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Original article

Electromyographic study of hip muscles involved in total hip arthroplasty: Surprising results using the direct anterior minimally invasive approach



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ABSTRACT

Background: The functional and clinical benefit of minimally invasive total hip arthroplasty (THA) is well-known, but the literature reports impaired gait and posture parameters as compared to the general population, especially following use of the anterior minimally invasive approach, which has more severe impact on posture than the posterior approach. The reasons for this impairment, however, remain unexplained. We therefore conducted a surface electromyography (sEMG) study of the hip muscles liable to be affected by arthroplasty surgery: gluteus maximus (GMax), gluteus medius (GMed), tensor fasciae latae (TFL), and sartorius (S). The study addressed the following questions: (1) Is bipodal and unipodal GMed activity greater following anterior THA than in asymptomatic subjects? (2) Is a single manual test sufficient to assess maximal voluntary contraction (MVC) in hip abductors (GMax, GMed, TFL) and flexors (TFL, S)?

Hypothesis: Bipodal and unipodal GMed activity is greater following anterior THA than in asymptomatic subjects.

Method: Eleven patients with anterior THA and 11 asymptomatic subjects, matched for age, gender and body-mass index, were included. Subjects underwent 3 postural tests: bipodal, eyes closed (BEC), unipodal on the operated side (UOP), and unipodal on the non-operated side (UnOP), with unipodal results averaged between both sides in the asymptomatic subjects. Data were recorded from 4-channel EMG and a force plate. EMG test activity was normalized as a ratio of MVC activity.

Results: Postural parameters (mean center of pressure displacement speed) were poorer and sEMG activity higher in anterior THA than asymptomatic subjects ($p < 0.005$). On the BEC test, GMax and GMed activity was higher on both operated and non-operated sides than in asymptomatic controls (respectively, 0.15 ± 0.12 and 0.12 ± 0.6 versus 0.07 ± 0.06 for GMax, and 0.13 ± 0.08 and 0.13 ± 0.08 versus 0.08 ± 0.05 for GMed; $p < 0.05$). On unipodal tests, both UOP and UnOP GMed activities were higher than in controls (respectively, 0.51 ± 0.3 and 0.48 ± 0.27 versus 0.28 ± 0.13 ; $p < 0.04$); GMax and TFL activities were higher than in controls only on the UOP tests (respectively, 0.49 ± 0.43 versus 0.24 ± 0.18 , and 0.23 ± 0.17 versus 0.12 ± 0.16 ; $p < 0.05$).

Discussion: sEMG activity in the hip abductors, which are the main stabilizing muscles for the pelvis, is increased following anterior THA, in parallel with impaired postural parameters. This finding may be due to intraoperative TFL and S neuromuscular spindle lesion. The present preliminary study is to be followed up by a comparison of all 3 common minimally invasive approaches (anterior, anterolateral and posterior) using the same study protocol.

Level of evidence: III, prospective case-control study.

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1. Introduction

Total hip arthroplasty (THA) is the second most frequent surgical procedure worldwide, with more than a million operations per year [1]. The minimally invasive anterior approach is reputed to have functional and clinical advantages, but this is a matter of debate [2–4]. It is theoretically an “anatomic”, muscle-sparing approach. Van Driessche et al. [5], however, reported significant postural impairment compared to asymptomatic controls following THA, whatever the approach, and notably for the anterior approach. We have moreover observed a significant rate of recalcitrant gluteus medius (GMed) tendinitis following anterior THA, despite muscle sparing. GMed is essential for active pelvic stabilization; postural regulation involves anticipation and feedback via mechanoreceptors in the aponeuroses (Pacini, Ruffini), tendons (Golgi tendon organ) and muscles (neuromuscular spindle).

We thus suspect that GMed activity regulation is altered following anterior THA in comparison with asymptomatic subjects, and that it is important to explore periarticular hip muscle activity in these cases. We therefore conducted a surface electromyography (sEMG) study of the GMed, gluteus maximus (GMax), tensor fasciae latae (TFL) and sartorius (S) muscles in bipodal and unipodal stance to shed light on changes in postural parameters following anterior THA [5]. The sEMG literature reports various, sometimes discordant, methodologies [6–17]. For our study in THA patients, we used a protocol that had proven effective in asymptomatic subjects [18]. Raw sEMG data depend on various factors, such as skin impedance and electrode positioning on the muscle body, and signal normalization is needed for intra- and inter-group comparison [12]. The present methodology was validated in asymptomatic subjects [18], with sEMG activity under maximal voluntary contraction (MVC) as reference. The princeps study [18] demonstrated that a single test session with a single test is enough to assess MVC in the hip abductors (abduction in lateral decubitus) and flexors (flexion-abduction-lateral rotation in dorsal decubitus). The present study population differed from that of Bernard et al. [18], and method validity required confirmation.

The study addressed two questions. Is bipodal and unipodal GMed activity greater following anterior THA than in asymptomatic subjects? And is a single manual test sufficient to assess MVC in hip abductors (GMax, GMed, TFL) and flexors (TFL, S)? The study hypothesis was that bipodal and unipodal GMed activity is greater following anterior THA than in asymptomatic subjects.

2. Material and method

2.1. Participants

Eleven control subjects and 11 patients with anterior THA were included, on the following criteria: age 50–80 years, body mass index (BMI) < 35 kg/m², unipodal balance \geq 10 s, and, in the case of the patients, first-line unilateral anterior THA for primary unilateral osteoarthritis of the hip. Patients were assessed at 45–60 days postoperatively. Exclusion criteria comprised: history of hip or knee arthroplasty; lower limb trauma in the preceding 6 months; neurologic, vestibular, visual, cardiovascular, respiratory, cognitive or psychiatric pathology; alcohol consumption during the 24 hours preceding assessment; and thromboembolic or infectious pathology. Eleven volunteer asymptomatic control subjects and 11 anterior THA patients (WOMAC score: 33.64 ± 26.80 ; Harris Hip Score: 80.64 ± 14.93) were recruited and matched for age, gender and BMI (Table 1).

THA material comprised: InstitutionTM femoral component (Lépine, Genay, France), MarkTM cemented polyethylene acetabular component (Lépine, Genay, France) and 28-diameter aluminum

Table 1

Comparison of groups (mean \pm standard deviation (range)).

	Anterior THA	Control	<i>p</i>
Age	64.55 \pm 9.53 (78–50)	62.36 \pm 8.15 (79–54)	0.57
Height (meters)	1.67 \pm 0.08 (1.78–1.55)	1.68 \pm 0.08 (1.82–1.59)	0.74
Weight (kg)	74 \pm 14.97 (104–49)	67.18 \pm 6.35 (75–58)	0.18
Body mass index	26.46 \pm 4.49 (33.57–19.89)	23.76 \pm 1.73 (27.55–21.13)	0.08

THA: total hip arthroplasty.

head. Abductor lever arm was restored: $\Delta \leq 5$ mm versus preoperative value on CT. All patients followed the same postoperative protocol: medical treatment, nursing care, first verticalization within 24–48 h, with full weight-bearing and aid (forearm crutch or walking-frame). No rehabilitation was prescribed at discharge from the surgery department.

2.2. Maximal voluntary contraction test

In each muscle, MVC was measured on manual testing [18,19] using the tests most commonly employed in sEMG studies [12,18]. Participants performed 8 MVC tests (2 per muscle), with manual resistance applied on the distal femur (Appendix 1):

- GMax test 1 (GMaxT1): extension in ventral decubitus;
- GMax test 2 (GMaxT2) extension in lateral decubitus;
- GMed test 1 (GMedT1): abduction in lateral decubitus (hip in extension);
- GMed test 2 (GMedT2): abduction in bipodal weight-bearing;
- TFL test 1 (TFLT1): abduction in lateral decubitus (hip in flexion);
- TFL test 2 (TFLT2): flexion in lateral decubitus;
- S test 1 (ST1): flexion/abduction/lateral rotation in dorsal decubitus;
- S test 2 (ST2): flexion/abduction/lateral rotation in seated posture.

Each test was performed twice at a weeks' interval, at the same time of day, with control of activity level during the preceding 24 h.

2.3. Postural tests

Participants then performed 3 postural tests on an AccuGaitTM force plate (AMTI, Watertown, MA, USA) for 10 or 50 s: bipodal, eyes closed (BEC), 50 s; unipodal on the operated side (UOP), 10 s; and unipodal on the non-operated side (UnOP), 10 s. The take-off and non-take-off foot (TOF, nTOF) were assessed separately in asymptomatic subjects and results were averaged.

Participants were barefoot, knees in extension and arms along the body, gaze horizontal focusing on a red dot 2 meters in front. Luminosity (2000 lux) and sound level were controlled during testing to avoid any outside interference. Participants had no pre-training in the tests before recording. In case of loss of balance, 3 trials per test were allowed.

2.4. Data processing

2.4.1. Postural analysis

An AMTI AccuGaitTM force plate (AMTI, Watertown, MA, USA) was used for stabilometry: recording frequency, 50 Hz; plate/computer feed and interface for analog-to-digital conversion (16bit): AMTI Model PJB-101TM (AMTI, Watertown, MA, USA).

The BalanceClinic application (version 1.4.2) recorded postural data: XAmpl: displacement amplitude (cm) of center of pressure along the mediolateral axis; YAmpl: displacement amplitude (cm) of center of pressure along the anteroposterior axis; Path Length: total distance (cm) covered by the center of pressure

during recording; VAvg: mean velocity (cm/s) of center of pressure displacement; and Area95: area (cm²) of the ellipse containing 95% of center of pressure projections during recording.

2.4.2. Surface electromyography

Four bipolar surface electrodes (SX-230, Biometrics Ltd, UK) were positioned according to SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) recommendations [20] over the GMax, GMed, TFL and S muscle bodies. Signals were recorded and filtered with 20–450 Hz bandpass and digitally sampled at 1000 Hz.

sEMG signals were offset by the resting EMG signal, smoothed by a sliding 50-Hz window, and rectified. Resting values were calculated from a specific recording. The value used for analysis was the minimum signal over 1 s as smoothed by the sliding 50-Hz window.

Methodology, and thus MVC, was assessed by selecting the maximal mean signal per test over a 0.3-s interval, normalized with the mean sEMG value on a 10-s unipodal test, after offset, smoothing and rectification.

$$\text{Value} = \frac{0.3 \text{ s Max of the offset and rectified MVC test}}{10 \text{ s Mean of offset and rectified Unipedal test}}$$

To assess sEMG activity under the various balance conditions (BEC, UOP and UnOP), signals were averaged over the test duration (10 or 50 s) and normalized according to sEMG on MVC test (maximum of normalized maxima per test) after offset, smoothing and rectification.

$$\text{Value} = \frac{(10 - 50 \text{ s}) \text{ Mean of offset and rectified postural test}}{0.3 \text{ s Max of the offset and rectified MVC test}}$$

2.5. Statistical analysis

Samples were characterized on descriptive statistics, with the mean as central measurement and the standard deviation and range as scatter measurements. Inter-group differences were assessed on non-parametric Mann-Whitney test to meet the minimal conditions of statistical power and robustness. Pearson correlation tests assessed correlations between muscle activity and postural parameters. First-order risk was set at 5%. Analyses used R software, version 2.14 (Bell Laboratories, Murray Hill, NJ, USA).

3. Results

3.1. Maximum voluntary contraction: differences between sessions and tests

There was no significant difference between MVC results between the 2 sessions at 1 week's interval ($p > 0.05$) (Table 2). There were no significant differences ($p > 0.05$) between MVC tests for abductors (GMax, GMed, TFL) versus flexors (TFL, S). Table 3 shows differences between the 8 tests for session 2 with respect to the respective reference tests: GMedT1 for GMax and GMed, and ST1 for TFL and S [18].

3.2. Balance test

3.2.1. Bipodal, eyes closed

GMax and GMed activity was greater in the anterior THA group on both UOP and UnOP than in the asymptomatic control group (Table 4). Force plate postural measurements showed inter-group differences: Path Length and VAvg were significantly greater in the anterior THA group than in controls (Table 4).

3.2.2. Unipodal

GMed activity was greater in the anterior THA group on both UOP and UnOP than in the asymptomatic control group (Table 5). GMax and TFL activity was greater in the anterior THA group on UOP only (Table 5). Force plate postural measurements showed inter-group differences: Path Length and VAvg were significantly greater in the anterior THA group than in controls (Table 5).

Significant correlations emerged for the anterior THA group: between Gmax and Xampl ($R = 0.61$; $p = 0.046$) for UOP; between Gmax and Xampl ($R = 0.71$; $p = 0.01$) and Area95 ($R = 0.64$; $p = 0.03$) for UnOP; and between both TFL and S and XAmpl ($R = 0.93$; $p = 0.00004$ and $R = 0.77$; $p = 0.006$, respectively), Path Length ($R = 0.85$; $p = 0.0009$ and $R = 0.62$; $p = 0.04$), VAvg ($R = 0.85$; $p = 0.0009$ and $R = 0.62$; $p = 0.04$), and Area95 ($R = 0.86$; $p = 0.0008$ and $R = 0.59$; $p = 0.05$) for UnOP (Fig. 1).

Table 2

Surface electromyography activity of each muscle in 2 maximum voluntary contraction test sessions. Mean ± standard deviation (range) in anterior total hip arthroplasty group on operated side (maximum value of 8 tests).

	Session 1	Session 2	p
Gluteus maximus	4.56 ± 3.01 (1.03–11.91)	6.56 ± 3.6 (1.99–13.26)	0.17
Gluteus medius	3.87 ± 1.25 (2.01–5.59)	6.35 ± 4.34 (1.78–14.49)	0.37
Tensor fasciae latae	28.88 ± 31.72 (4.64–105.9)	24 ± 34.78 (3.28–106.11)	0.4
Sartorius	27.49 ± 25.62 (5.77–90.94)	29.28 ± 35.65 (5.02–123.84)	0.61

Table 3

Surface electromyography activity of each muscle on the 8 tests. (maximal voluntary contraction session 2).

	Gluteus maximus	Gluteus medius	Tensor fasciae latae	Sartorius
GMaxT1	4.53 ± 3.49 (1.21–13.26)	3.15 ± 2.59 (1.17–10.21)	1.76 ± 1.82 (0.14–5.89) ^b	3.67 ± 4.47 (0.23–16.24) ^b
GMaxT2	3.89 ± 3.68 (0.26–10.76)	3.06 ± 3.1 (1.01–11.79)	1.7 ± 1.44 (0.27–5.35) ^b	2.63 ± 2.46 (0.53–8.21) ^b
GMedT1	4.07 ± 2.74 (0.95–9.19) ^a	3.85 ± 2.5 (1.38–9.17) ^a	11.41 ± 20.2 (1.82–71.06)	10.02 ± 134.86 (1.96–53.53)
GMedT2	4.02 ± 2.83 (1.28–10.59)	5.29 ± 4.12 (1.52–14.89)	9.21 ± 7.51 (1.91–27.79)	9.31 ± 10.06 (1.79–34.12)
TFLT1	2.34 ± 2.21 (0.38–7.9)	3.08 ± 2.15 (1.31–7.69)	16.16 ± 25.92 (1.8–89.4)	11.87 ± 17.9 (1.77–63.93)
TFLT2	0.99 ± 1.02 (0.1–3.5) ^b	2.29 ± 1.17 (0.71–4.28)	14.91 ± 24.47 (2.11–84.62)	10.21 ± 15.49 (2.42–55.06) ^b
ST1	0.47 ± 0.3 (0.12–1.1) ^b	1.52 ± 0.86 (0.41–3.73) ^b	22.63 ± 35.43 (2.24–106.11) ^a	23.78 ± 27.76 (3.46–87.89) ^a
ST2	0.51 ± 0.35 (0.12–1.41) ^b	1.54 ± 0.62 (0.43–2.6) ^b	16.73 ± 23.13 (2.75–81.25)	21.38 ± 34.41 (5.01–123.84)

GMaxT1: hip extension in prone position; GMaxT2: hip extension in lateral decubitus; GMedT1: hip abduction in lateral decubitus (hip in extension); GMedT2: hip abduction in bipodal weight-bearing; TFLT1: hip abduction in lateral decubitus (hip in flexion); TFLT2: hip flexion in lateral decubitus; ST1: hip flexion/abduction/lateral rotation in supine position; ST2: hip flexion/abduction/rotation in seated posture.

^a Reference test: GMedT1 for GMax and GMed, ST1 for TFL and S.

^b Significant difference ($p < 0.05$) with respect to reference test.

Table 4
Surface electromyography and postural parameters for bipodal eyes-closed test. Mean \pm standard deviation (range).

	Anterior THA		Asymptomatic controls	p-value
	Operated side (Op)	Non-operated side (nOP)	Asymptomatic (AS)	OP vs AS/nOP vs AS
Gluteus maximus	0.15 \pm 0.12 (0.06–0.49)	0.12 \pm 0.06 (0.04–0.25)	0.07 \pm 0.06 (0.01–0.22)	$p = 0.006/p = 0.01$
Gluteus medius	0.13 \pm 0.08 (0.03–0.31)	0.13 \pm 0.06 (0.05–0.25)	0.08 \pm 0.05 (0.01–0.24)	$p = 0.05^*/p = 0.005$
Tensor fasciae latae	0.06 \pm 0.07 (0.01–0.23)	0.03 \pm 0.02 (0.01–0.08)	0.03 \pm 0.02 (0–0.08)	$p = 0.22/p = 0.78$
Sartorius	0.04 \pm 0.04 (0.01–0.14)	0.03 \pm 0.03 (0.01–0.11)	0.03 \pm 0.03 (0.01–0.4)	$p = 0.99/p = 0.56$
XAmpl (cm)	1.4 \pm 0.5 (0.7–2.3)	1.5 \pm 0.6 (1–2.6)		$p = 0.98$
YAmpl (cm)	3 \pm 0.94 (2.19–6.11)	3.3 \pm 1 (2.2–5.3)		$p = 0.26$
Path Length (cm)	101 \pm 24.1 (61.9–138.1)	78.5 \pm 10.5 (62.3–95)		$p = 0.013$
VAvg (cm/s)	2 \pm 0.5 (1.2–2.8)	1.6 \pm 0.2 (1.2–1.9)		$p = 0.02$
Area95 (cm ²)	2.6 \pm 1.5 (0.8–8.1)	3 \pm 1.5 (1.4–6.1)		$p = 0.31$

For asymptomatic subjects, mean of take-of and non-take-off foot values. XAmpl: center of pressure (CP) displacement amplitude along mediolateral axis; YAmpl: CP displacement amplitude along anteroposterior axis; Path Length: total distance covered by CP during recording; VAvg: average velocity of CP displacement; Area95: area of ellipse containing 95% of CP projections during recording.

* p rounded off to 0.05.

Table 5
Surface electromyography activity and postural parameters on unipodal test. Mean \pm standard deviation (range).

	Anterior THA		Asymptomatic controls	p-value
	Operated side (Op)	Non-operated side (nOP)	Asymptomatic (AS)	OP vs AS/nOP vs AS
Gluteus maximus	0.49 \pm 0.43 (0.13–1.6)	0.34 \pm 0.28 (0.05–0.82)	0.24 \pm 0.18 (0.02–0.7)	$p = 0.04/p = 0.61$
Gluteus medius	0.51 \pm 0.3 (0.15–1.1)	0.48 \pm 0.27 (0.12–0.99)	0.28 \pm 0.13 (0.11–0.61)	$p = 0.02/p = 0.04$
Tensor fasciae latae	0.23 \pm 0.17 (0.02–0.52)	0.16 \pm 0.22 (0.01–0.73)	0.12 \pm 0.16 (0.01–0.72)	$p = 0.05^*/p = 0.73$
Sartorius	0.15 \pm 0.11 (0.02–0.31)	0.09 \pm 0.11 (0.01–0.4)	0.09 \pm 0.12 (0.01–0.34)	$p = 0.17/p = 0.9$
XAmpl (cm)	8 \pm 8.2 (2.6–25.4)	5.8 \pm 5.2 (1.9–17.6)	3.2 \pm 0.5 (2.3–4.4)	$p = 0.28/p = 0.39$
YAmpl (cm)	6 \pm 3.9 (2.9–13.8)	4.8 \pm 2.8 (2.5–10.4)	3.5 \pm 0.7 (2.8–4.6)	$p = 0.06/p = 0.86$
Path Length (cm)	89 \pm 45.5 (35.2–201.2)	84.7 \pm 42 (33.3–165.9)	48.8 \pm 10 (37.7–73)	$p = 0.003/p = 0.004$
VAvg (cm/s)	8.9 \pm 4.5 (3.5–20.1)	8.5 \pm 4.2 (3.3–16.6)	4.9 \pm 1 (3.8–7.3)	$p = 0.003/p = 0.004$
Area95 (cm ²)	45.5 \pm 64 (7.9–191.4)	29.8 \pm 33.3 (5.1–97.1)	10.1 \pm 3.3 (6.2–17.9)	$p = 0.08/p = 0.51$

For asymptomatic subjects, mean of take-of and non-take-off foot values. XAmpl: center of pressure (CP) displacement amplitude along mediolateral axis; YAmpl: CP displacement amplitude along anteroposterior axis; Path Length: total distance covered by CP during recording; VAvg: average velocity of CP displacement; Area95: area of ellipse containing 95% of CP projections during recording.

* p rounded off to 0.05.

4. Discussion

Static postural balance following THA is increasingly studied [21], particularly since the spread of minimally invasive approaches [1,5], which theoretically spare muscular and capsular elements and are expected to shorten postoperative course and hospital stay, although results are in fact controversial [2–5]. Data on posture and sEMG in periarticular muscles involved in anterior THA should supplement existing evidence. Methodology for sEMG lacks consensus [6–17], and we therefore first assessed a protocol that had proved effective in asymptomatic subjects [18]. We then analyzed sEMG activity and postural variables in anterior THA patients and asymptomatic controls, under BEC static balance to highlight proprioception, and under unipodal stance. To the best of our knowledge, this was the first sEMG study of static balance in THA.

We found that a single 2-test session was enough to assess MVC and normalize sEMG signals, confirming the findings of Bernard et al. [18]. The GMedT1 test (hip abduction in lateral decubitus (hip in extension)) was enough to determine sEMG activity in GMax and GMed during MVC, and ST1 (flexion/abduction/lateral rotation in dorsal decubitus) was enough to determine sEMG activity in TFL and S during MVC. These 2 tests are the easiest to perform, and no significant differences emerged between MCV results in abductors (GMax, GMed, TFL) or flexors (TFL, S). This will allow sEMG research protocols for these 4 periarticular hip muscles to be simplified, reducing muscle fatigue for patients following THA, whatever the approach.

GMed activity was greater on both bipodal and unipodal tests after anterior THA than in asymptomatic controls. As expected,

GMed but also GMax and TFL activity was greater after anterior THA than in asymptomatic controls: on BEC tests (GMed and GMax) and unipodal tests (GMed, GMax and TFL). These 3 muscles are the main mediolateral hip stabilizers, and the fact that they are more active following THA testifies to greater energy expenditure to maintain static postural balance, both with eyes closed (BEC) and unipodally. This is further evidence for what is already known from postural studies [1,5]: static postural balance is impaired by THA. Moreover, like Quagliarella et al. [1] and Van Driessche et al. [5], we found that THA patients showed greater displacement of the center of pressure (Path Length) and greater displacement velocity than controls. Certain correlations also emerged between sEMG and postural data: in anterior THA patients, TFL and S sEMG activity correlated with almost all postural parameters (XAmpl, Path Length, VAvg and Area95) on the non-operated but not on the operated side. This is in agreement with Van Driessche et al.'s hypothesis [5] that balance disorder in anterior THA patients is due to intraoperative TFL and S stretching by the retractors. Moreover, the vascular trauma associated with the anterior approach, due to ligating the anterior circumflex artery, induces postoperative TFL hypotrophy. TFL and S contain a large number of neuromuscular spindles and may play a major role in static balance regulation, which may account for the large number of recalcitrant gluteus medius tendinites observed in anterior THA patients. Although GMed is spared on the anterior approach, it is essential for active pelvic stabilization and is highly active, as the present sEMG data show. As posture regulation involves anticipation and feedback via mechanoreceptors in the aponeuroses, tendons and muscles, TFL and S lesions may be partly responsible for loss of regulation. Amiridis et al. [7] showed that over-60 year-olds tend to use hip

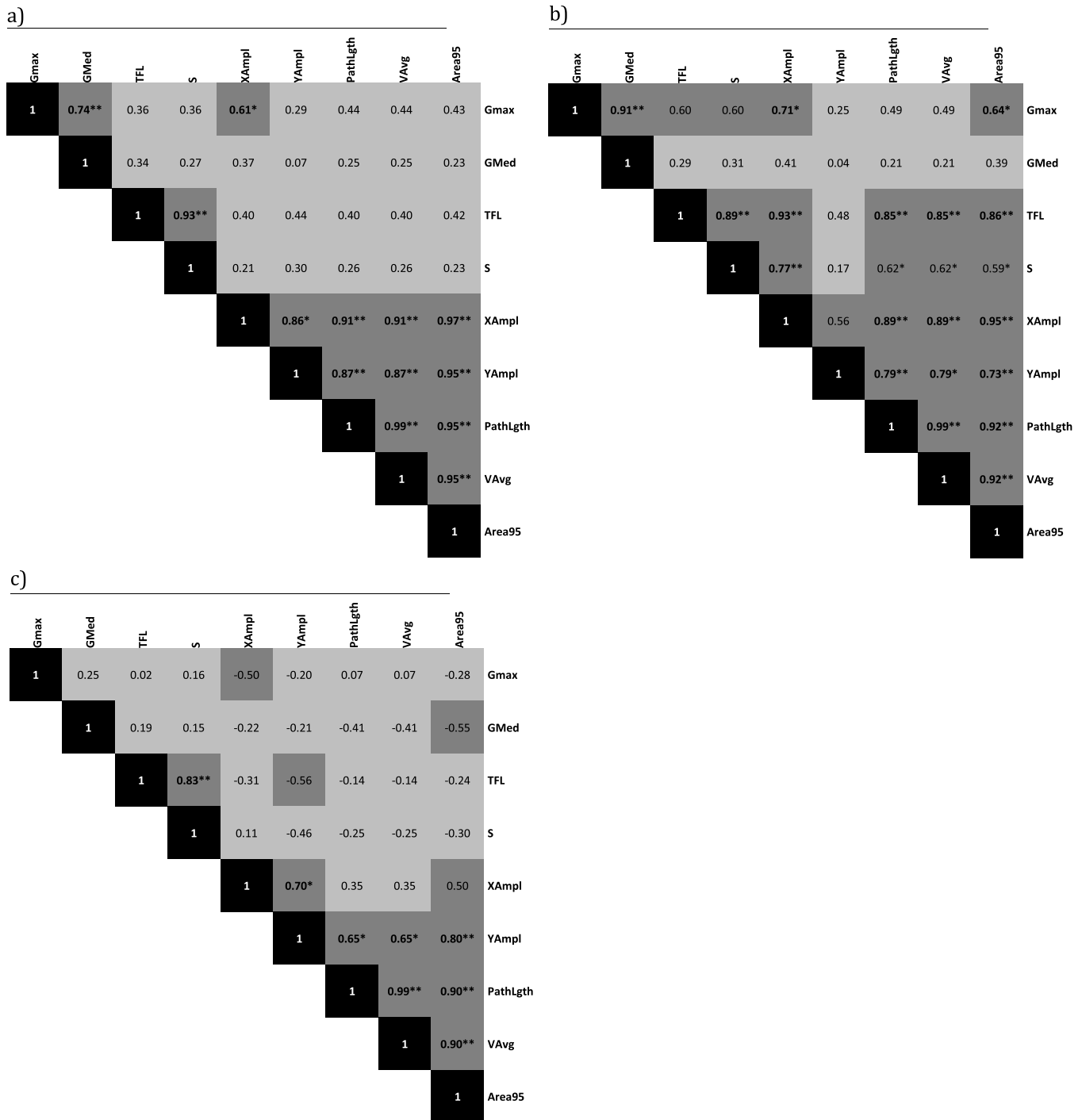


Fig. 1. Correlations between Surface electromyography and postural parameters on unipodal test: a: anterior total hip arthroplasty group, operated side (OP); b: anterior total hip arthroplasty group, non-operated side (nOP); c: asymptomatic group. GMax: gluteus maximus; GMed: gluteus medius; TFL: tensor fasciae latae; S: sartorius; XAmpl: center of pressure (CP) displacement amplitude along mediolateral axis; YAmpl: CP displacement amplitude along anteroposterior axis; Path Length: total distance covered by CP during recording; VAvg: average velocity of CP displacement; Area95: area of ellipse containing 95% of CP projections during recording. *Significant at $p < 0.05$; **significant at $p < 0.01$. Significant correlations between Surface electromyography and postural parameters on unipodal test (*, **). For anterior total hip arthroplasty group: between Gmax and Xampl on OP side (a), between Gmax and Xampl and Area95 on nOP side (b), and between TFL and S and XAmpl, Path Length, VAvg and Area95 on nOP side (b). Correlations between Surface electromyography and postural parameters confirm the hip as the origin of the postural disorder. Postural disorder is associated with activity of muscles crossing the hip joint.

muscles to maintain static balance, in a so-called “hip strategy”, due to diminished strength and distal proprioceptive afference [7], accounting for postural disorder since the main components of balance in this population are impaired. These findings agree with the literature: Poehling-Monaghan et al. [4] showed that patients recovered more slowly when operated on via an anterior than a

posterior approach; Van Driessche et al. [5] showed that the anterior approach was associated with greater postural impairment than other minimally invasive approaches; and Rodriguez et al. [22] showed that postoperative rehabilitation was not shorter for patients operated on via an anterior approach.

The present study involved several limitations:

- small sample size limited the power to disclose significant differences, notably for correlations between sEMG and postural parameters; however, statistical tests were non-parametric;
- inter-observer reproducibility was not assessed for MVC tests. These should be performed by an experienced investigator, as variability can be considerable, given the techniques employed; on the other hand, there were no significant differences between the two trials, indicating that intra-observer reproducibility was good;
- there was no preoperative assessment, which could have shed greater light on the impact of surgery on postural and sEMG parameters; pain and restricted range of motion prevented assessment of sEMG activity associated with MVC, hindering pre- to post-operative comparison;
- there were no THA groups with posterior or anterolateral approaches; the study focused on the anterior approach, but comparison between approaches would broaden perspectives. Such a study is underway, and results will be reported.

5. Conclusion

The study hypothesis was confirmed: sEMG activity in the hip abductors, which are the main pelvis stabilizers, is increased after anterior THA. This is associated with deterioration in postural parameters such as displacement and mean velocity of the center of pressure, which were greater than in asymptomatic subjects. This may be due to intraoperative lesions to the neuromuscular spindles in the TFL and S muscles.

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None.

Contribution of the authors

Project management: Billuart, Beldame, Matsoukis, Van Driessche, Razanabola.

Data collection: Bernard, Billuart.

Writing: Bernard, Razanabola, Billuart.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at [doi:10.1016/j.plantsci.2004.08.011](https://doi.org/10.1016/j.plantsci.2004.08.011).

References

- [1] Quagliarella L, Sasanelli N, Monaco V, Belgiovine G, Spinarelli A, Notarnicola A, et al. Relevance of orthostatic posturography for clinical evaluation of hip and knee joint arthroplasty patients. *Gait Posture* 2011;34:49–54.
- [2] Malagelada F, Del Carmen VA, Barke SJ, Guirao Cano L, Pleguezuelos Cobo E. The anterior mini-open approach for femoroacetabular impingement: gait and functional assessment at one year post-surgery. *Ann Phys Rehabil Med* 2015;58:60–5.
- [3] Mirza AJ, Lombardi Jr AV, Morris MJ, Berend KR. A mini-anterior approach to the hip for total joint replacement: optimising results: improving hip joint replacement outcomes. *Bone Joint J* 2014;96:32–5.
- [4] Poehling-Monaghan KL, Kamath AF, Taunton MJ, Pagnano MW. Direct anterior versus minimiposterior THA with the same advanced perioperative protocols: surprising early clinical results. *Clin Orthop Relat Res* 2015;473:623–31.
- [5] 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.
- [6] Agostini V, Ganio D, Facchin K, Cane L, Moreira Carneiro S, Knafitz M. Gait parameters and muscle activation patterns at 3, 6 and 12 months after total hip arthroplasty. *J Arthroplasty* 2014;29:1265–72.
- [7] Amiridis IG, Hatzitaki V, Arabatzi F. Age-induced modifications of static postural control in humans. *Neurosci Lett* 2003;350:137–40.
- [8] Billot M, Simoneau EM, Van Hoecke J, Martin A. Age-related relative increases in electromyography activity and torque according to the maximal capacity during upright standing. *Eur J Appl Physiol* 2010;109:669–80.
- [9] Burden A, Bartlett R. Normalisation of EMG amplitude: an evaluation and comparison of old and new methods. *Med Eng Phys* 1999;21:247–57.
- [10] Claudino R, dos Santos EC, Santos MJ. Compensatory but not anticipatory adjustments are altered in older adults during lateral postural perturbations. *Clin Neurophysiol* 2013;124:1628–37.
- [11] French HP, Huang X, Cummiskey A, Meldrum D, Malone A. Normalisation method can affect gluteus medius electromyography results during weight bearing exercises in people with hip osteoarthritis (OA): a case control study. *Gait Posture* 2015;41:470–5.
- [12] Halaki M, Ginn K. Normalization of EMG signals: to normalize or not to normalize and what to normalize to? INTECH; 2012 [Last access June 1, 2017] <https://www.intechopen.com/books/computational-intelligence>.
- [13] Horstmann T, Listringhaus R, Haase G-B, Grau S, Mündermann A. Changes in gait patterns and muscle activity following total hip arthroplasty: a six-month follow-up. *Clin Biomech* 2013;28:762–9.
- [14] Lin HT, Hsu AT, Chang JH, Chien CS, Chang GL. Comparison of EMG activity between maximal manual muscle testing and cybex maximal isometric testing of the quadriceps femoris. *J Formos Med Assoc* 2008;107:175–80.
- [15] Mohamed O, Perry J, Hislop H. Relationship between wire EMG activity, muscle length, and torque of the hamstrings. *Clin Biomech* 2002;17:569–79.
- [16] Santos MJ, Kanekar N, Aruin AS. The role of anticipatory postural adjustments in compensatory control of posture: 1. Electromyographic analysis. *J Electromyogr Kinesiol* 2010;20:388–97.
- [17] Tsai YC, Hsieh LF, Yang S. Age-related changes in posture response under a continuous and unexpected perturbation. *J Biomech* 2014;47:482–90.
- [18] Bernard J, Beldame J, Van Driessche S, Brunel H, Poirier T, et al. Does hip-joint positioning affect maximal voluntary contraction in the gluteus maximus, gluteus medius, tensor fasciae latae and sartorius muscles? *Orthop Traumatol Surg Res* 2017;103:999–1004.
- [19] Hislop HJ, Montgomery J. Daniels and Worthingham's muscle testing: techniques of manual examination. 8th ed. St Louis, MO: Saunders/Elsevier; 2007.
- [20] Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol* 2000;10:361–74.
- [21] Szymanski C, Thouvarecq 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.
- [22] Rodriguez JA, Deshmukh AJ, Rathod PA, et al. Does the direct anterior approach in THA offer faster rehabilitation and comparable safety to the posterior approach? *Clin Orthop Relat Res* 2014;472:455–63.