



Stabilometric assessments of two rehabilitation protocols on postural parameters after posterior total hip arthroplasty: A prospective randomized comparative study

Lucas Martinez, Nathalie Noé, Hermann Simon, Julien Beldame, Jean Matsoukis, Helena Brunel, Stéphane van Driessche, Fabien Billuart

► To cite this version:

Lucas Martinez, Nathalie Noé, Hermann Simon, Julien Beldame, Jean Matsoukis, et al.. Stabilometric assessments of two rehabilitation protocols on postural parameters after posterior total hip arthroplasty: A prospective randomized comparative study. *Orthopaedics & Traumatology: Surgery & Research*, 2022, 108 (1), <10.1016/j.otsr.2021.103174>. <hal-03579485>

HAL Id: hal-03579485

<https://hal.science/hal-03579485v1>

Submitted on 22 Jul 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY-NC 4.0 - Attribution - Non-commercial use - International License

Stabilometric assessments of two rehabilitation protocols on postural parameters after posterior total hip arthroplasty: a prospective randomized comparative study.

Lucas **Martinez**^a, Nathalie **Noé**^a, Hermann **Simon**^a, Julien **Beldame**^b, Jean **Matsoukis**^c, Helena **Brunel**^a, Stéphane **Van Driessche**^d, Fabien **Billuart**^{a,e,*}.

a Laboratoire d'analyse du mouvement, Institut de Formation en Masso-Kinésithérapie Saint Michel, 68 rue du commerce, 75015 Paris, France.

b Clinique Mégival, 1328 avenue de la Maison-Blanche, 76550 Saint-Aubin-sur-Scie, France

c Département de chirurgie orthopédique, Groupe Hospitalier du Havre, BP24, 76083, Le Havre cedex, France

d Clinique de Montargis, 46 rue de la Quintaine, 45200 Montargis, France

e Unité de Recherche ERPHAN, UR 20201, UVSQ, France

* **Corresponding author:** Fabien Billuart

Laboratoire d'analyse du mouvement, Institut de Formation en Masso-Kinésithérapie Saint Michel, 68, rue du commerce, 75015 Paris, France.

Email: f.billuart@ifmk.fr

Tel.: +33 (0)6 62 13 39 51

Abstract

Introduction

After total hip arthroplasty (THA), patients continue to have muscular, functional and postural deficits. The literature seems to support the use of postoperative rehabilitation, especially self-directed programs. However, there is no set protocol for the management of postural disorders. Therefore, the purpose of this study was to compare postural parameters of a group of patients who underwent posterior THA followed by 2 different types of rehabilitation (stabilometric platform (SP) and home-based self-directed protocols) with a control group of operated patients who did not undergo rehabilitation and a control group of age-matched asymptomatic subjects.

Hypothesis

We hypothesized that rehabilitation would normalize the stabilometric parameters.

Patients and Methods

A total of 67 subjects were enrolled in this study (mean age 67.85 ± 1.22 years) and divided into 4 groups. Forty-one of these subjects had undergone a posterior THA were randomly assigned between D10 and D21 to one of the following 3 groups: no rehabilitation control group (THACG = 14), supervised rehabilitation with a stabilometric platform group (RSPG = 16), and a self-directed home-based rehabilitation group (SDHRG = 11). The 4th group was a control group made up of 26 age-matched asymptomatic nonoperated subjects (CG55-80). These rehabilitation protocols lasted 3 weeks. At the end of the 3 weeks, the groups performed the same stabilometric single leg and double leg stance tests (considering lower limb dominance) on an SP.

Results

No significant differences were observed between groups in the bipedal stance, except between the CG55-80 and the THACG, where a higher energy expenditure was observed in the THACG during the static stance with eyes open (EO) and eyes closed (EC): increase in the path length (P_{length}) covered by the center of pressure (COP) (EO: $p = .01$; EC: $p = .03$) and the average velocity (V_{avg}) of the COP (EO: $p = .01$; EC: $p = .03$). These differences were not observed in the SDHRG and RSPG whether they were compared with one another or with both control groups. In the unipedal stance, subjects in the RSPG and SDHRG showed greater muscle activity in the anterior and posterior chains and hip abductors, and used less energy to maintain the stance than those in the CG55-80, regardless of lower limb dominance: decrease in the mediolateral range of COP displacement (X_{range}) (hip abductor muscles) ($p = .02$) and anteroposterior range of COP displacement (Y_{range}) (anterior and posterior chains) ($p = 3.49 \cdot 10^{-3}$), 95% confidence ellipse area (E_{area}) of COP data ($p = 1.47 \cdot 10^{-3}$), P_{length} ($p = .04$) and V_{avg} ($p = .04$). The RSPG had a smaller E_{area} than the SDHRG

($p = .04$), demonstrating a better postural stability during the unipedal stance performed on the dominant operated leg.

Discussion

Our results were consistent with the literature on the benefits of rehabilitation after THA, thus confirming our hypothesis that rehabilitation normalized stabilometric parameters between D31-D45, depending on the subjects. These results provide new information regarding rehabilitation techniques to be implemented postoperatively after a THA. A home-based self-directed rehabilitation program is just as effective as an SP program in managing postural disorders.

Level of Evidence: II; randomized controlled trial with low statistical power.

Keywords: Total hip arthroplasty; rehabilitation; postural parameters; stabilometric platform; self-directed rehabilitation.

Abbreviations: THA: Total hip arthroplasty / SP: Stabilometric platform / COP: Center of pressure

1. Introduction

THA is also indicated for younger and more active individuals who complain of pain and limited range of motion [1]. This phenomenon has led to modifications of the surgical techniques and intraoperative care [2–5]. A successful surgical procedure is mainly characterized by improved functional scores such as the WOMAC (Western Ontario and McMaster Universities Arthritis Index) and Harris Hip Score [6]. However, patients still present reduced walking ability, pain, weakness of the periarticular hip muscles [7,8], motor deficits [9] and static balance disorders [10–12] after surgery.

The literature seems to support postoperative rehabilitation [13–15], and particularly self-directed protocols, despite the current trend toward earlier home discharges and decreases in postoperative rehabilitation prescriptions [3–5,16–18]. Self-directed rehabilitation appears to be effective [8,13,15,19-20], even if its impacts on static balance have never been studied. These are important to study because, according to Van Driessche et al. [11], there is a significant deterioration of postural parameters 45 days after surgery. They reported a deterioration of postural parameters after THA that was marked by either an increased displacement of the center of pressure (COP) or asymmetry in weight bearing.

The purpose of this study was to compare, from D45 onwards, the postural parameters of patients who had undergone a posterior THA followed by 2 different types of rehabilitation (stabilometric platform (SP) and home-based self-directed protocols) with a control group of operated patients who did not undergo rehabilitation and a control group of age-matched asymptomatic subjects. By comparing the stabilometric parameters of the 2 rehabilitation groups with both control groups, we hypothesized that both study protocols would normalize postural parameters compared to the group of age-matched asymptomatic subjects.

1. Patients and methods

2.1 Patients

Data were collected between April 2014 and April 2015. A total of 67 volunteers were divided into 4 groups (Table 1). There were 2 control groups: a group of asymptomatic subjects between the ages of 55 and 80 (CG55-80, n = 26) with no hip pain or functional limitations (recruited through an advertisement posted at the Clinique Montargis) and a group of patients who had undergone a posterior THA with no rehabilitation (THACG, n = 14) (Figure 1).

All operated patients in the study groups were randomly assigned to either the THACG, the rehabilitation with an SP Group (RSPG, n = 16) or the self-directed home-based rehabilitation group (SDHRG, n = 11) (Figure 1).

All patients who underwent a THA were operated at the Clinique Montargis by the same experienced surgeon (SVD) who only performs this type of procedure through a minimally invasive posterior approach and has performed at least 2,000 posterior THAs. All operated subjects were assessed preoperatively with a WOMAC questionnaire [21] (Table 1).

2.2 Methods

The inclusion criteria for operated subjects were the completion of a simple randomization (using a random number table) performed between D10 and D21 after surgery and the indication of THA for primary coxarthrosis, which was diagnosed by radiologic and clinical examinations. The inclusion criteria for asymptomatic control subjects were an age between 55 and 80 years old, a body mass index (BMI) <35 kg/m² and the ability to stand on one leg without assistance.

The exclusion criteria for operated subjects were: revision THA, congenital hip dislocation or episodes of hip dislocation after the procedure, THA on the contralateral side performed less than 5 years ago, knee arthroplasty regardless of the side, and infectious or thromboembolic complications following the THA. We also excluded patients with musculoskeletal disorders of less than 6 months, visual disturbances, neurologic, vestibular, cardiovascular, respiratory, cognitive and psychiatric disorders, and alcohol or drug use within the last 24 hours (exclusion criteria also shared by the CG55-80).

The following prosthetic materials were used in all operated subjects: cementless, Corail®-like, quadrangular stems with standard or lateralized offset and 2 types of acetabular

component (standard or dual mobility cup). All stems were combined with either a 28, 32 or 36 mm diameter alumina head (Table 1).

The moment arms of the hip stabilization muscles were restored ($\Delta \leq 5$ mm, compared to preoperative measurements taken with OrthoView™, Materialise™, Belgium) in all 3 groups. The piriformis muscle was spared during exposure, the capsule was sutured, and the released short lateral rotators (obturator internus and externus) were left unsutured.

The same postoperative care protocol was put in place: medical treatments, nursing care several times daily, no orthoses, patients allowed to stand up on D1 or D2 postoperatively with full-weight bearing using either 2 forearm crutches or a walker, and immediate resumption of walking. The average hospital stay was 3 days (between 1 and 5 days).

The rehabilitation protocol followed by the RSPG was performed on an AccuGait™ 50 Hz SP (AMTI™, Watertown, MA, USA) with Balance Trainer™ (version 1.4.1) software (AMTI™, Watertown, MA, USA). This 3-week protocol, which was performed under the supervision of a physiotherapist, was started between D10 and D21 postoperatively. The exercise regimen of 30-minute sessions 3 times per week (Appendix 1) increased in difficulty and included static holds, mediolateral and anteroposterior movements and multidirectional target tracking tasks. All these exercises were performed with visual biofeedback. Each patient had a tailored rest period between each exercise.

The SDHRG started their 3-week self-directed rehabilitation protocol between D10 and D21 postoperatively with 30-minute sessions 6 days a week (Appendix 2). The first session was supervised by a physiotherapist who made sure that patients understood the instructions and distributed individual exercise booklets, which included exercise progression and regimen. Patients were also encouraged to walk 30 minutes a day and asked to keep a record of other physical activities. A telephone follow-up with a questionnaire (Appendix 1) was carried out twice a week to assess program compliance. The only instruction given to the THACG was to walk as often as possible.

2.3 Assessment methods

The AccuGait™ SP was used with Balance Clinic™ (version 1.4.2) software (AMTI™, Watertown, MA, USA).

The stabilometric measurements taken for all the study subjects (after the 3-week protocol for SDHRG and RSPG and carried out between D45 and D60 postoperatively for all operated subjects) consisted of 4 tests: 2 × 50-second bipedal static stance tests with eyes open (EO) then eyes closed (EC), followed by a 15-second, right and left unipedal stance test in the EO condition.

Subjects were asked to stand quietly barefoot on the SP, with knees extended and arms at their sides, while looking at a visual reference point (red cross) placed on the wall at eye level 2 m away (Figure 2). The lighting (2,000 lux) and sound environments were controlled. The subjects did not undergo any training before the data was recorded. The test was repeated if there was a loss of balance or a special request (rest or sound and visual disturbances). Three attempts were allowed per test. The following measurement parameters were selected (Figure 3):

- X_{range} : range of COP displacement along the mediolateral axis (cm), reflecting the strength of the hip abductor muscles.
- Y_{range} : range of COP displacement along the anteroposterior axis (cm), reflecting the activity of the anterior and posterior chains.
- P_{length} : distance covered by the COP during the recording (cm), estimating the energy expenditure needed to control the orthostatic posture.
- V_{avg} : average velocity of the COP (cm/sec). The higher these values are, the more energy is required to hold the posture.

- E_{area} : area of the 95% confidence ellipse (cm^2) of COP data during the recording and representing the COP displacement during the task. The larger the E_{area} , the less stable the subject.

Lower limb dominance was also established for each subject with a functional performance test (first foot instinctively put forward to keep balance) to determine:

- Preferred and nonpreferred hip for the CG55-80
- Preferred and nonpreferred operated hip for THACG, RSPG and SDHRG

This classification enabled us to compare lower limbs without the stabilometric variations associated with lower limb dominance.

2.4 Statistical analysis

Statistics were expressed as means and standard deviations: ranges for the quantitative variables and frequencies for the categorical variables. Nonparametric statistics were used to compare the different groups, because normal distribution of variables could not be guaranteed. Overall comparisons were performed for each variable and for each test on the stabilometric platform with a Kruskal-Wallis H test, while paired comparisons were obtained using a Mann-Whitney U test with a Monte Carlo permutation procedure [22]. The statistical significance was set at .05. A power threshold of 80% was used for this study, which required, according to the sample size calculation, 12 subjects per group. All statistical analyses were performed using R (version 2.14) software (Bell Laboratories, Murray Hill, NJ, USA).

3. Results

3.1 Group characteristics

Pairwise comparisons of groups for each of these characteristics did not reveal any significant statistical differences between them (Table 1: Δ ; Ω ; #; †; ‡; \diamond), except for the BMI ($p = .005$) and weight ($p = .04$) when comparing CG55-80 with THACG (Table 1). Two patients in the THACG group had a higher weight than the rest of the sample, thus increasing the mean of their group and impacting the BMI. A significant difference was also observed in the WOMAC results ($p = .005$) between RSPG and SDHRG. This was because 1 of the patients in the RSPG group had a low WOMAC score (58), which decreased the mean of their group. Finally, the operated groups were homogeneous in terms of the prosthetic materials implanted: no differences were found regarding the distribution of the types of stem (standard or lateralized offset), types of cup (standard or dual mobility), cup size and head diameter.

3.2 Protocol compliance

All of the 11 patients in the SDHRG completed more than 50% of the exercises, i.e. 5 out of 9 of the exercises programmed for each week of the protocol (assessed with the protocol's weekly telephone follow-up questionnaire, Appendix 2). Fourteen of the 16 RSPG patients completed the protocol. The 2 patients who could not complete the program (1 no longer had any means of transportation and 1 was in pain) were excluded from the study.

3.3 Results of the rehabilitation protocols on the bipedal parameters

All subjects successfully passed the 2 bipedal stance tests. These results are summarized in Table 2. The pairwise comparisons between groups (Table 3) showed that there were no significant differences between the groups of operated patients (THACG, SDHRG and RSPG) no matter the parameter studied or the EO or EC condition. The comparison between CG55-80 and THACG showed that the stabilometric parameters deteriorated in the THACG when subjects performed the tasks with EO: significant increase in P_{length} ($p = .01$), with 73.71 ± 9.99 cm (min: 69.44 cm – max: 97.02 cm) for CG55-80 vs 90.57 ± 20.00 cm (min: 88.00 cm – max: 110.34 cm) for THACG, and V_{avg} ($p = .01$) with 1.47 ± 0.19 cm/sec (min: 1.03 cm/sec – max: 2.24 cm/sec) for CG55-80 vs 1.81 ± 0.40 cm/sec (min: 1.34 cm/sec – max:

1.99 cm/sec). The same results were found in the EO condition for P_{length} ($p = .03$), with 99.43 ± 37.29 cm (min: 80.67 cm – max: 104.23 cm) for CG55-80 vs 121.48 ± 36.71 cm (min: 102.34 cm – max: 115.67 cm) for THACG, and V_{avg} ($p = .03$) with 1.98 ± 0.74 cm/sec (min: 1.45 cm/sec – max: 3.07 cm/sec) for CG55-80 vs 2.42 ± 0.73 cm/sec (min: 1.31 cm/sec – max: 2.69 cm/sec). These results demonstrated that more energy was required to maintain a static erect posture in both conditions. These significant differences were not observed in SDHRG or RSPG with EO and EC when compared with CG55-80.

3.4 Results of the rehabilitation protocols on the unipedal parameters

To assess the impact of the preferred hip, we classified them as “preferred operated hip” and “nonpreferred operated hip.” SDHRG and RSPG subjects were compared with those in the THACG and CG55-80, and then compared with one another according to the rehabilitation modalities (Table 4). The SDHRG had significantly better results for 3 parameters when the nonpreferred hip was operated: P_{length} (60.37 ± 2.41 cm, min: 54.57 cm – max: 67.69 cm ($p = .04$)), E_{area} (7.14 ± 0.06 cm², min: 5.24 cm² – max: 6.01 cm² ($p = 3.10^{-4}$)), and V_{avg} (6.04 ± 0.24 cm/sec, min: 5.56 cm/sec – max: 6.18 cm/sec ($p = .04$)) were significantly lower than the CG55-80 (Table 4). Moreover, these findings also meant that subjects in the SDHRG used less energy to hold the unipedal stance and had better unipedal postural stability. The RSPG had better results for 3 parameters when the preferred hip was operated: X_{range} (2.57 ± 0.66 cm, min: 2.00 cm – max: 3.21 cm ($p = .02$)), Y_{range} (2.86 ± 0.88 cm, min: 1.88 cm – max: 4.34 cm ($p = 3.49 \cdot 10^{-3}$)), and E_{area} (6.44 ± 3.39 cm², min: 4.09 cm² – max: 6.02 cm² ($p = 1.47 \cdot 10^{-3}$)) were significantly lower than the THACG (Table 4). There were no significant differences between SDHRG, RSPG, and THACG when the preferred hip was operated. The SDHRG had better results than the THACG when the nonpreferred hip was operated: P_{length} (60.37 ± 2.41 cm, min: 54.57 cm – max: 67.69 cm ($p = .03$)) and the V_{avg} (6.04 ± 0.24 cm/sec, min: 5.56 cm/sec – max: 6.18 cm/sec ($p = .03$)) were significantly lower than the THACG. This difference was not observed in the RSPG (Table 4). There were no differences between the SDHRG and the RSPG when the preferred hip was operated, except for better RSPG

results for the E_{area} ($p = .04$): $10.45 \pm 3.58 \text{ cm}^2$ (min: 7.23 cm^2 – max: 14.03 cm^2) for the SDHRG vs $6.44 \pm 3.39 \text{ cm}^2$ (min: 4.09 cm^2 – max: 6.02 cm^2) for the RSPG, which meant they had better unipedal postural stability. No significant differences were found between SDHRG and RSPG when the nonpreferred hip was operated (Table 4).

4. Discussion

Postural parameters deteriorate after THA [11]. Despite a literature largely in favor of rehabilitation, there is no consensus on what rehabilitation protocol is best to manage postural disorders [19,20,23,24]. Therefore, the purpose of this study was to compare the stabilometric parameters of patients who underwent a posterior THA followed by 2 different types of rehabilitation protocols (SDHRG and RSPG) with a control group of operated subjects who did not undergo rehabilitation and a control group of age-matched asymptomatic participants. Our hypothesis that the 2 types of rehabilitation protocols would normalize the stabilometric parameters between D45 and D60 postoperatively was confirmed. The patients who completed the 2 different rehabilitation programs had the same stabilometric parameters in the bipedal stance than the CG55-80. Therefore, both these protocols restored the stabilometric parameters in the bipedal stance, while the THACG showed deficits compared to the CG55-80 (Table 3). However, these results should be interpreted with caution because they are only found in the EO condition. According to Van Driessche et al. [11], patients who underwent a posterior THA with no rehabilitation showed a deterioration in bipedal parameters on D45 compared to the asymptomatic subjects. Our study confirmed this trend.

However, when the rehabilitation groups were compared with the THACG in the unipedal stance, only 2 parameters were significantly better in the SDHRG when the nonpreferred hip was operated (P_{length} ($p = .03$) and V_{avg} ($p = .03$)). The lack of significant results may be due to the fact that sorting hips according to limb dominance reduced the sample size and, as a

result, the statistical significance of these findings. A larger sample size would address this limitation. The RSPG had significantly better X_{range} ($p = .02$), Y_{range} ($p = 3.49 \cdot 10^{-3}$), and E_{area} ($p = 1.47 \cdot 10^{-3}$) than the CG55-80 when the preferred hip was operated. The SDHRG showed significantly better P_{length} ($p = .04$), E_{area} ($p = 3.00 \cdot 10^{-4}$) and V_{avg} ($p = .04$) than the CG55-80 when the nonpreferred hip was operated. In other words, patients who underwent rehabilitation performed better than the group of age-matched asymptomatic patients only 45 days after their surgery. This last result provided an argument for rehabilitation, thereby improving postural parameters of patients who underwent THA. For Judge et al. [25], maintaining balance in the unipedal [stance] depended on the strength of the gluteal muscles. Although the present study did not include force measurements, based on the improvements of X_{range} , V_{avg} , P_{length} and E_{area} , we can assume that these also improved with the 2 rehabilitation protocols. Statistical analyses showed that results were not influenced by supervised rehabilitation. There were no significant differences between SDHRG and RSPG in the bipedal stance. The same was true for the unipedal stance, where only 1 result was significantly better in the RSPG (Table 4). Specific supervised balance rehabilitation on an SP was as effective as the home-based self-directed rehabilitation. Offering an SP protocol reflected our desire to provide a specific balance rehabilitation. This last point was not confirmed. However, it is interesting to note that, based on the significant correlations between stabilometric and clinical tests (FIM, TUG, gait speed, hip mobility [2,12,16,26–29] and fall risk assessments [30–31]), SP has proven to be a useful clinical tool.

Home-based self-directed rehabilitation appears to be a viable and effective method if it is performed under direct supervision. Indeed, patient compliance plays a significant role in the success of a home-based self-rehabilitation protocol. For Sashika et al. [8], it was the most important factor. A standardized telephone follow-up of 2 weekly calls was carried out to encourage patients to follow the protocol. Moreover, the exercise difficulty level was increased each week according to the patients' progress. In the present study, 100% of

patients who completed the protocol reported having performed more than 50% of the exercises, which according to the literature is considered good program compliance [10,32].

This study had several limitations: 1) The study only assessed improvements with postural parameters and did not take into consideration kinematic parameters (i.e. walking). We plan to study the effects of rehabilitation on locomotion in a future study. 2) The normalization of the observed parameters was only valid for the assessment period from D10–21 to D31–45. Since no follow-ups were scheduled at a later date, it is impossible to evaluate the sustainability of these results over the long term. 3) The home-based rehabilitation proposed in this study is not currently refunded by the French health insurance fund (CPAM) as it is not recognized by the French general nomenclature of professional procedures (NGAP) for physiotherapists. This limitation does not exist in other countries. Nonetheless, we chose to assess rehabilitative modalities that focused on specific objectives. The preliminary results were encouraging and highlighted the value of a functional rehabilitation that focuses on the management of static balance disorders, whether it be with home-based self-directed rehabilitation or supervised rehabilitation with an SP. 4) We chose to report lower limb dominance for the unipedal stance tests. However, we did not compare dominant and nondominant lower limbs in the CG55-80 or assess the impact of THA on the dominant or nondominant side, as this was not in keeping with the purpose of this study. Sorting the lower limbs according to their dominance did not consider the impact of lateral preference for the unipedal parameters. However, stabilometric results may be different depending on which hip is operated (dominant vs nondominant) and a rehabilitation protocol for using an SP adapted to this effect needs to be implemented. This will be the subject of a future study. 5) Even though different implants were used between the 3 groups and within each of these groups, we believe that this did not affect our results, because all the stems were straight, quadrangular, and cementless, and the femoral offset was restored. However, different acetabular cups (standard and dual mobility) were also implanted, and dual mobility cups might improve hip stability. Nonetheless, this did not seem to affect our results, insofar as the

rehabilitation group with the most dual mobility cups (RSPG) did not show better results than the other groups. 6) Finally, the sample size was small because of the many exclusion criteria. However, the statistical power was maintained except for 1 of the groups (SDHRG).

5. Conclusion

This study is the first to propose and compare 2 rehabilitation protocols for static balance after THA and compare them with a control group of operated patients who did not undergo rehabilitation and a control group of age-matched asymptomatic subjects. Both rehabilitation protocols in the early postoperative phase of posterior THA normalized stabilometric parameters in both the bipedal and unipedal stances. These results confirmed that more intensive rehabilitation, than just simply walking, is necessary to counteract postural deficits and completely restore postural capacities. We therefore recommend the early implementation of either a home-based self-directed rehabilitation program or a rehabilitation program with an SP, depending on the patient's abilities.

Acknowledgment: We thank Helena Brunel for the statistical processing of data.

International Review Board: authorization was obtained by the institutional review board of the Le Havre Hospital Group on February 1, 2014.

Conflicts of interest: Fabien Billuart, Lucas Martinez, Nathalie Noé, Hermann Simon and Helena Brunel declared that they have no conflicts of interest. Jean Matsoukis receives remunerations and benefits from SANOFI Euros, Amplitude and RIVORTHO that are not related to this study. Julien Beldame receives benefits from Arthrex, Smith and Nephew FH Orthopedics and DJO that are not related to this study. Stéphane Van Driessche receives benefits from Symbios and FH Orthopedics that are not related to this study.

Funding: no funding was received for this study.

Author contributions: Study design: Fabien Billuart; Measurements: Hermann Simon, Nathalie Noé, Lucas Martinez; Drafting of the manuscript: Lucas Martinez, Hermann Simon, Nathalie Noé; Project management, supervision, revisions and corrections: Fabien Billuart, Jean Matsoukis, Stéphane Van Driessche; Critical revision of the manuscript: Julien Beldame; Statistics: Helena Brunel.

References

- [1] Trudelle-Jackson E, Emerson R, Smith S. Outcomes of total hip arthroplasty: a study of patients one year postsurgery. *J Orthop Sports Phys Ther* 2002;32:260-7.
- [2] Nantel J, Termoz N, Centomo H, Lavigne M, Vendittoli PA, Prince F. Postural balance during quiet standing in patients with total hip arthroplasty and surface replacement arthroplasty. *Clin Biomech (Bristol, Avon)* 2008;23:402-7.
- [3] De Ladoucette A, Mertl P, Henry MP, Bonin N, Tracol P, Courtin C, et al. Fast track protocol for primary total hip arthroplasty in non-trauma cases reduces the length of hospital stay: Prospective French multicenter study. *Orthop Traumatol Surg Res* 2020;106:1527-31.
- [4] Micicoi G, Bernard de Dompure R, Tran L, Carles M, Boileau P, Bronsard N, et al. Early morbidity and mortality after one-stage bilateral THA: Anterior versus posterior approach. *Orthop Traumatol Surg Res* 2019;105:1265-70.
- [5] Roger C, Debuyzer E, Dehl M, Bulaïd Y, Lamrani A, Havet E, et al. Factors associated with hospital stay length, discharge destination, and 30-day readmission rate after primary hip or knee arthroplasty: Retrospective Cohort Study. *Orthop Traumatol Surg Res* 2019;105:949-55.
- [6] Ng CY, Ballantyne JA, Brenkel IJ. Quality of life and functional outcome after primary total hip replacement. A five-year follow-up. *J Bone Joint Surg Br* 2007;89:868-73.
- [7] Frost KL, Bertocci GE, Wassinger CA, Munin MC, Burdett RG, Fitzgerald SG. Isometric performance following total hip arthroplasty and rehabilitation. *J Rehabil Res Dev* 2006;43:435-44.
- [8] Sashika H, Matsuba Y, Watanabe Y. Home program of physical therapy: effect on disabilities of patients with total hip arthroplasty. *Arch Phys Med Rehabil* 1996;77:273-7.

- [9] Talis VL, Grishin AA, Solopova IA, Oskanyan TL, Belenky VE, Ivanenko YP. Asymmetric leg loading during sit-to-stand, walking and quiet standing in patients after unilateral total hip replacement surgery. *Clin Biomech (Bristol, Avon)* 2008;23:424-33.
- [10] Barber TC, Roger DJ, Goodman SB, Schurman DJ. Early outcome of total hip arthroplasty using the direct lateral vs the posterior surgical approach. *Orthopedics* 1996;19:873-5.
- [11] Van Driessche S, Billuart F, Martinez L, Brunel H, Guiffault P, Beldame J, et al. Short-term comparison of postural effects of three minimally invasive hip approaches in primary total hip arthroplasty: Direct anterior, posterolateral and Röttinger. *Orthop Traumatol Surg Res* 2016;102:729-34.
- [12] Szymanski C, Thouwarecq R, Dujardin F, Migaud H, Maynou C, Girard J. Functional performance after hip resurfacing or total hip replacement: a comparative assessment with non-operated subjects. *Orthop Traumatol Surg Res* 2012;98:1-7.
- [13] Coulter CL, Scarvell JM, Neeman TM, Smith PN. Physiotherapist-directed rehabilitation exercises in the outpatient or home setting improve strength, gait speed and cadence after elective total hip replacement: a systematic review. *J Physiother* 2013;59:219-26.
- [14] Minns Lowe CJ, Barker KL, Dewey ME, Sackley CM. Effectiveness of physiotherapy exercise following hip arthroplasty for osteoarthritis: a systematic review of clinical trials. *BMC Musculoskelet Disord* 2009;10:98. doi: 10.1186/1471-2474-10-98
- [15] Mikkelsen LR, Mechlenburg I, Søballe K, Jørgensen LB, Mikkelsen S, Bandholm T, et al. Effect of early supervised progressive resistance training compared to unsupervised home-based exercise after fast-track total hip replacement applied to patients with preoperative functional limitations. A single-blinded randomised controlled trial. *Osteoarthritis Cartilage* 2014;22:2051-8.

- [16] Nantel J, Termoz N, Ganapathi M, Vendittoli PA, Lavigne M, Prince F. Postural balance during quiet standing in patients with total hip arthroplasty with large diameter femoral head and surface replacement arthroplasty. *Arch Phys Med Rehabil* 2009;90:1607-12.
- [17] Genêt F, Gouin F, Coudeyre E, Revel M, Rannou F. The benefits of ambulatory physiotherapy after total hip replacement. Clinical practice recommendations. *Ann Readapt Med Phys* 2007;50:776-82.
- [18] Coudeyre E, Lefevre-Colau MM, Griffon A, Camilleri A, Ribinik P, Revel M, et al. Is there predictive criteria for transfer of patients to a rehabilitation ward after hip and knee total arthroplasty? Elaboration of French clinical practice guidelines. *Ann Readapt Med Phys* 2007;50:327-36.
- [19] Galea MP, Levinger P, Lythgo N, Cimoli C, Weller R, Tully E, et al. A targeted home- and center-based exercise program for people after total hip replacement: a randomized clinical trial. *Arch Phys Med Rehabil* 2008;89:1442-7.
- [20] Mikkelsen LR, Mikkelsen SS, Christensen FB. Early, intensified home-based exercise after total hip replacement--a pilot study. *Physiother Res Int* 2012;17:214-26.
- [21] Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988;15:1833-40.
- [22] Hothorn T, Hornik K, van de Wiel M, Zeileis A. Implementing a Class of Permutation Tests: The coin Package. *Journal of Statistical Software* 2008;28:1-23.
- [23] Di Monaco M, Castiglioni C. Which type of exercise therapy is effective after hip arthroplasty? A systematic review of randomized controlled trials. *Eur J Phys Rehabil Med* 2013;49:893-907.

- [24] Di Monaco M, Vallero F, Tappero R, Cavanna A. Rehabilitation after total hip arthroplasty: a systematic review of controlled trials on physical exercise programs. *Eur J Phys Rehabil Med* 2009;45:303-17.
- [25] Judge JO, Lindsey C, Underwood M, Winsemius D. Balance improvements in older women: effects of exercise training. *Phys Ther* 1993;73:254-62.
- [26] Ache Dias J, Borges L, da Silva Mattos DJ, Wentz MD, Domenech SC, Kauffmann P, et al. Validity of a new stabilometric force platform for postural balance evaluation. *Rev Bras Cineantropom Desempenho Hum* 2011;13:367-72
- [27] da Silva RA, Bilodeau M, Parreira RB, Teixeira DC, Amorim CF. Age-related differences in time-limit performance and force platform-based balance measures during one-leg stance. *J Electromyogr Kinesiol* 2013;23:634–9.
- [28] Dujardin F, Aucouturier T, Bocquet G, Duparc F, Weber J, Thomine JM. Kinematics of the healthy and arthritic hip joint during walking. A study of 136 subjects. *Rev Chir Orthop* 1998;84:689–99.
- [29] Belaid D, Rougier P, Lamotte D, Cantaloube S, Duchamp J, Dierick F. Clinical and posturographic comparison of patients with recent total arthroplasty. *Rev Chir Orthop* 2007;93:171–80.
- [30] Pajala S, Era P, Koskenvuo M, Kaprio J, Törmäkangas T, Rantanen T. Force platform balance measures as predictors of indoor and outdoor falls in community-dwelling women aged 63-76 years. *J Gerontol A Biol Sci Med Sci* 2008;63:171-8
- [31] Hita-Contreras F, Martínez-Amat A, Lomas-Vega R, Álvarez P, Aránega A, Martínez-López E, et al. Predictive value of stabilometry and fear of falling on falls in postmenopausal women. *Climacteric* 2013;16:584-9

[32] Jan MH, Hung JY, Lin JC, Wang SF, Liu TK, Tang PF. Effects of a home program on strength, walking speed, and function after total hip replacement. Arch Phys Med Rehabil 2004;85:1943-51

Figure legends

Figure 1: Study CONSORT flow diagram. CG55-80: control group 55–80 years old; THACG: no rehabilitation control group; SDHRG: self-directed home-based rehabilitation group; RSPG: rehabilitation with an SP group.

Figure 2: Stabilometric assessment system: example of a unipedal balance test. Subjects step onto the platform barefoot and stand, quietly, with their knees extended and arms along their sides, looking at a visual marker (red cross) placed on the wall 2 m away.

Figure 3: Representation of the different stabilometric parameters. A: P_{length} : corresponds to the sum of the distances between 2 successive COP positions (black dots). B: Base of support with anteroposterior and mediolateral axes. C: 95% ellipse area.

Table 1. Characteristics of the 4 groups

	Control group 55–80 years old MEAN ± SD (min–max)	No rehabilitation control group MEAN ± SD (min–max)	Rehabilitation on SP group MEAN ± SD (min–max)	Self-directed home-based rehabilitation group MEAN ± SD (min–max)	p values
Number	26	14	16	11	
Age (a)	66.65 ± 5.99 (57–79)	69.64 ± 5.77 (59–80)	69.33 ± 7.44 (58–79)	68.43 ± 11.47 (55–78)	Δ; Ω; #; †; ‡; ◇
Sex (M/F)	6 M/20 F	7 M/7 F	5 M/9 F	6 M/5 F	Δ; Ω; #; †; ‡; ◇
Height (m)	1.66 ± 0.09 (1.60–1.90)	1.67 ± 0.11 (1.52–1.80)	1.69 ± 0.08 (1.61–1.89)	1.64 ± 0.05 (1.60–1.82)	Δ; Ω; #; †; ‡; ◇
Weight (kg)	68.12 ± 12.52 (50–100)	80.79 ± 19.03 (56–109)	76.67 ± 12.74 (63–98)	73.67 ± 16.77 (65–93)	Ω; #; †; ‡; ◇
BMI (kg/m ²)	24.44 ± 2.63 (19.81–30.86)	28.86 ± 4.47 (21.83–33.75)	27.19 ± 6.13 (24.89–31.17)	27.33 ± 4.62 (25.39–32.60)	Ω; #; †; ‡; ◇
Operated side (L/R)	∅	7 L/7 R	7 L/9 R	8 L/3 R	†; ‡; ◇
Preoperative WOMAC (/100) [21]	∅	61.21 ± 13.35 (60–67)	62.5 ± 3.18 (58–67)	67.18 ± 3.82 (60–74)	‡; ◇
Femoral stem (type, model, number of patients)	∅	Cementless EVOK™: 11 Targos™: 1 SAMBATM: 2	Cementless EVOK™: 1 Meije™: 15	Cementless EVOK™: 3 Targos™: 2 Meije™: 6	
Lateralized offset stem (number of patients)	∅	7	8	5	†; ‡; ◇
Standard offset stem (number of patients)	∅	7	8	6	†; ‡; ◇
Standard cup (number of patients)	∅	8	6	5	†; ‡; ◇
Dual mobility cup (number of patients)	∅	6	10	6	†; ‡; ◇
Cup size (manufacturer size)	∅	46, 48, 50, 52, 54	48, 50, 52	42, 48, 50, 54, 56	†; ‡; ◇
Alumina head diameter (mm)	∅	28, 32, 36.	28, 36	28, 36	†; ‡; ◇

SD: standard deviation; (min–max): minimum and maximum values in the series; y: year; BMI: body mass index; M/F: male/female; L/R: left/right; ∅: no THA; mm: millimeters; SP: stabilometric platform; Δ: p >.05 for CG55-80 vs THACG; Ω: p >.05 for CG55-80 vs RSPG; #: p >.05 for CG55-80 vs SDHRG; †: p >.05 for RSPG vs SDHRG; ‡: p >.05 for THACG vs SDHRG; ◇: p >.05 for THACG vs RSPG.

Table 2. Stabilometric data for the 4 groups in the bipedal stance tests with eyes open and eyes closed

	<i>Control group 55–80 years old</i> MEAN ± SD (min–max)		<i>No rehabilitation control group</i> MEAN ± SD (min–max)		<i>Self-directed home rehabilitation group</i> MEAN ± SD (min–max)		<i>Rehabilitation on SP group</i> MEAN ± SD (min–max)	
Test conditions	EO	EC	EO	EC	EO	EC	EO	EC
X_{range} (cm)	1.48 ± 0.53 (0.80–2.37)	1.63 ± 0.58 (1.02–2.87)	1.39 ± 0.45 (0.89–2.32)	1.53 ± 0.71 (1.45–3.21)	1.44 ± 0.71 (0.92–2.38)	1.86 ± 1.69 (1.01–3.56)	1.63 ± 0.94 (1.09–2.47)	1.36 ± 0.74 (1.89–2.34)
Y_{range} (cm)	2.60 ± 0.68 (1.45–4.28)	3.10 ± 0.93 (2.56–3.89)	2.84 ± 0.67 (1.40–4.42)	3.23 ± 0.77 (2.19–4.01)	2.65 ± 0.75 (1.56–6.27)	3.41 ± 1.49 (2.98–4.54)	2.82 ± 0.84 (1.39–4.26)	2.91 ± 0.99 (2.00–5.39)
P_{length} (cm)	73.71 ± 9.99 (69.44–97.02)	99.43 ± 37.29 (80.67–104.23)	90.57 ± 20.00 (88.00–110.34)	121.48 ± 36.71 (102.34–115.67)	78.48 ± 10.48 (75.73–99.44)	107.39 ± 35.5 (73.40–119.87)	93.55 ± 39.55 (77.51–126.10)	119.68 ± 37.17 (104.19–134.12)
V_{avg} (cm/sec)	1.47 ± 0.19 (1.03–2.24)	1.98 ± 0.74 (1.45–3.07)	1.81 ± 0.40 (1.34–1.99)	2.42 ± 0.73 (1.31–2.69)	1.57 ± 0.21 (1.26–1.98)	2.15 ± 0.71 (1.46–2.39)	1.87 ± 0.79 (1.34–1.96)	2.39 ± 0.74 (2.28–3.67)
E_{area} (cm²)	2.53 ± 1.55 (1.87–3.22)	2.65 ± 1.16 (2.03–3.53)	2.29 ± 1.30 (1.77–3.32)	2.90 ± 2.49 (1.78–4.40)	2.98 ± 2.28 (1.95–5.33)	3.87 ± 5.22 (1.98–3.93)	2.59 ± 1.75 (2.07–3.51)	2.82 ± 2.69 (2.23–4.89)

SD: standard deviation; (min–max): minimum and maximum values of the series; EO: eyes open; EC: eyes closed; SP: stabilometric platform.

Table 3. Bipedal stance test with eyes open and eyes closed: pairwise comparisons of the different groups

Comparisons	Eyes Open						Eyes Closed					
	THACG vs CG55-80	SDHRG vs CG55-80	RSPG vs CG55-80	RSPG vs SDHRG	THACG vs SDHRG	THACG vs RSPG	THACG vs CG55-80	SDHRG vs CG55-80	RSPG vs CG55-80	RSPG vs SDHRG	THACG vs SDHRG	THACG vs RSPG
X_{range} (cm)	.43	.76	.67	.56	.42	.09	.47	.77	.15	.34	.44	.2
Y_{range} (cm)	.28	.83	.41	.34	.69	.06	.43	.43	.77	.09	.15	.3
P_{length} (cm)	.01*	.17	.08	.16	.77	.22	.03*	.34	.05	.11	.23	.27
V_{avg} (cm/sec)	.01*	.16	.08	.44	.75	.90	.03*	.33	.05	.06	.07	.41
E_{area} (cm²)	.79	.46	.74	.78	.92	.93	.77	.48	.87	.19	.12	.39

Vs = versus; CG55-80: control group 55–80 years old; THACG: no rehabilitation control group; SDHRG: self-directed home-based rehabilitation group; RSPG: rehabilitation with an SP group, * p values in bold red indicate significant differences.

Table 4. Unipedal stance test results and pairwise comparison of different hips

*	X _{range} (cm) MEAN ± SD (min–max)	Y _{range} (cm) MEAN ± SD (min–max)	P _{length} (cm) MEAN ± SD (min–max)	E _{area} (cm ²) MEAN ± SD (min–max)	V _{avg} (cm/sec) MEAN ± SD (min–max)
Preferred operated hip in THACG (1)	10.51 ± 10.73 (8.56–21.06)	4.66 ± 2.42 (3.81–6.28)	65.72 ± 10.11 (60.12–76.34)	6.48 ± 3.38 (4.44–8.29)	7.39 ± 1.52 (5.56–8.32)
Preferred operated hip in SDHRG (2)	3.05 ± 1.02 (2.89–6.67)	3.98 ± 1.16 (3.01–5.20)	72.38 ± 20.35 (56.03–80.89)	10.45 ± 3.58 (7.23–14.03)	7.24 ± 2.03 (5.24–9.12)
Preferred operated hip in RSPG (3)	2.57 ± 0.66 (2.00–3.21)	2.86 ± 0.88 (1.88–4.34)	62.43 ± 31.81 (58.09–91.42)	6.44 ± 3.39 (4.09–6.02)	6.24 ± 3.18 (4.21–8.34)
Preferred hips in CG55-80 (4)	3.31 ± 0.91 (3.02–4.57)	4.26 ± 1.47 (3.12–6.65)	68.46 ± 20.00 (66.45–84.23)	12.7 ± 6.41 (6.20–14.23)	6.85 ± 2.00 (5.01–8.97)
Nonpreferred operated hip in THACG (5)	3.40 ± 0.38 (2.09–5.26)	4.96 ± 1.33 (3.32–5.29)	77.41 ± 12.32 (65.23–81.02)	7.74 ± 1.23 (4.19–8.02)	14.21 ± 9.67 (5.99–15.21)
Nonpreferred operated hip in SDHRG (6)	2.91 ± 0.3 (2.34–3.33)	3.19 ± 0.32 (2.10–4.71)	60.37 ± 2.41 (54.57–67.69)	7.14 ± 0.06 (5.24–6.01)	6.04 ± 0.24 (5.56–6.18)
Nonpreferred operated hip in RSPG (7)	2.60 ± 0.92 (2.45–3.99)	3.79 ± 1.89 (2.12–5.01)	71.72 ± 26.44 (59.89–91.31)	11.02 ± 10.14 (6.48–14.23)	7.17 ± 2.64 (5.78–8.36)
Nonpreferred hips in CG55-80 (8)	3.09 ± 0.51 (2.89–4.22)	3.84 ± 0.85 (2.40–4.19)	68.74 ± 17.24 (60.02–87.21)	10.38 ± 3.91 (7.12–13.01)	6.87 ± 1.72 (4.23–7.62)
p value (4) vs (1)	.21	.73	.79	.24	.51
p value (4) vs (2)	.56	.60	.66	.24	.66
p value (4) vs (3)	.02*	3.49.10⁻³ *	.63	1.47.10⁻³ *	.63
p value (8) vs (5)	.16	.35	.22	.43	.22
p value (8) vs (6)	.55	.13	.04*	3.00.10⁻⁴ *	.04*
p value (8) vs (7)	.31	.95	.82	.9	.82
p value (1) vs (2)	.20	.58	.59	.22	.88
p value (1) vs (3)	.17	.17	.82	.20	.40
p value (6) vs (5)	.18	.17	.03*	.18	.03*
p value (7) vs (5)	.13	.41	.68	.62	.68
p value (3) vs (2)	.31	.06	.48	.04*	.48
p value (6) vs (7)	.53	.53	.39	.44	.39

SD: standard deviation; (min–max): minimum and maximum values of the series; vs = versus; CG55-80: control group 55–80 years old; THACG: no rehabilitation control group; SDHRG: self-directed home-based rehabilitation group; RSPG: rehabilitation with an SP group, * p values in bold red indicate significant differences



CONSORT

TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram





