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Which Restoration of Walking after Minimally Invasive total Hip Arthroplasty?

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Abstract

Introduction: The current craze for minimally invasive approaches is leading to a renewed interest in total hip arthroplasty, but to our knowledge there is no evidence of the superiority of an operative technique in terms of quality of walking recovery.

This review aims to analyze the restoration of the spatio-temporal parameters of gait in first-line total hip arthroplasty suites on hip osteoarthritis and perform a comparison of recovery according to the surgical technique.

Materials and Method: 15 studies were analyzed according to the main criteria of walking speed, unipodal support time, step length and preoperative loading and in the short, medium- and long-term postoperative period.

Results: Although most of the results obtained in the studies analyzed show an improvement in these criteria post-operatively, they remain lower than those obtained in a healthy population.

Conclusion: This work does not highlight the superiority of recovery of the operation of a surgical technique.

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Abbreviation:

THA: Total Hip Arthroplasty
AP: Anterior Pathway
ALP: Anterolateral Pathway
PLP: Posterolateral Pathway
GMax: LargeGluteal
STP: Spatio-temporal Parameters
PtO: Post-operative
PrO: Pre-operative
TP: Transgluteal Pathway

Introduction

Total Hip Arthroplasty (THA) is one of the most common surgical procedures in France with, from 2008 to 2014, according to the Hospital Information Systems Program database, 1,049,637 hip arthroplasties. The annual incidence rate increased from 222 in 2008 to 241 per 100,000 population in 2014 [1]. According to the 2015 report of the French Society of Orthopedic Surgery and Traumatology, hip osteoarthritis is the main indication of THA in 75.2% of them. Coxarthrosis and aging of individuals are responsible for many structural and functional disorders, such as posture, balance and walking.

The techniques of minimally invasive intervention of THA have been developing since the beginning of the 2000s and therefore present a real boom. The authors seem to agree on certain characteristics of these acts: a cutaneous incision of less than 10 cm, a maximum saving of the capsulo-ligamentary elements and the muscular tissue as well as less blood losses. These minimally invasive techniques also make it possible to obtain simpler operating sequences with a shorter hospital stay, a faster functional recovery and, finally, a decreased dislocation rate [2].

Among these minimally invasive techniques, several pathways are distinguished, two of which have no muscle section: the anterior (AP), the anterolateral (ALP) [3]. In addition, there is a third popular minimally invasive approach, the Posterolateral Pathway (PLP), which is characterized by passage through the fibers of the Large Gluteal (GMax) and then by the section of certain pelvic muscles. Posterolateral approaches for THA leave the abductors intact but have historically been associated with a higher risk of dislocation. Some studies show a dislocation rate of 1% while that of Poehling-Monaghan shows an equivalence in the functional results, in terms of resumption of walk without technical assistance, activities of the daily and return to work according to AP and PLP [4].

Despite the cited advantages of minimally invasive techniques, some studies have shown that gait disturbances, balance disorders and muscle deficits can persist for several months after surgery [5]. Indeed, in the context of the PLP, the muscle section of GMax and some pelvic muscles could have consequences on the activity of these muscles, those surrounding but also have consequences on postural control.

Indeed, Trudelle-Jackson et al. [5] recently reported strength deficits of 10% to 18% in the muscles surrounding the replaced hip compared to the uninvolved side 1 year after the THA. Authors have reported average differences of 25.9%, 27.2% and 31.5% between the involved and uninvolved sides for mediolateral stability and anteroposterior stability. Other studies show the relationship between this persistent muscular deficit and modified walking cycles according to spatio-temporal parameters (STP).

This work aims to analyze the evolution of the STP of walking after total hip arthroplasty of first intention after hip osteoarthritis,

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in the short, medium and long term, according to the objective of to know if the walk is restored by this treatment. The second aim of the analysis is to develop a comparison according to the different surgical techniques available to deduce their respective effectiveness.

Materials and Method

Here, by focusing on the consequences on the gait of the total hip replacement surgery, the keywords were determined via CisMef in international language: it is "hip arthroplasty," "gait", "walking" and "kinematic". The resulting search equation is ((hip arthroplasty) OR (hip replacement)) AND (gait OR walking OR kinematic). The query of the PubMed scientific database on July 20, 2018 yielded 3691 results. In order to limit the number of results, but also by applying the following filters: "Article types: clinical trial", "Text availability: free full text", "Publication dates: 15 years", "Species: Humans", 64 results are obtained.

After reading titles and abstracts and then taking into account the availability of full-text documents, 22 articles were selected for full reading. Criteria for the inclusion of articles are studies on walking or even muscle and/or postural analysis in human subjects who have benefited from a more or less recent intervention of uni or bilateral THA. Original articles, case reports or reviews of literatures or meta-analyzes have been excluded. Work on pediatrics, interventions other than THA indicated for hip osteoarthritis, and articles on the benefits of various post-THA rehabilitation protocols were not selected. Articles dealing with femoral re-surfacing interventions have been ruled out.

In order to refine the selection, an evaluation of the study methodology was carried out. Those that do not follow the IMRAD structure, that have significant biases or that do not present their results have been ruled out. After full reading, 15 studies were included for benchmarking. The development of the research is summarized in Figure 1. In total, there are 6 surgical techniques that are compared via 551 patients and control subjects.

Results

The overall results are presented in Table 1.

Walking Speed

Walking speed is the parameter most frequently used to analyze walking. The standard of spontaneous walking speed is estimated at 1.6 m/s or 5.8 km/h in a healthy adult population according to Gasq [6]. The standard limit is 1 m/s or 3.6 km/h; it is considered that below this standard, the risk of falling is increased. In case of pain or functional impotence, this parameter tends to decrease.

In the short-term post-operative period of 6 weeks, Meneghini et al. [3], Benett et al. [8] and Queen et al. [19] agree to observe an improvement in gait speed according to the minimally invasive approach (ALP, PLP) then the standard pathways (AP, Transgluteal Pathway and Posterior Pathway) at 6 weeks with no significant difference between the groups. This improvement of the speed is calibrated of 10 to 12%, but Meneghini et al. note a speed lower than 1m/s. Krych et al. [14] shows that PP shows a significantly greater improvement in walking speed at 6 weeks post-operative (PtO) than the 2 incisions technique.

In the medium term, the authors agree again with the observation of a significant improvement in walking speed without distinction between different surgeries at 3 months according to Zeni et al. [18] with +25% and an average of 1.3 m/s. At 6 months, Reininga et al. obtained an improvement of 20% with 1.3 m/s on average [9], Kopec et al. observed an improvement of 12% but a worrying average speed of 0.72 m/s [11] and Madsen et al. also see an improvement in speed with an average of 1.17 m/s [17].

At 1-year PtO, Krych et al. [15] or Queen et al. [10,20] explain that there is no difference between surgeries, but the latter highlights an average improvement of 30% in walking speed for standard and minimally invasive pathways. However, Agostini et al. [12] found that patients with PLP walk more slowly, with an average speed of 0.78 m/s, than healthy subjects at 3 months PtO. Nevertheless, this difference is normalized at one year with values comparable to the norm (0.92 m/s).

The walking speed seems to follow a progressive improvement with the postoperative delay according to the different surgeries without a clear difference except the technique by 2 incisions which shows poor results vis-à-vis other techniques. If walking speed improves, it remains lower than that of healthy subjects, even at 1-year PtO.

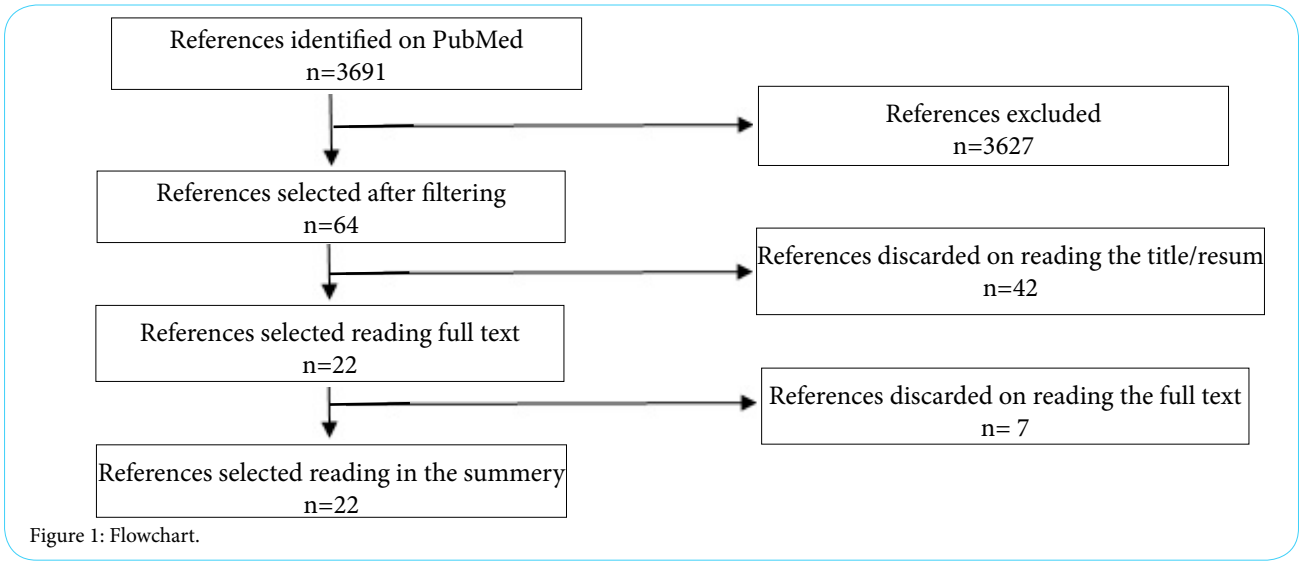

Figure 1: Flowchart.

Title	Date	Type of study	Population	Intervention	Results
A Randomized, Prospective Study of 3 Minimally Invasive Surgical Approaches in Total Hip Arthroplasty [3]	2008	Random control trial	23 Patients	Patients: 3 groups (Gr) randomized (8 patients for double incision, 8 for PLP and 7 for ALP) Intervention: comparison of walking analysis according to 3 routes in preoperative (PrO) and postoperative (PtO) at 6 weeks Duration: 6 weeks PtO	Walking speed: improvement of 10% on average according to the 3 routes initially at 6 weeks without significant difference between the Gr between the PrO and PtO Unipodal support time: increase of 5 to 25% of the support time according to the 3 paths between PrO and PtO without significant difference between the Grids Charging: No difference between groups and between PrO and PtO values at 6 weeks
Changes in gait patterns and muscle activity following total hip arthroplasty: A six-month follow-up [7]	2013	Control trial	76 patients	Patients: 2 Gr (52 patients with TP and 24 control subjects) Intervention: comparison of the 6-month PtO run analysis Duration: 6 months PtO	Loading: in PrO significantly reduced operated side compared to healthy (-2,4%) / similar in bilateral in PtO but reduced vis-à-vis the control group (-2,7%) Length of the step: no difference between the PrO and the PtO of the operated group but a significant difference with respect to the control group with 4 cm less on average
Comparison of gait kinematics in patients receiving minimally invasive and traditional hip replacement surgery: A prospective blinded study [8]	2006	Comparative study from a random control trial	27 patients	Patients: 3 Gr (9 patients operated by minimally invasive PP, 8 operated by standard PP and 10 control subjects) Intervention: Comparison of PrO and 6-week PtO run analysis Duration: 6 weeks PtO	Walking speed: no difference between the Gr operated with at 6 weeks values equivalent to those found in PrO Cadence: reduction of the higher rate of immediate PtO (J2) for the minimally invasive group but regularization of this difference at 6 weeks Length of the step: no difference between the Gr operated with 6 weeks of values equivalent to those found in PrO Unipodal support: no difference between the Gr operated with at 6 weeks values equivalent to those found in PrO
Comparison of gait in patients following a computer-navigated minimally invasive anterior approach and a conventional posterolateral approach for total hip arthroplasty: A randomized controlled trial [9]	2013	Random control trial	105 patients	Patients: 3 Gr (35 patients operated by AP, 40 by PLP and 30 control subjects) Intervention: comparison of the walk analysis in PrO then at 6 weeks PtO, 3 and 6 months Duration: 6 months PtO	Walking speed: no difference between the Gr both in the PrO evaluation and in the evolution at 6 months but improvement of 20% on average over 6 months Length of step: comparable results between the Gr no significant change between 6 weeks and 6 months PtO Cadence: comparable results between the Gr and no significant change between 6 weeks and 6 months PtO
Does Surgical Approach During Total Hip Arthroplasty Alter Gait Recovery During the First Year Following Surgery [10]	2008	Control trial	30 patients	Patients: 3 Gr (10 patients operated by TP, 10 by PP and 10 ALP) Intervention: comparison of the PrO walking analysis and then at 6 weeks PtO and at 1 year Duration: 1-year PtO follow-up	Walking speed: significant improvement on average of 30% between the PrO and the PtO at 1 year but comparable between the Gr Length of the step: significant improvement on average of 10% between the PrO and the PtO at 1 year but comparable between the Gr

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Gait analysis in Patients after Unilateral Hip Arthroplasty [11]	2015	Comparative study	16 patients	Patients: 1 group of patients operated by ALP Intervention: comparison of the PrO and 6-month PtO analysis between the healthy limb and the operated limb Duration: 6 months PtO follow-up	Walking speed: significant improvement at 6 months (+ 12%) Unipodal support time: decreased compared to the healthy side in PrO (-5.6%) and at 6 months (-1.4%) Cadence: significant improvement at 6 months (+ 8.9%)
Gait Parameters and Muscle Activation Patterns at 3, 6 and 12 Months After Total Hip Arthroplasty [12]	2014	Comparative study	40 patients	Patients: 2 Gr (20 patients operated by PLP and 20 control subjects) Intervention: comparison of walking analysis and EMG muscle activity in PrO and at 3, 6 months and 1-year PtO Duration: 1-year PtO follow-up	Walking speed: the ATH group works more slowly at 3 months PtO (0.78 m/s) but eventually regains values comparable to the norm (0.92m/s) Support time: improvement during the first 6 months but significant difference with the control group at 1 year (-5.6%) Atypical cycles: improvement during the first 6 months but significant difference with the control group at 1 year (+ 6%)
Muscle strength, gait, and balance in 20 patients with hip osteoarthritis followed for 2 years after THA [13]	2010	Comparative study	20 patients	Patients: 20 patients operated on THA by PP Intervention: comparison between the operated limb and the healthy limb according to the evolution of walking at 6 months and 2 years Duration: 2 years PtO follow-up	Unipodal support: decreased in PrO (-4,1%), more significant difference from 6 months PtO
No Benefit of the Two-incision THA over Mini-posterior THA: A Pilot Study of Strength and Gait [14]	2010	Random control trial	21 patients	Patients: 2 Gr (11 patients operated by 2 incisions and 10 by PLP) Intervention: comparison in pre, immediate PT and at 6 weeks of the analysis of the market Duration: 6 weeks PtO	Walking speed: VPL group shows better improvement in PtO Unipodal support: VPL group shows better improvement in PtO
No Strength or Gait Benefit of Two-incision THA: A Brief Follow up at 1 Year [15]	2011	Random control trial	19 patients	Patients: 2 Gr (11 patients operated by 2 incisions and 8 byPP) Intervention: comparison in PrO, at 6 weeks of PtO then at 1 year of the analysis of walking and the muscular strength Duration: 1 year PtO follow-up	Walking speed: no significant difference between the Gr Unipodal support: improvement of unipodal support time at walking in the group PP at 1 year compared to group 2 incisions
Surgical access and damage extent after total hip arthroplasty influence early gait pattern and guide rehabilitation treatment [16]	2011	Random control trial	30 patients	Patients: 2 Gr (15 patients operated by ALP and 15 by TP) Intervention: Comparison of walking analysis and muscle activity in immediate PtO and then at 1 and 3 months Duration: 3 months PtO	Unipodal support: at 1-month, greater improvement in the ALP group (+ 16%), parameter restored to 3 months for the TP Loading: at 1 month, deficit for the TP group due to the achievement of lateral stabilizers, recovery at 3 months
The effect of total hip arthroplasty surgical approach on gait [17]	2004	Control trial	29 patients	Patients: 3 Gr (10 patients operated by ALP, 10 by TP and 9 control subjects) Intervention: comparative analysis of walking at 6 months PtO Duration: 6 months PtO	Walking speed: no significant difference between Gr (1.17m/s on average) Cadence: no significant difference between Gr (114.5 steps/min on average) Step length: no significant difference between Gr (1.22 m on average)

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The effect of surgical approach on gait mechanics after total hip arthroplasty [18]	2018	Comparative study	45 patients	Patients: 2 Gr (30 patients operated by PP and 15 by ALP) Intervention: PrO step analysis and 3 month PtO Duration: 3 months PtO	Walking speed: comparable improvement between 2 Gr at 3 months (+ 25% and 1.3 m/s at 3 months on average)
The effect of total hip arthroplasty surgical approach on postoperative gait mechanics [19]	2011	Comparative study	35 patients	Patients: 3 Gr (8 patients operated by TP, 12 by PP and 15 by ALP) Intervention: PrO walking analysis and 6 weeks PtO Duration: 6 weeks PtO	Walking speed: comparable improvement between Gr (+12% with 1.22m/s on average at 2 weeks PtO) Step length: comparable improvement between Gr (+ 10% at 6 weeks PtO) Unipodal support: comparable improvement between the Gr
Total Hip Arthroplasty Surgical Approach Does Not Alter Postoperative Gait Mechanics One Year After Surgery (20)	2014	Control trial	35 patients	Patients: 3 Gr (12 patients operated by TP, 18 by PP and 11 by ALP) Intervention: PtO 1-year run analysis Duration: 1-year PtO	Walking speed: no significant difference between the Gr Step length: no significant difference between the Gr Unipodal support: no significant difference between the Gr Charging: no significant difference between the Gr

Table 1: Comparison between selected study for analyze.

Step length

The length of the step is evaluated according to the international standard during the phase of double support, between the two heels and is defined by the member located at the front. Its norm in the adult subject is 80 cm and approximate to the size of the subject. In case of pain or functional impotence, this parameter tends to decrease.

In the short term, Bennett and al do not observe a difference in the length of the step between the different approaches, but he does not note any improvement between the values measured in pre-operative (PrO) and those collected at 6 weeks [8]. This is not the case of Queen et al. [19] who finds a slight improvement in the length of the step (+ 10%) at the same time without significant variation between surgical techniques.

At 6 months, Horstmann et al. [7] found no improvement between the PrO and PtO but a reduction of 4 cm in average of the step length of patients operated by VTG vis-à-vis healthy subjects. Reininga et al. [9] do not observe any difference according to the surgeries and noted that the improvement in the length of the step did not change significantly between 6 weeks and 6 months PtO. Madsen et al. [17] do not observe any difference between the groups. In the long run, Queen et al. note a similar improvement in groups of 10% of the step length [10,20].

The improvement of the length of the step seems to be visible but discrete during the evolution PtO and does not present a difference between the surgical techniques.

Cadence

The rate is expressed by the number of steps developed in 1 minute. It depends on the walking speed and the length of the steps. Its norm is evaluated between 100-130 steps / min. In case of pain or functional impotence, this parameter tends to decrease.

In the short term, Bennett et al. [8] note a significant reduction in the rate in the minimally invasive group compared to standard surgery, but this result is normalized at 6 weeks no longer showing any difference between the groups. At 6 months, Reininga et al., on a cohort of 105 patients do not observe any difference between groups and no significant post-operative evolution [9]. Kopec et al. and Madsen and al observe an improvement in the rate with respectively + 8.9% and 93.3 pas/min for 114.5 steps/min, with no significant difference between the surgeries studied [11,17].

In total, the slight improvement in the rate is observed at 6 months PtO and shows no difference between surgical techniques.

Unipedal Support time

The unipedal support time is defined by the time during which the limb is supported alone on the ground. This represents on average 40% of the walking cycle but some studies speak of the ground support time of the member studied, which then represents 60% of the walking cycle. In case of pain or functional impotence, this parameter tends to decrease.

In the short term, Meneghini et al. [3] noted an increase of 5 to 25% of the support time on the operated limb according to the 3 pathways between PrO and PtO without significant difference between the different pathways observed just like Queen et al. [19] which do not find any difference between the groups operated but an improvement of this parameter. In them study, Krych et al. [14] show that the group operated by PLP shows a better improvement of the unipodal support time parameter than the group operated by the double incision technique. However, Bennett et al. [8] do not observe any difference in support time following the various surgeries and obtains values equivalent to those found in PrO.

In the medium term, the study conducted by Palieri [16] shows that at 1 month there is an improvement of the greater unipodal support time of 16% in the group operated by ALP than in the TP group. This

parameter is normalized at 3 months PtO then showing no significant difference between the groups. In his 2-year study, the Rasch team [13] reported a lack of difference in support time between the healthy limb and the limb operated at 6 months PtO, despite a difference of 4.1% in PrO. This difference between healthy and operated limbs is taken up by Kopec et al. [11] who note a decrease in support time of 5.6% in PrO for 1.4% at 6 months. The evolution of the Rasch results is validated by the work of Agostini et al. [12], who note a stagnation of progress at 6 months, but explains that there is a difference in unipodal support time compared to a control group of 5.6 %. In the long term, Krych's team work [15] shows a better improvement of the unipodal support time on limb operated by the PP technique than by the double incision technique. Queen et al. [20] found no difference at 1-year PtO between TP, ALP and PP.

The unipodal support time seems to present a highly variable improvement depending on the studies, highlighting the once again mediocre results of the double incision technique; the other techniques still seem to be worthwhile. However, it is important to note the persistence of a unipodal support time deficit at 6 months compared to a healthy member or population.

Management of the operated limb

The loading corresponds to the percentage of the weight of the body applied on the carrying member during the unipodal support phase and the double support phase. Some studies distinguish these phases for more precision. For the sake of simplification, a simplified analysis covering the entire support phase is presented. In case of pain or functional impotence, this parameter tends to decrease.

In the short term, the study conducted by Meneghini [3] does not show any significant difference between groups or between pre- and post-operative values. The work of Palieri [16] shows a loading operated side deficit in the group operated by VTG, explained by the achievement of lateral stabilizers pelvis but this parameter is normalized with other surgeries at 3 months PtO.

The Horstmann study [7] explains that in PrO, loading is significantly reduced on the operated side compared to healthy 2.4%. It states that this parameter becomes similar in two-month PtO at 6 months but remains reduced compared to the control group of 2.7%. Finally, Queen's work shows that at 1 year PtO, there is no significant difference between the operated groups, without referring to the norm in the healthy subject.

The loading seems to present a favorable evolution during the first 6 months regardless of the technique but persists a deficit compared the healthy population.

Discussion

Coxarthrosis is a degenerative process of cartilage tissue and subchondral bone; it causes pain and functional impotence on the affected limb or joint. This impotence is at the origin of certain disorders such as a reduction of the walking speed or the unipodal support time, which are observable during the walking of the subject during the PrO period. It is then accompanied by motor control disorders which, in connection with pain, lead to proprioceptive and postural disorders. The studies must emphasize that the results obtained in PrO are therefore not from healthy subjects and highlight the positive evolution of the functional status of operated patients. According to a 2013 Heiberg et al. census, walking is the aspect of the job in which THS candidates want or expect the most from improvement. In a meta-analysis comparing the post-operative walking analysis of patients operated on by various routes, Ewen et al. [21] confirm the results observed in this work: if certain parameters of walking have their respective performances improve, they remain lower than those of the healthy population at age equivalent to 1, 2 and 10 years PtO. The walking speed therefore remains lower than that of the healthy population with an average of 0.9 m/s; it is also below the risk threshold of 1 m/s. This second statement must be weighted because the treatment of hip osteoarthritis by THA is for the most part proposed to patients whose age is advanced (70.2 years on average in France); however, the age factor is recognized as having detrimental consequences on posture and limiting walking speed [22].

In a 10-year study, Kubonova et al. [23] show that step length and unipodal support are restored in the long term by recovering values equivalent to the non-operated limb, in agreement with the results described above. According to Petis' work, these data could be explained by the muscular weakness found in the pelvic stabilizers in the first year of PtO. Indeed, a deficit of force leads to a tredelenbourg lameness (active or passive) which generates significant repercussions on the spatio-temporal parameters of walking. According to the previous analysis, this phenomenon would be even more important for VTG and the double incision technique. Bennett et al. [24] tested patients approximately 10 years after surgery, after which pain should not be a problem for these patients, but they nevertheless had reduced stride length and reduced walking speed. This reduction may be due to residual muscle weakness. Based on the analysis presented here, it appears that some adaptations of the approach are evident following the THA. Walking speed is reduced in patients because of a shorter stride length.

Limitations

This work is not meant to be exhaustive and has some limitations. The analysis of the level of evidence of the selected studies was not carried out, making the bibliography non-homogeneous in terms of quality. The studies analyzed for some small cohorts by group (<15 patients) reduce the power of results; some do not have a control group. The subjects from the groups to be compared are not necessarily stratified according to their physical characteristics (height, weight, age), making comparisons questionable. On the other hand, some studies present results without numerical data and without specifying the values of the p-value. In addition, only one database was queried for this work, reducing the power of the results obtained.

Conclusion

In the literature included at the heart of this review, a number of market parameters have been reported. The analysis revealed key variables for which differences are observed between the THA and control groups. In operated patients, the walking speed and the length of the step are reduced, as well as the loading and the support time, compared to a healthy population. These parameters still follow an improvement if one refers to the results obtained before benefiting from the surgical intervention. While most surgical techniques lead to comparable results on the spatio-temporal parameters of walking, two techniques seem to give poor results: the double incision technique, which is also not widespread in France, and the VTG, which is also infrequent. Because abandoned in favor of minimally invasive

techniques. Future work on the other components of walking and its postural and muscular prerequisites would complement this analysis. The success of arthroplasty surgery cannot be evaluated on the unique results of the gait analysis. Patient satisfaction and quality of life, assessed by functional scales and scores, are all ways to analyze the success of treatment.

Competing Interests

The authors declare that they have no competing interests.

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