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Case report

Muscle activation pattern during gait and stair activities following total hip arthroplasty with a direct anterior approach: a comprehensive case study

Swati Chopra, PhD [a], Michael Taunton, MD [b], Kenton Kaufman, PhD [a,*]

[a] Motion Analysis Laboratory, Mayo Clinic, Rochester, MN, USA
[b] Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN, USA

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ABSTRACT

Muscle activation following total hip arthroplasty with a direct anterior approach has not previously been reported in the literature. This case report details the electromyography outcome of a 60-year-old male patient with unilateral direct anterior approach-total hip arthroplasty during walking and stair activities. Outcome reports the continuation of altered muscle activation 12 months postoperatively, even with a good clinical outcome.

Introduction

Total hip arthroplasty (THA) is one of the most common and successful surgical procedures in orthopaedics [1]. Various approaches for THA exist, with direct anterior approach (DAA) considered to be the least traumatic to the soft tissues and thus exhibiting faster recovery. Following DAA, patients are expected to recover within 2 weeks postoperatively, so are therefore not prescribed postoperative physical therapy [2]. Studies objectively assessing all THA approaches have found no significant difference 1-2 years postoperatively [3,4], but report inconsistent outcomes in the early postoperative gait [5–7]. One study assessing muscle structure 2 years postoperatively reported a persistent reduction in the cross-sectional area and density of the muscles around the hip joint [8]. Moreover, muscle function following DAA-THA was and has not previously been presented. As such, the following case report presents an empirical outcome analysis of muscle function recovery following DAA-THA.

Case history

A 60-year-old male with symptoms of severe right hip pain and stiffness is presented. Anteroposterior (AP) and cross-table lateral radiographs diagnosed bilateral advanced hip arthritis with bone-on-bone changes. The arthritic pattern was consistent with cam-type femoroacetabular impingement with secondary arthritis. The left hip, however, was asymptomatic. The patient reported no other joint or chronic health problems. The patient was a power lifter as a young adult.

DAA-THA was performed on the right hip in 2014 at the Mayo Clinic in Rochester, MN. Based on the previously described standardized surgical technique [9], an oblique incision was made over the anterior margin of the tensor muscle ~2 cm lateral from the anterior superior iliac spine and extending 8-12 cm. The fascia of the tensor muscle was identified and incised. The muscle was swept digitally-laterally and a retractor was placed over the superior aspect of the femoral neck. A retractor was then placed beneath the inferior femoral neck. The ascending branch of the lateral femoral circumflex artery was identified and cauterized. The hip capsule was then incised and retracted. A measured resection of the

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* Corresponding author. 200 First Street SW, Rochester, MN 55905, USA. Tel.: +1 507 282 2262.

E-mail address: kaufman.kenton@mayo.edu

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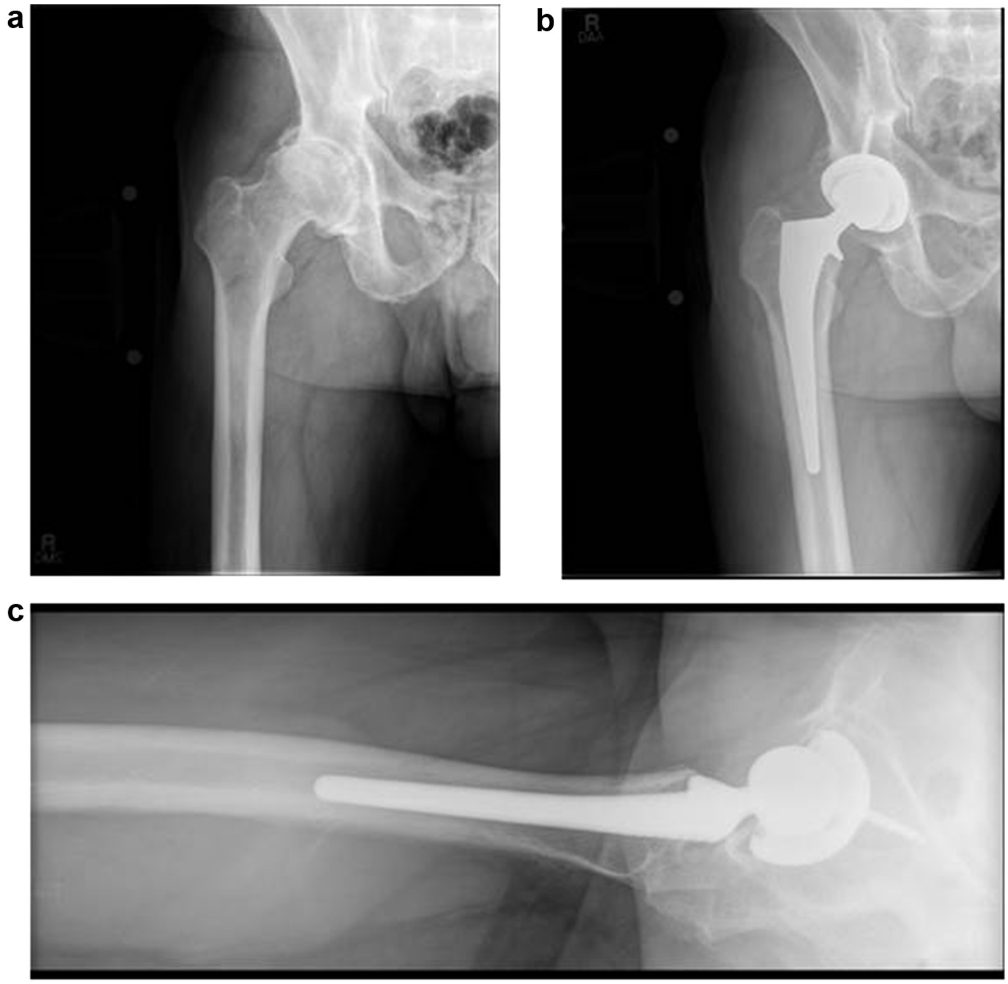

Figure 1. Preoperative anteroposterior (AP) (a), postoperative AP (b), and cross-table lateral (c) radiographic imaging of the right hip. Implant positioning postoperatively is found to be optimal.

femoral neck was performed with the assistance of fluoroscopy and preoperative templates. The traction was released and the leg was left in a slightly externally rotated position. Retractors were then placed to expose the acetabulum. Acetabular reaming was performed with the fluoroscopic assistance and direct visualization. After placement of the acetabular component and fluoroscopic confirmation of the position, attention was directed to the femur. A retractor hook was placed beneath the femur in the recess of the vastus lateralis ridge. This hook was contoured to avoid soft tissue injury. The operative extremity was externally rotated, extended, and adducted, allowing axial access to the proximal femur. Releases typically include superior capsular release, inferior capsular release, and often piriformis release in the piriformis fossa. The posterior muscular structures remain intact. Surgical implantation of the femoral implant trial was followed by a trial reduction. The femoral component sizing, offset, and leg length was evaluated fluoroscopically. After appropriate sizing, the final femoral implant was placed. Trial head sizes were performed. After placement of the final arthroplasty head, closure included reapproximation of the anterior capsule and interrupted Vicryl suture closure of the tensor fascia. Subcutaneous closure and skin closure were per routine. Components utilized included the following: a hemispherical uncemented acetabular component, pinnacle, an uncemented hydroxyapatite-coated femoral stem, corail, and ceramic femoral heads on highly cross-linked ultra-high molecular weight polyethylene acetabular bearing surfaces (DePuy). All components have been approved by the U.S. Food and Drug Administration.

The patient was trained to use crutches and a cane and was asked to bear as much weight as tolerable on the operated side. Physical therapy was not prescribed to the patient following discharge from the hospital. The patient was discharged 2 days after surgery. Patient consent was taken to publish the medical records as a case report.

The patient's preoperative and postoperative subjective Harris hip scores were 64/100 and 100/100, respectively. Radiographic preoperative and 3-month postoperative outcome is shown in Figure 1. Objective biomechanical assessment, including comprehensive bilateral gait and stair climbing assessments, was carried out preoperatively as well as 3 and 12 months postoperatively.

Table 1
Average walking speed (m/s).

Speed	Level walking	Stair ascend	Stair descend
Preoperative	1.17	0.59	0.57
Three-month DAA-THA	1.28	0.56	0.52
Twelve-month DAA-THA	1.30	0.62	0.59
Normal older control average (SD) [14]	1.31 (0.23)	0.55 (0.11)	0.67 (0.11)

SD, standard deviation.

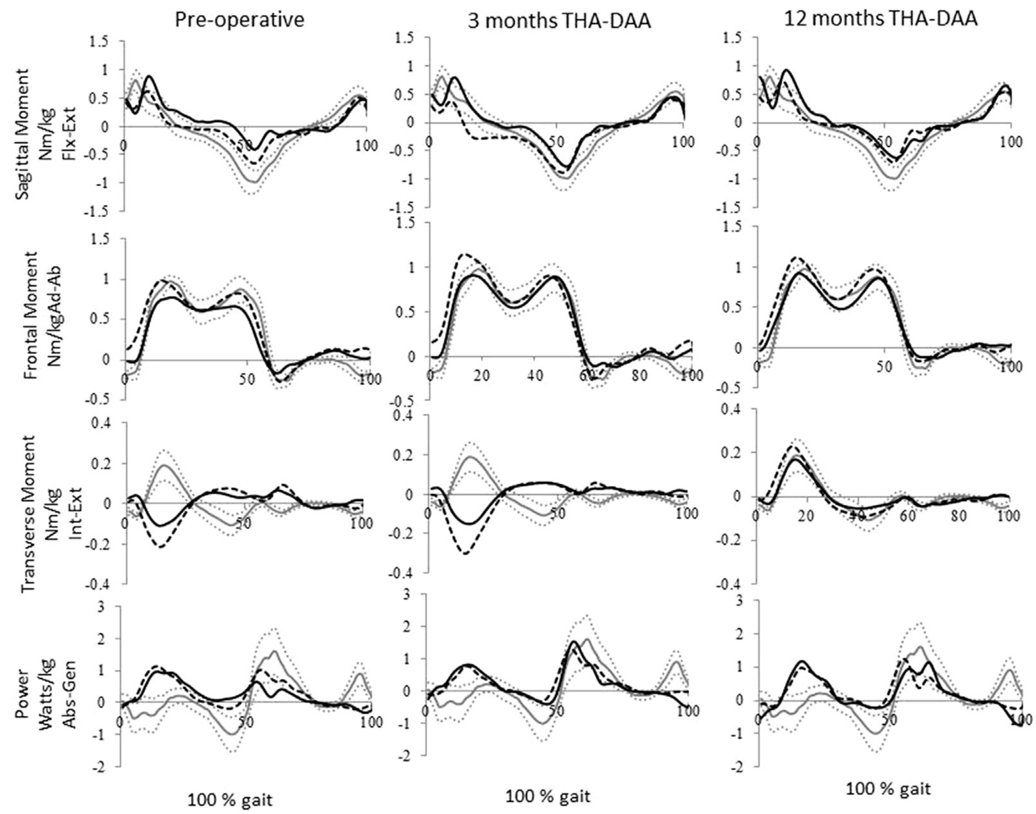

Figure 2. Moment and power outcome over 100% of the gait cycle. Gray solid and dashed lines represent means and standard deviation in controls; black solid lines represent operated side and black dotted lines represent the contralateral asymptomatic side.

A control dataset ($n = 10$) from the same laboratory was used as a reference. For each of the 3 visits, 3 trials were performed for each activity including level walking, stair ascending, and stair descending. Gait data were captured at 120 fps with 10 infrared cameras (Raptor-12 cameras; Motion Analysis Corporation, Santa Rosa, CA) and an electromyography (EMG) system (MA300; Motion Lab Systems, Inc., Baton Rouge, LA). Surface and fine-wire EMG data were collected at 2400 Hz, rectified and passed through a fourth order, low-pass Butterworth filter with a 6 Hz cutoff using custom MATLAB (MathWorks, Natick, MA) scripts [10]. EMG data were collected from the major hip muscles including the gluteus maximus (G Max), gluteus medius (G Med), iliopsoas (IP), tensor fascia lata (TFL), rectus femoris (RF), hamstrings (HM), and lumbar paraspinal (LPS) muscles. Parameters evaluated included joint kinematics and kinetics as well as time (TEMG) and frequency (FEMG) domain analysis of the EMG. TEMG monitors muscle activation in a gait cycle. FEMG is used to determine muscle dystonic behavior [11]. Typical FEMG median power frequency (MdPF) for slow and fast twitch muscle fibers are 70-125 and 126-250 Hz, respectively [10]. As such, if a muscle MdPF is read to be <70 Hz, it is considered to be dystonic [10]. Muscle MdPF >200 Hz also represents abnormal muscle activation and may represent failure to produce the maximum voluntary isometric contraction. Note that muscle activation during walking and stair activities should not be compared. The higher activity recorded during stair activities is due to the increased range of hip motion, requiring the muscle to produce enough power to complete the movement [10].

The patient exceeded their self-selected walking speed 3 months postoperatively, further increasing after 12 months (Table 1), representing an overall postoperative improvement. Joint moments in all 3 planes of motion showed a general improvement postoperatively compared to the preoperative outcome with an exception of the transverse moment continuing an atypical external rotation during initial stance and internal rotation during late stance, at 3 months postoperatively (Fig. 2). However, this atypical moment pattern resolved by 12 months postoperatively. Joint power also reported a postoperative improvement, except the abnormal power absorption at heel strike reported at 12 months

Table 2
Median power frequency EMG outcome for operated and contralateral asymptomatic side.

Muscles	Preoperative		Three-month postoperative		Twelve-month postoperative	
	Rt.	Lt.	Operated (Rt.)	Unoperated (Lt.)	Operated (Rt.)	Unoperated (Lt.)
G Max	67.3 (2.3)	70.3 (1.1)	48.7 (4.5)	67.3 (2.3)	51 (3.6)	62 (1.41)
G Med	152.3 (11.0)	208.7 (3.5)	98.7 (7.8)	89 (3.6)	121.7 (7.5)	159.3 (6.7)
Hamstrings	84.3 (8.5)	79 (7.5)	84 (4.6)	76.3 (2.1)	84.7 (4.5)	74 (2)
Iliopsoas	210.5 (6.4)	78 (11.3)	52 (0)	103 (19.8)	36 (2.8)	30.3 (2.1)
Lumbar	62.0 (2.6)	71.3 (2.1)	63.7 (4.5)	75 (6)	82.3 (3.2)	44.7 (5.0)
RF	65.7 (2.1)	72 (5)	84 (9.6)	81.3 (4.2)	79.3 (4.2)	78.3 (3.2)
TFL	77.0 (0)	42 (2.6)	80 (3)	94 (1)	73.3 (4.2)	73.7 (3.8)

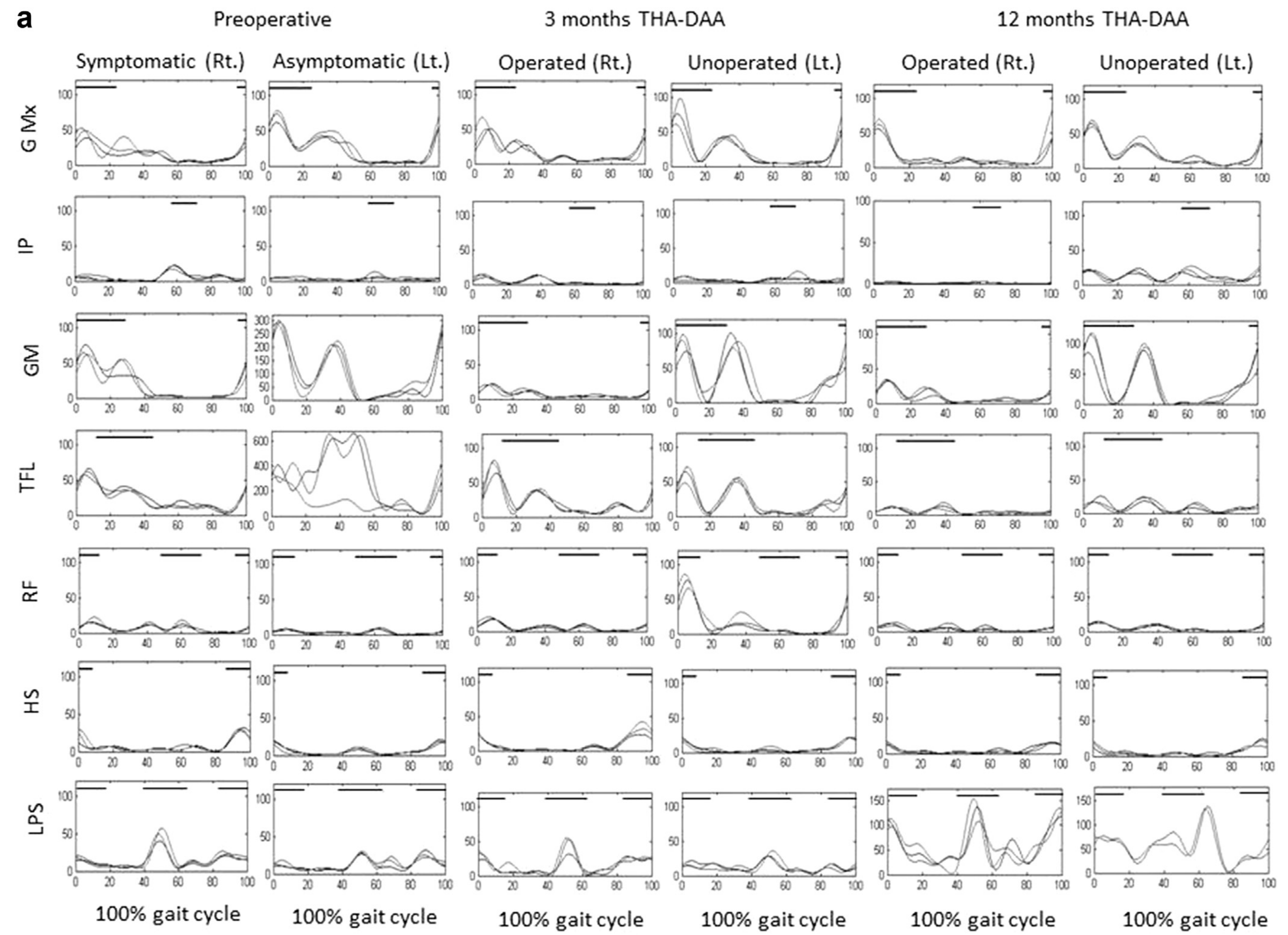

Figure 3. Time domain EMG outcome over 100% of the gait cycle in % of maximum voluntary isometric contraction during 3 trials of (a) level walking, (b) stair ascent, and (c) stair descent. Black horizontal lines represent the period of normal muscle activation in a gait cycle; 3 vertical lines near 60% of the cycle represent toe-off for each of the 3 trials. GM, gluteus medius; G Mx, gluteus maximus; HS, hamstrings.

postoperatively. Note, however, that the first peak of the power curve of the controls in this study was in contrast with the literature. Kinematic outcome at the hip joint in the sagittal plane preoperatively showed an average range of motion (RoM) of 33° (Max Flx. +45°/Max. Ext +18.2°), while at 12 months postoperatively, the RoM was seen to reduce to 24.2° (Max Flx. +42.4°/Max. Ext +0.42°). At 12 months postoperatively, during the end of stance phase, the hip was seen to stay in a less flexed position compared to preoperatively; however, the optimal hip extension was still not resumed. Detailed RoM in 3 planes for lower limb joints are given in Appendix I. The MdPF of the studied muscles during level walking is shown in Table 2. IP and G Max continued to show abnormal MdPF postoperatively, representing dystonic behavior. However, it was suggested not to consider MdPF outcome of G Max literally because of high chances of intrinsic noise in the EMG recording due to the general high volume of adipose tissue at the gluteal region [12]. Finally, TEMG for the hip muscles during all activities reported alterations and notable compensatory patterns, both preoperatively and postoperatively, specifically in IP, RF, TFL, and LPS muscles (Fig. 3).

Discussion

This case report looked at the outcome of DAA-THA in terms of muscle efficiency in a 60-year-old male patient. The patient, formerly a competitive power lifter, exhibited an impressive muscular physique. An outcome analysis of muscle activation, compensation, and adaptation during different phases of the gait cycle is discussed.

Muscles contract concentrically, eccentrically, and/or isometrically based on their function. Contractions lead to power generation and absorption which are important for a smooth and energy efficient gait. Following symptomatic femoroacetabular impingement and hip arthritis, hip muscle weakness has been reported, leading to suboptimal muscle function and altered power generation [13,14]. This study reports similar results which can be seen via insufficient joint power, moments, TEMG, and FEMG outcomes.

Looking at the sagittal plane, 1 year postoperatively, the pelvis stayed in an anterior position and both the hip and knee stayed in a flexed position. However, the trunk leaned more posteriorly in a hyperextended position, suggesting a thoracic kyphotic and lumbar lordotic posture. This specific postural orientation was the result of having shortened IP, LPS, and HM muscles. The activation pattern of these muscles confirmed their inefficient function (Fig. 3a). The low MdPF reported for the IP and left LPS also depicted dystonic behavior. Moreover, the aphasic low amplitude contraction of RF and HM notably continued to exist at 1 year postoperatively, and the flexion moment continued to stay low at both the hip and knee joints. This resulted in overall reduction of power generation at the

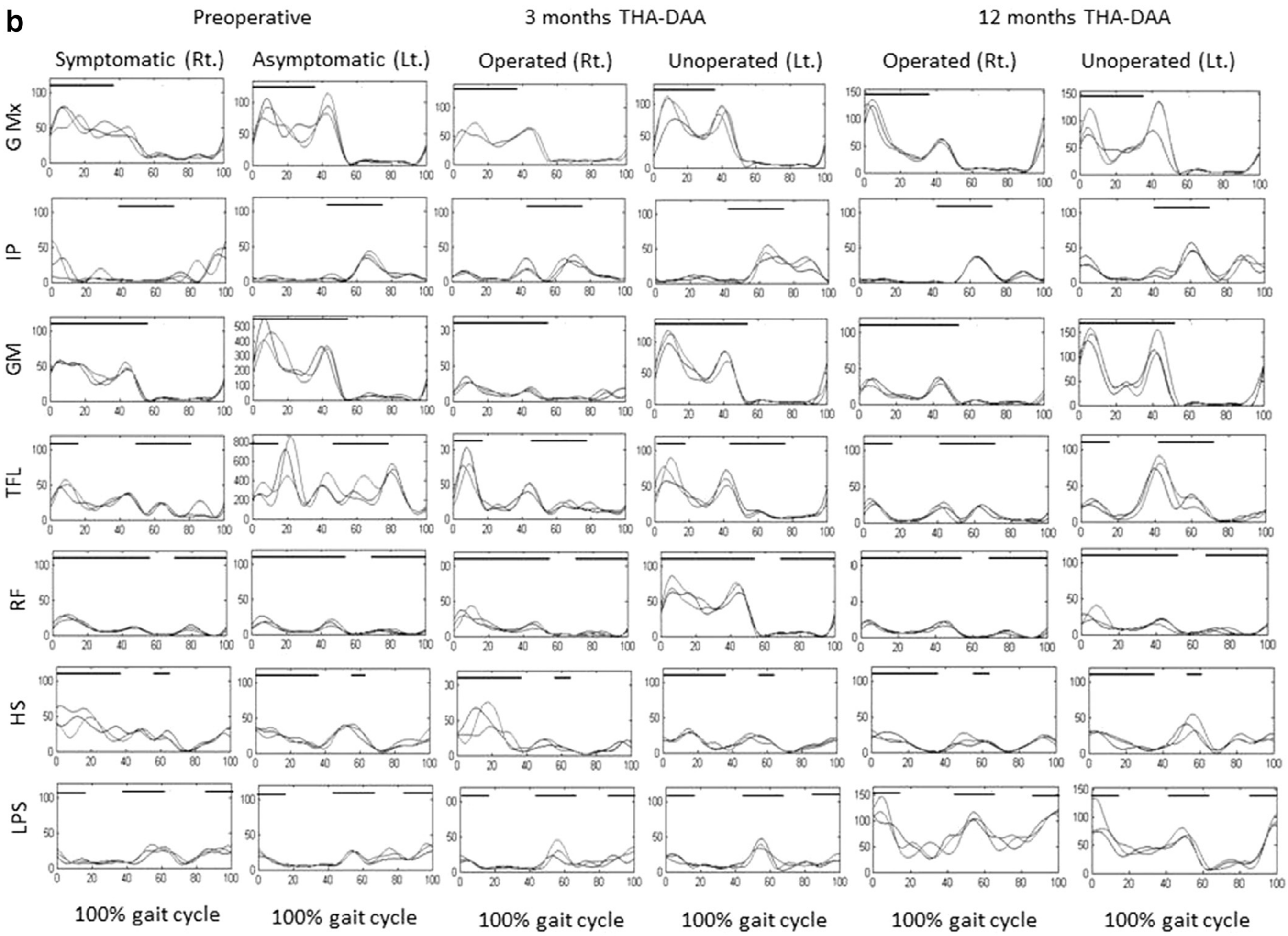

Figure 3. (*continued*).

hip to initiate swing and therefore a reduction in power absorption at the knee to decelerate the leg for initial contact.

In the frontal plane, 1 year postoperatively, the hip stayed in a more adducted position throughout the stance phase which was a notable improvement over the preoperative outcome. This was also shown in the TEMG results, when compared to preoperatively no over-activity of G Med, TFL, or G Max was reported. In contrast, the contralateral hip still showed aphasic continuous activity of these muscles. This could have been due to the existing left hip pathology, even if asymptomatic. Hip joint moments, however, demonstrated an improved second peak on both sides.

In the transverse plane, 1 year postoperatively, the pelvis, hip, and knee stayed in an externally rotated position, leading to a more externally rotated foot progression angle, as was the case preoperatively. However, compared to preoperative outcome, less external rotation at the hip was reported, suggesting some improvement. Furthermore, the moment pattern was also seen to have returned to normal.

In terms of stair activity, an improvement was reported in the trunk, pelvis, and hip position. Hip joint moments in all 3 planes also showed improvement. Looking at TEMG during stair ascent, an improvement was seen in the activation pattern of all studied muscles (Fig. 3b). However, IP and HM reported aphasic contractions on both sides. During stair descent, TEMG results reported an improvement in IP, TFL, and RF activation patterns (Fig. 3c). However, G Max, G Med, HM, and LPS muscles continued to report aphasic activation.

Overall, there was a notable improvement reported following DAA-THA in our patient in terms of walking speed, RoM, joint moments, and power. However, due to a continuously flexed hip posture with anterior pelvic tilt, muscle imbalance seemed to persist. Because the patient had good muscle control preoperatively, it can be concluded that, for this patient, prescribed postoperative physical therapy would have likely helped improve muscle function and posture, allowing for a more natural gait to be resumed. In conclusion, this isolated case report may not be representative but, nonetheless, suggests that there might be value in a prospective series utilizing the study methodology not just of DAA but across other approaches to draw more concrete conclusions.

Summary

The EMG outcome of a patient who underwent DAA-THA and was exhibiting suboptimal muscular activity 1 year postoperatively was presented. In contrast to both clinical assessment and radiological outcome, which reported a successful outcome, the patient was shown to exhibit continued weakness/inactivity of the hip muscles as well as corresponding postoperative compensatory posture and gait pattern. In conclusion, this case study calls for more objective muscle function assessment following THA-DAA and other THR surgical approaches for a better understanding of the functional outcomes and preventative measures for persistent gait and posture abnormalities.

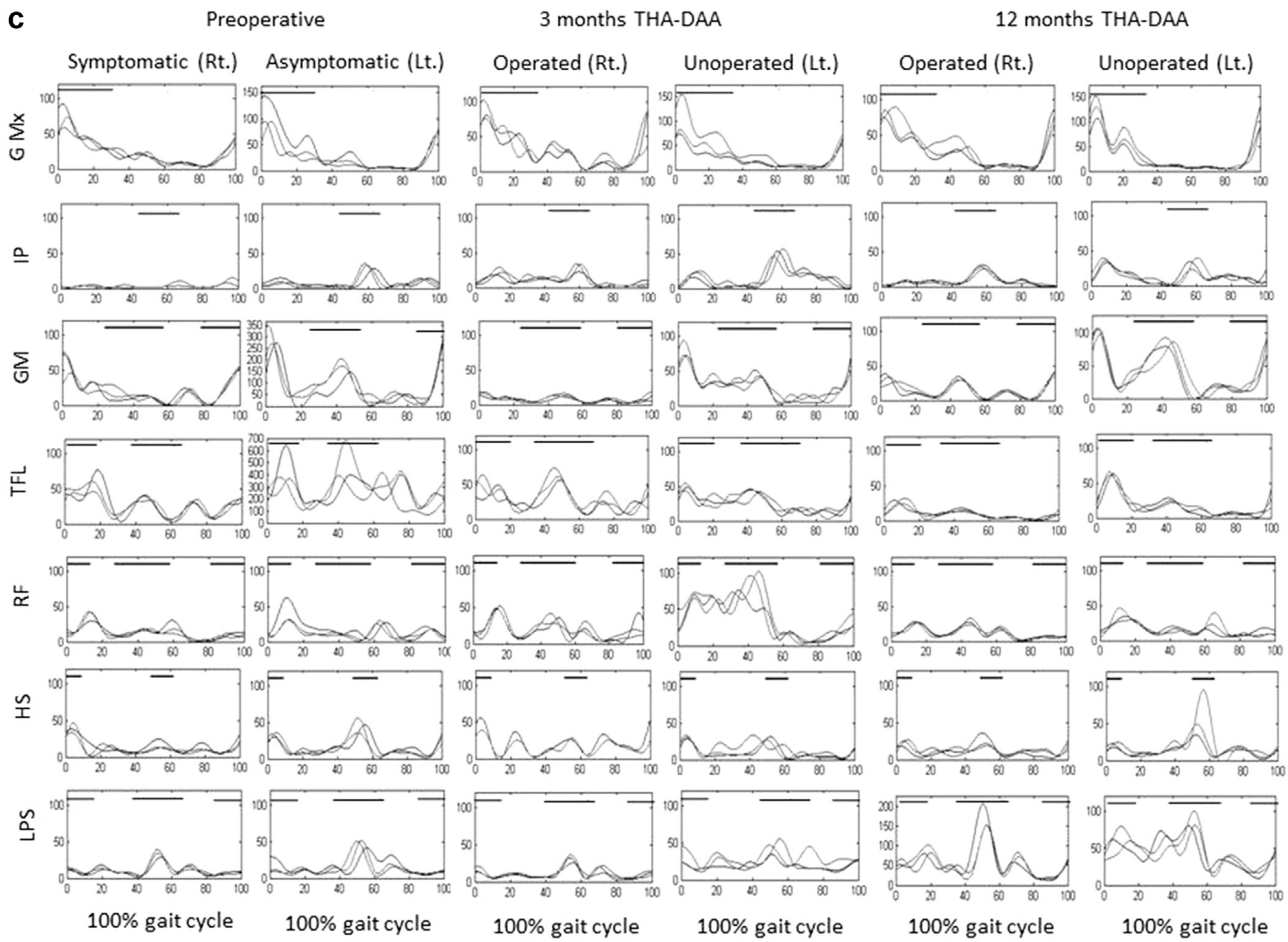

Figure 3. (*continued*).

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.artd.2017.06.006

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