < 0.05$). Thus, preoperative clinical scores were comparable: PMA, 10.8 in resurfacing and 11 in replacement ($p = 0.6$); Harris Hip Score (HHS) [23], 45.8 in resurfacing and 45.1 in replacement ($p = 0.8$), indicating comparable preoperative clinical hip status. The preoperative subjective Oxford score [24] was also the same in both groups: 41.5 in resurfacing and 39.5 in replacement ($p = 0.07$). BMI was significantly greater in the resurfacing group ($p < 0.05$).

Study design

The patients all underwent specific follow-up for posture platform measurement. The experimental design was approved by the North-West IV ethics committee (reference No. 2010-A00384-35).

Table 1 Demographic data for the three groups.

	Controls	Resurfacing	Total hip replacement
Sex	10 M, 10 F	12 M, 8 F	10 M, 10 F
Age	31.2 ± 7 yrs (24–53)	54.1 ± 7.6 yrs (33–64)	61.2 ± 11.6 yrs (32–73)
Weight	72.2 ± 13.1 kg (53–94)	79.5 ± 4.24 kg (53–115)	71.6 ± 12.3 kg (53–89)
Height	176 ± 10.2 cm (161–190)	172 ± 8.6 cm (156–185)	171 ± 7.8 cm (158–189)
BMI	23.4 ± 2.9 kg/m^2 (18.5–31.1)	26.9 ± 4.77 kg/m^2 (21.8–42.8)	24.5 ± 3 kg/m^2 (18–28.8)

BMI: body-mass index.

Static stabilometric undisturbed balance was measured on a platform (QFP Système, Medicapteurs, Nice, France; CE certified (Dekra) under EU directive 93/42 appendix VI, normalized under standard 85 of the French Posturology Association). Its size was 46 × 46 cm and weight 19 kg, measuring displacement to one-tenth of a millimeter. Sampling frequency ranged from 5 to 50 Hz, with 16-bit analog-to-digital conversion and 12-bit (4095 point) resolution. It has high sensitivity (0.16 N resolution with ± 0.16 N quantification error). Data were saved to a computer via the WinPosture 1.27™ software package.

The foot pressure center was considered as the result of the forces of reaction to the forces exerted by the patient's feet on the platform. The subject stood in mono- or bipedal weight-bearing on the platform, which recorded the ground projection of the pressure centers from moment to moment. Measurement time was 25.6 s, with 50 Hz reception (i.e., 50 pressure center position data points per second), recording more than 1000 parameters per measurement. At a given moment T, there was no information to analyze: to study system dynamics required observation over a certain time period to assess the non-linear dynamics of the motor pattern [25]. The pressure center was taken as equivalent to the projection of the center of gravity in normal upright stance. During measurement, the subject was standing (at ease, arm along the body and feet in 30° external rotation in line with AFP standard 85 (Fig. 1)).

The subject was to focus on a point 3.5 m in front of him or her, and remain standing for 25.6 s, followed by 25.6 s focusing on the point in monopedal weight-bearing on the operated side and then on the contralateral (healthy) side for 25.6 s; the contralateral healthy side served as reference for all measurements. In the healthy control group, the same three tests were performed, with bipedal and left and right monopedal weight-bearing. An observer stood at either side of the subject to guard against any fall. Total test duration was about 20 min.

Test feasibility (possible/impossible) was noted. Certain operated patients could not maintain monopedal stance for the whole test time, and returned to bipedal stance (posture correction). Certain leaned on the observers standing at either side. To homogenize analysis and reduce bias, patients failing to complete the test unassisted were eliminated from analysis.

The data from each test were represented as an area under the curve (statokinesigram, in mm^2), corresponding to the area of displacement of the center of pressure, assimilated to the center of gravity, of the feet in the plane of the platform. It thus analyzed variation in individual center of gravity at plantar level (in mono- or bipedal weight-bearing), expressing the subject's adaptation to a loss of balance on a sagittal or transverse axis. Analysis therefore focused on the precision with which the postural system situated the subject in his or her environment: the dispersion of the successive positions of the projection of the center of gravity on the polygonal plane of support. The larger the area under the curve, the greater the variation in balance.

The area covered by the center of gravity expressed the precision of postural control, corresponding not to the real statokinesigraphic area but to the ellipse of the 95% confidence intervals: the 5% outliers in the statokinesigram, resulting from iterative postural adjustment (''aberrant points'') and not from a pathological problem, were automatically eliminated [26]. The set of points which was conserved traced an ellipse passing through a maximum of remaining points. The normal area of a statokinesigram in bipedal weight-bearing with the subject's eyes open is a ''bunch'' of some 100 mm^2 [27] (Fig. 2).

Statistics

Statistical analysis by group used the Kruskal-Wallis test and, where significant, post hoc comparison with Bonferroni correction. Data for the resurfacing and replacement groups were compared by Mann-Whitney U test (for matching) and Chi^2 and Fischer tests for non-parametric data. The significance threshold was set at $p < 0.05$.

Results

Stabilometric test feasibility

All subjects in the control and resurfacing groups completed all three series of measurements without particular difficulty or loss of balance requiring assistance or return to bipedal stance. All total hip replacement patients successfully performed bipedal weight-bearing, but some were unable to achieve monopedal stance without significant loss of balance: only five maintained monopedal weight-bearing on the operated side without assistance or return to bipedal stance, while 11 returned to bipedal stance at least once, including two more than twice; six patients in all required lateral assistance on the test.

Area under the curve (statokinesigram, in mm^2)

Fig. 3 shows the areas under the curve for the three groups. In all groups, transition from bi- to monopedal

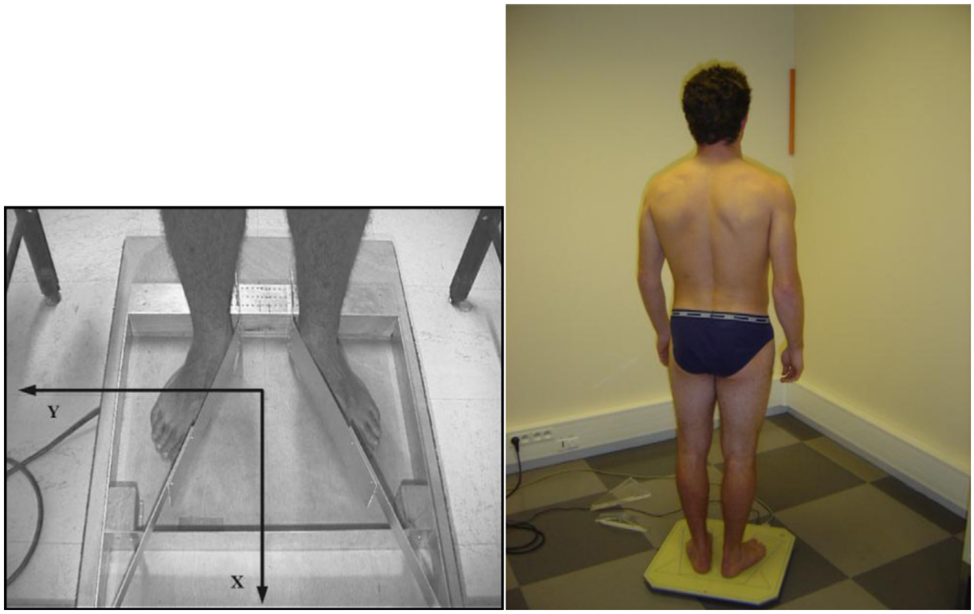


Figure 1 Bipedal stance with feet in 30° external rotation.

weight-bearing (left or right, healthy or operated) was accompanied by significant increase in the area under the curve ($p < 0.00001$).

Thus, in the control group, the area under the curve increased from 470 mm^2 in bipedal stance to 1298 mm^2 ($p < 0.001$) and 1425 mm^2 ($p < 0.001$) in right and left monopedal stance respectively; the difference between left and right monopedal stance, on the other hand, was non-significant ($p = 0.2$), confirming the healthy status of both hips. There was no significant correlation between dominant side and area under the curve in monopedal stance ($p = 0.1$).

In the resurfacing group, the area under the curve increased from 375 mm^2 in bipedal stance to 2447 mm^2 ($p < 0.001$) and 2114 mm^2 ($p < 0.001$) in right and left monopedal stance respectively; the difference between left and right monopedal stance was again non-significant ($p = 0.3$), confirming the functional equivalence of operated and healthy hips. In the replacement group, the area under the curve increased from 1840 mm^2 in bipedal stance to 4741 mm^2 ($p < 0.001$) and 4853 mm^2 ($p < 0.001$) in right and left monopedal stance respectively; the difference between left and right monopedal stance was again non-significant ($p = 0.3$), confirming the functional equivalence of operated and healthy hips.

There was no significant difference in area under the curve under bipedal weight-bearing between the control and resurfacing groups ($p = 0.8$). In contrast, the area under the curve under bipedal weight-bearing was significantly greater in the total hip replacement group ($p < 0.01$) compared to the control and resurfacing groups ($p < 0.01$), and five times

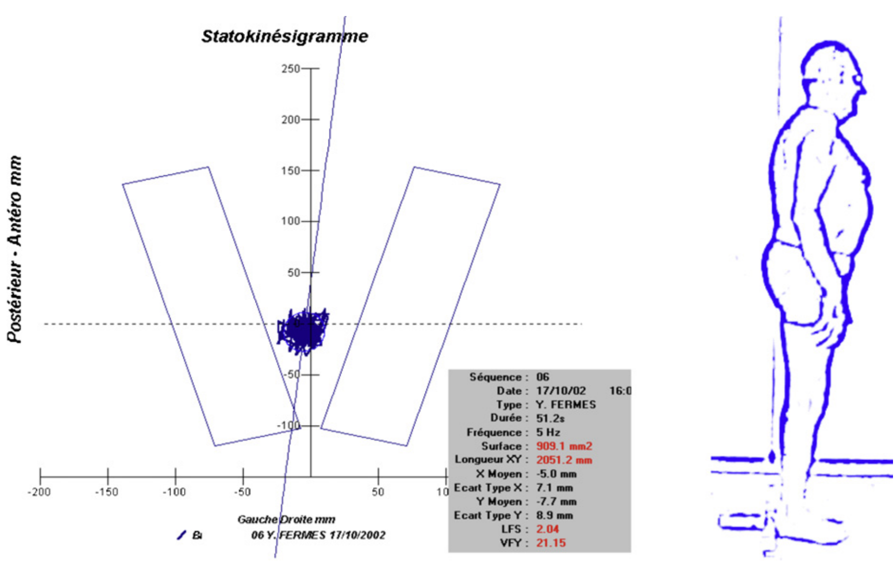


Figure 2 Statokinesigram for control subject in bipedal stance.

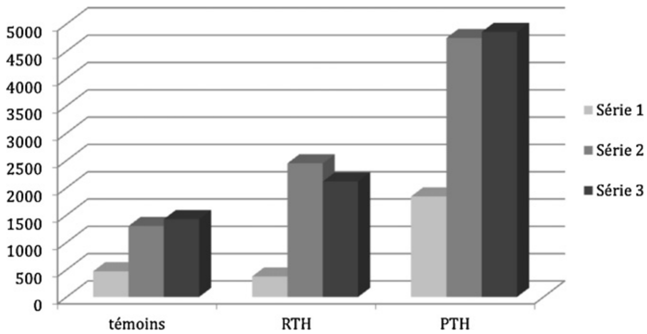


Figure 3 Area under the curve in the three groups (light gray: bipedal stance (series 1); medium gray: operated or right side monopedal stance (series 2); dark gray: healthy or left side monopedal stance (series 3)).

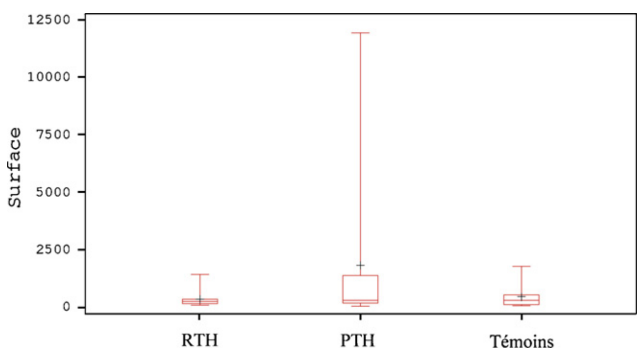


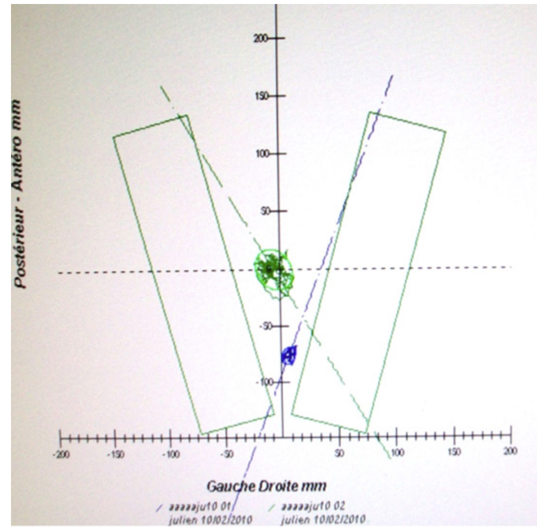
Figure 4 Bipedal stance in the three groups (resurfacing, total hip replacement, control) on *y*-axis and area (mm^2) on *x*-axis.

greater in the replacement than in the resurfacing group ($p < 0.01$) (Fig. 4).

Under monopedal weight-bearing on the right or operated side, the total hip replacement group showed significantly higher values than controls ($p = 0.005$), unlike the resurfacing group, where a trend could, however, be observed ($p = 0.06$). There was no significant difference between the resurfacing and replacement groups for this parameter ($p = 0.29$). Likewise, under monopedal weight-bearing on the left or operated side, the total hip replacement group showed significantly higher values than controls ($p = 0.0001$), while there was no significant difference between the resurfacing and control groups for this parameter, although a trend could be observed ($p = 0.063$). There was no significant difference between the resurfacing and replacement groups for this parameter ($p = 0.11$). There was a significant difference in area under the curve under monopedal weight-bearing (operated and healthy sides) between the resurfacing and replacement groups ($p < 0.005$), with two-fold greater area in the latter, whether for the operated (2447 mm^2 vs. 4741 mm^2 ($p = 0.001$)) or the healthy side (1914 mm^2 vs. 4853 mm^2 ($p = 0.001$)) (Fig. 5).

Discussion

Balance analysis found identical data for resurfacing and control subjects. To the best of our knowledge, this was the first study to compare postural balance between healthy and implanted hips. Resurfaced hips were thus shown to behave in terms of balance like the healthy contralateral hip of the same patient. The results further pointed to comparable balance between resurfaced hips and those of healthy subjects.



Y-axis: Posterior-anterior (mm)
X-axis: Left-right (mm)
Julien Feb. 10, 2010

Figure 5 Analysis and comparison of statokinesigrams for two subjects in operated-side monopedal stance (blue, resurfacing group patient; green, total hip replacement group patient).

Other authors have published similar results for total knee replacement [8,9]. Arokoski et al. [28], on the other hand, found no difference in balance or fatigue between hips with declared osteoarthritis and healthy hips, suggesting that ideal hip arthroplasty should leave the patient with their preoperative quality of balance. Only resurfacing seems to restore the patient's preoperative physiological balance [19]. Conserved bone capital and the numerous intraosseous receptors would seem to contribute to this advantage.

Postoperative pain or poor clinical results fail to account for the differences between the present resurfacing and replacement groups: both had comparable functional results, with PMA scores [22] equal to or greater than 17 points. Moreover, many reports have shown that absence of pain alone does not explain improved proprioception [29]. The same findings were reported for the knee: Hassan et al. [30] showed no benefit in knee proprioception with intra-articular bupivacaine injection.

For bipedal balance, the tests seem easy to perform. The areas under the curve were comparable between the resurfacing and control groups, with a clearly significant difference with respect to the total hip replacement group, where the area was five times greater. These poor results were related to impaired balance on the operated side. The differences between the various monopedal stances were much greater: half of the total hip replacement patients were unable to maintain stable monopedal posture for 21 s. Only 25% of total hip replacement patients, compared to 100% of resurfacing patients, were able to perform the tests, testifying to significant stabilometric differences between the two groups. Despite their apparent simplicity, the tests required considerable effort on the part of total hip replacement patients. Routine clinical balance tests in at-risk patients are much less difficult: the ''get up and go test'' [31] simply analyzes 15 s' slow walking; the ''monopedal stance test'' is judged non-pathological if the patient can maintain the posture for at least 5 s, versus 20 s in the present protocol. In contrast, resurfacing patients were able to perform the test without great difficulty. Statokinesigram area-under-the-curve analysis found comparable values in the control and resurfacing groups. However, the control group's bipedal stance values were slightly higher than normal (reported as about 100 mm^2 [32]), probably due to test performance conditions: values were taken without a ''trial run'' on the platform and without the control subjects precisely knowing the objectives of the study.

The present results found a significant difference between the ideal group and both resurfacing and replacement groups, with greater areas under the curve (on both bi- and monopedal weight-bearing on the operated side) in the latter; this difference was moreover also found with respect to the healthy side of the resurfacing and replacement groups compared to controls: contralateral surgery would seem to have altered the template for bipedal balance. To stabilize the operated side, the emergent postural dynamic modifies stress adaptation by widening the area under the curve so as to correct balance. This adaptation is enduring, as healthy-side monopedal weight-stance remains more unstable in both resurfacing and replacement patients than in controls, and would seem to be an emergent phenomenon.

The tests described in the present report seem better adapted to detecting the impact of arthroplasty in young patients, being more highly discriminating than classical clinical scores such as PMA or HHS, which show poor validity and relevance in a young active population, where PMA scores are often very elevated (ceiling effect), making any difference between types of implant difficult to discern. More specific tests, dedicated to hip arthroplasty, are required, such as the balance test used in the present study.

The impact of rehabilitation was not examined here. To avoid secondary bias, however, it should be noted that the rehabilitation program was identical for both groups, comprising immediate weight-bearing without restriction, and active-passive physiotherapy exercises.

Conclusion

The present static stabilometric study applied in orthopedics to the analysis of new hip arthroplasty techniques found an advantage in terms of balance and postural control for resurfacing over total hip arthroplasty. The findings confirm a hypothesis as to the excellent clinical results obtained with resurfacing [33], which showed better stability and motor patterns than did total hip replacement. On stabilometric parameters, postural coordination was stable following both resurfacing and hip replacement, becoming indeed regular at whatever level of stress. These posturologic techniques, however, are only marginally employed in the field at present, although providing an innovative technical aid in refining analysis in ever younger and more active patients. The resurfacing results were close to control values. These data validate this innovative technique from the stabilometric standpoint and confirm the advantages of this type of arthroplasty.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

[1] Danielsson L, Lindberg H. Prevalence of coxarthrosis in an urban population during four decades. Clin Orthop Relat Res 1997;342:106—10.

[2] Felson DT, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum 1998;41:1343—55.

[3] Arokoski MH, Haara M, Helminen HJ, Arokoski JP. Physical function in men with and without hip osteoarthritis. Arch Phys Med Rehabil 2004;85:574—81.

[4] Arokoski MH, Arokoski JP, Haara M, Kankaanpaa M, Vesterinen M, Niemitukia LH, et al. Hip muscle strength and muscle cross sectional area in men with and without hip osteoarthritis. J Rheumatol 2002;29:2185—95.

[5] Wegener LC, Kisner, Nichols D. Static and dynamic balance responses in persons with bilateral knee osteoarthritis. J Orthop Sports Phys Ther 1997;25:13—8.

[6] Sharma L, Pai YC, Holtkamp K, Rymer WZ. Is knee joint proprioception worse in the arthritic knee versus the unaffected knee in unilateral knee osteoarthritis? Arthritis Rheum 1997;40:1518—25.

[7] Pai YC, Rymer WZ, Chang RW, Sharma L. Effect of age and osteoarthritis on knee proprioception. Arthritis Rheum 1997;40:2260—5.

[8] Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Ann Rheum Dis 1997;56:641—8.

[9] Hassan BS, Mockett S, Doherty M. Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis 2001;60:612—8.

[10] Nashner LM. Computerized dynamic posturography. Practical management of dizzy patient. Philadelphia: Lippicott Williams & Wilkins; 2001.

[11] Horak FB, Nashner LM. Central programming of postural movements: adaptation to altered support-surface configurations. J Neurophysiol 1986;55:1369—81.

[12] Nashner LM. Strategies for organization of human posture. In: Black I, editor. Vestibular and visual control on posture and locomotor equilibrium. Basel, New York: Karger; 1985.

[13] Cross MJ, McCloskey DI. Position sense following surgical removal of joints in man. Brain Res 1973;55:443—5.

[14] McChesney JW, Woollacott MH. The effect of age-related declines in proprioception and total knee replacement on postural control. J Gerontol A Biol Sci Med Sci 2000;55:658—66.

[15] Zimny ML, Albright DJ, Dabezies E. Mechanoreceptors in the human medial meniscus. Acta Anat (Basel) 1988;133:35—40.

[16] Grigg P, Finerman GA, Riley LH. Joint-position sense after total hip replacement. J Bone Joint Surg Am 1973;55:1016—25.

[17] Karanjia PN, Ferguson JH. Passive joint position sense after total hip replacement surgery. Ann Neurol 1983;13:654—7.

[18] Ishii Y, Tojo T, Terajima K, Terashima S, Bechtold JE. Intracapsular components do not change hip proprioception. J Bone Joint Surg Br 1999;81:345—8.

[19] Girard J, Lavigne M, Vendittoli PA, Roy AG. Biomechanical reconstruction of the hip: a randomised study comparing total hip resurfacing and total hip arthroplasty. J Bone Joint Surg Br 2006;88:721—6.
[20] Mont MA, Seyler TM, Ragland PS, Starr R, Erhart J, Bhave A. Gait analysis of patients with resurfacing hip arthroplasty compared with hip osteoarthritis and standard total hip arthroplasty. J Arthroplasty 2007;22:100—8.
[21] Naal FD, Maffiuletti NA, Munzinger U, Hersche O. Sports after hip resurfacing arthroplasty. Am J Sports Med 2007;35:705—11.
[22] Merle D'Aubigné R. Numerical classification of the function of the hip. Rev Chir Orthop Reparatrice Appar Mot 1990;76: 371—4.
[23] Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am 1969;51:737—55.
[24] Delaunay C, Epinette JA, Dawson J, Murray D, Jolles BM. Cross-cultural adaptations of the Oxford-12 HIP score to the French speaking population. Orthop Traumatol Surg Res 2009;95:89—99.
[25] Nakamura T, Horikawa E, Sasaki H. Postural and gait instability in patient with Alzheimer's disease. Nippon Ronen Igakkai Zasshi 2000;37:897—9.
[26] Takagi A, Fujimura E, Suehiro S. A new method of statokinesigram area measurement. Application of a statistically calculated ellipse. In: Igarashi M, Black O, editors. Vestibular and visual control on posture and locomotor equilibrium. Karger (Bâle); 1985. p. 74—9.
[27] Duplan B. Étude de la prévalence des troubles posturaux au sein d'une cohorte de 106 patients lombalgiques. In: Gagey PM, Weber B, editors. Entrées du système postural fin. Paris: Masson; 1995. p. 71—7.
[28] Arokoski JP, Leinonen V, Arokoski MH, Aalto H, Valtonen H. Postural control in male patients with hip osteoarthritis. Gait Posture 2006;23:45—50.
[29] Ekdahl C. Postural control, muscle function and psychological factors in rheumatoid arthritis. Are there any relations? Scand J Rheumatol 1992;21:297—301.
[30] Hassan BS, Doherty SA, Mockett S, Doherty M. Effect of pain reduction on postural sway, proprioception, and quadriceps strength in subjects with knee osteoarthritis. Ann Rheum Dis 2002;61:422—8.
[31] Podsiadlo D, Richardson S. The timed ''Up & Go'': a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142—8.
[32] Gagey PM, Weber B. Posturologie; régulation et dérèglements de la station debout. Troisième édition. Paris: Masson; 2005.
[33] Girard J, Vendittoli PA, Roy AG, Lavigne M. Femoral offset restoration and clinical function after total hip arthroplasty and surface replacement of the hip: a randomized study. Rev Chir Orthop 2008;94:376—81.