Gait analysis of a patient with severe motor impairment post-intensive care due to COVID-19: 1 year follow up and physical therapy

Análise da marcha de paciente com comprometimento motor grave após terapia intensiva por COVID-19: acompanhamento de 1 ano e fisioterapia

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Abstract

Introduction: Viral infections, such as infection by SARS-CoV-2, can affect gait biomechanics, but this effect can be overlapped by consequences of critical illness and time in intensive care unit. **Objective:** To report biomechanical alterations during the clinical evolution of a post-COVID-19 patient who presented severe motor impairment after intensive care. **Methods:** Data was collected from the patient's chart at José Silveira Foundation and previous medical reports from the hospitalization period. The patient was wheelchair bound, with physiotherapy twice a week, and by the end of 1-year follow-up was able to walk independently. Three-dimensional gait analysis with kinetics and electromyography were conducted at three time points. **Results:** All spatiotemporal gait parameters, kinematic, kinetic and electromyographic data was importantly altered when compared to the normal range of values. With physiotherapy, gait quality indicators showed important improvements and all muscles presented a significant increase in the magnitude of the electromyographic signal (at least a two-fold increase). Trunk kinematic alterations decreased significantly during this period. Kinetic and kinematic changes perceived in the hips, knees and ankles showed approximation to the expected pattern, however still without normalizing, and patient's muscle coordination improved over time. **Conclusion:** This report has great clinical importance, as it describes, using an instrumented gait laboratory, the evolution of a patient with severe motor impairment post intensive care due to COVID-19, a condition in lack of description in the literature, which will help health professionals in the planning of rehabilitation strategies.

Keywords: Critical illness patient. COVID-19. Gait biomechanics. Polyneuropathy.

Resumo

Introdução: *Infecções virais, como a infecção por SARS-CoV-2, podem afetar a biomecânica da marcha, mas esse efeito pode ser sobreposto por consequências de doença crítica e tempo em unidade de terapia intensiva.* ***Objetivo:*** *Relatar as alterações biomecânicas durante a evolução clínica de um paciente pós-COVID-19 que apresentou comprometimento motor severo após terapia intensiva.* ***Métodos:*** *Os dados foram coletados a partir do prontuário do paciente na Fundação José Silveira e dos relatórios médicos anteriores referentes ao período de internação. O paciente estava em cadeira de rodas, com fisioterapia duas vezes por semana, e ao final de 1 ano de acompanhamento era capaz de deambular de forma independente. A análise tridimensional da marcha com cinética e eletromiografia foi realizada em três momentos.* ***Resultados:*** *Todos os parâmetros espaço-temporais da marcha, dados cinemáticos, cinéticos e eletromiográficos estavam significativamente alterados quando comparados com a faixa normal de valores. Com a fisioterapia, os indicadores de qualidade da marcha apresentaram melhorias importantes e todos os músculos apresentaram um aumento significativo na magnitude do sinal eletromiográfico (aumento de pelo menos duas vezes). As alterações cinemáticas do tronco diminuíram significativamente neste período. As alterações cinéticas e cinemáticas percebidas nos quadris, joelhos e tornozelos mostraram aproximação do padrão esperado, porém ainda sem normalização, e a coordenação muscular do paciente melhorou com o passar do tempo.* ***Conclusão:*** *Este relato é de grande importância clínica, pois descreve, por meio de um laboratório de marcha instrumentado, a evolução de um paciente com comprometimento motor severo após terapia intensiva por COVID-19, quadro pouco descrito na literatura, o que ajudará profissionais de saúde no planejamento de estratégias de reabilitação.*

Palavras-chave: *Paciente crítico. COVID-19. Biomecânica da marcha. Polineuropatia.*

Introduction

Patients with moderate forms of COVID-19 usually have a full recovery, but patients who presented severe or critical form of the disease may present multiple impairments.[1] The clinical presentation after COVID-19 may be due to viral infection[2] or to the consequences of post-intensive care syndrome (PICS), which can result in impairment of physical and cognitive function.[3] PICS consequences are observed for up to six months post-discharge, emphasizing the importance of rehabilitation for these patients.[4]

Important gait impairments previously reported are Guillain-Barré syndrome,[2] axonal polyneuropathy,[5] bilateral intentional tremor and increased base support,[6] and coordination and strength loss.[7] Description of gait biomechanics in patients with polyneuropathies[8-12] and patients with PICS[13] are scarce. However, to the best of our knowledge, there are no reports on changes in gait kinematics, kinetics, and electromyography in patients with severe motor impairment and peripheral polyneuropathy after intensive care by COVID-19. Such description is fundamental to better understand pathologies effects in movement strategies.[14] Thus, the aim of this study was to report gait biomechanics of a patient who presented severe motor impairment and peripheral polyneuropathy due to COVID-19 and PICS.

Methods

This study followed all ethical instructions by National Health Council and was approved by local Ethics Committee (53183221.0.0000.5543). Data was collected from patient's chart at Bahian Institute of Rehabilitation of the José Silveira Foundation (IBR-FJS) and from reports of hospitalization period.

Case description

A 53-yo male patient with a medical history of hypertension, type 2 diabetes, myalgia and polyarthralgia presented with a fever lasting two days (April 27th, 2020). Despite normal vital signs, the patient experienced glycemic decompensation (HGT 375 mg/DI) and tested positive for dengue (IgG and IgM antibodies), along with mild thrombocytopenia (Hb 16.1 and plaq 103000). The patient returned with severe myalgia, high blood glucose levels (HGT 310mg/DI), dry cough and severe sweating (May 1st). RT-PCR test was positive for SARS-CoV-2, leading to the patient's admission to the intensive care unit due to acute respiratory failure and oxygen desaturation (May 4th). Nasal oxygen catheter was administered, followed by intubation, and 15 days later a tracheostomy was performed. The patient also started hemodialysis (May 7th) due to renal dysfunction.

Additionally, the patient experienced a tonic-clonic seizure, which was successfully treated with Diazepam, and Hidantal was prescribed. A skull magnetic resonance imaging revealed the presence of a bilateral mastoiditis jugulotympanic glomus tumor. The patient remained hospitalized for a duration of 95 days, during which he received 30-minute physiotherapy sessions consistently throughout his hospital stay, including the period spent in the intensive care unit. Following his discharge on August 6th, the patient initiated home-based physiotherapy, 30-minute sessions twice a week, starting August 11th.

On November 25th the patient was evaluated at IBR-FJS, still relying on a wheelchair and with no respiratory complaints. He presented significant muscular atrophy and initiated clinical physical therapy for lower limbs strengthening, functional independence and gait retraining with a walker. Outdoors he used a wheelchair until December. In January he started to use a walker full time. Polyneuropathy was diagnosed (February 11th, 2021) and in February he performed the first gait analysis (A1). In March he began using crutches at home and walker on outdoor walks. In April he started using crutches outdoor and a cane at home.

On April 13th, an ankle foot orthosis was prescribed due to footdrop of the right foot. On July 27th, he began using a cane outdoors and independent gait at home. In August the second gait analysis (A2) was performed. On August 26th, he progressed to a fully independent gait. He maintained rehabilitation until the last gait analysis (A3), in October 2021. Events are summarized in Figure 1.

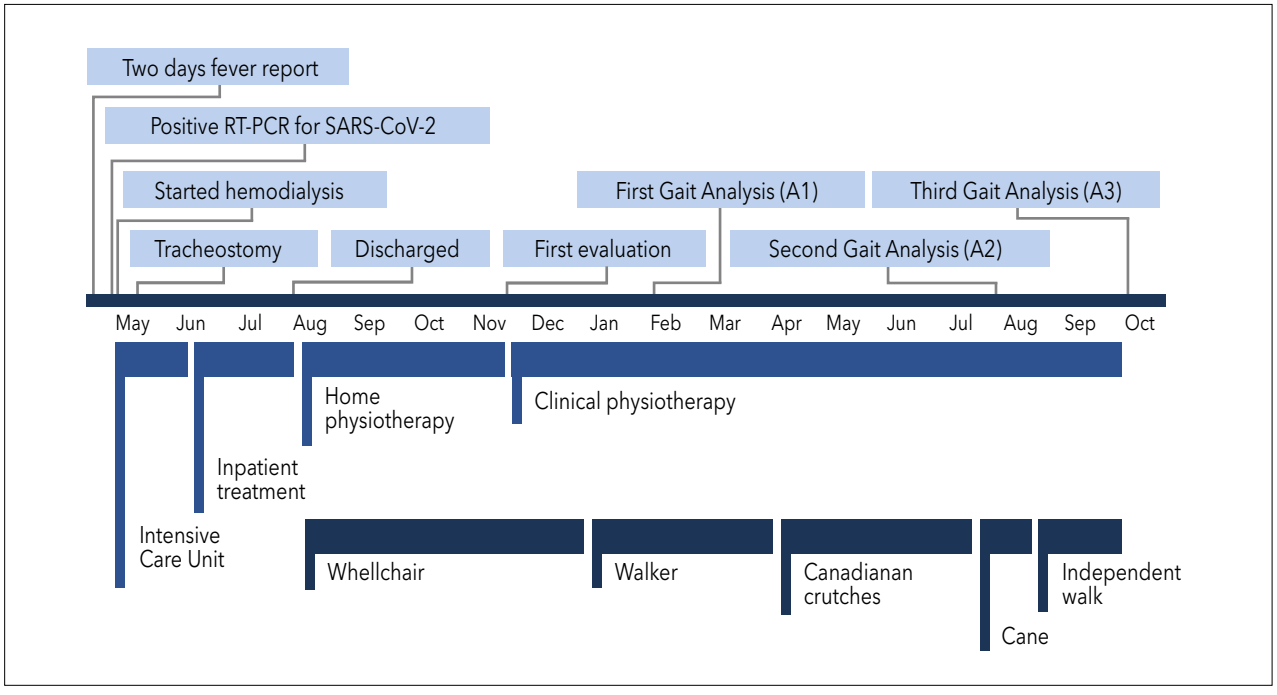

Figure 1 - Timeline of events occurred from disease onset until end of follow-up period.

Data acquisition

Kinematic (8 SMART-DX 400 infrared cameras), Kinetic (4 P-6000 force platforms), and EMG (8 channels FreeEMG 1000) gait data was collected from three-dimensional gait reports (BTS Bioengineering Milano, Italy) from February (A1), August (A2) and October (A3) using 22 markers Helen-Hayes protocol.[15,16] Surface electromyography of tibialis anterior, gastrocnemius medialis, rectus femoris and semitendinosus muscles were acquired according to SENIAM project recommendations (Surface ElectroMyoGraphy for Non-Invasive Assessment of Muscles). Selected data from the three-dimensional gait reports were: the patient's joints

angles, joints internal moments, muscle power and electromyographic data during the three evaluations; and the following spatiotemporal gait parameters (SGP): stride, stance and swing times; stance, swing, single support, double support phases; stride length, step length, mean velocity, cadence, step width, propulsion, Gait Profile Score (GPS),[17] Gait Deviation Index (GDI)[18] and Timed Up and Go (TUG) test time.

Results

All SGP were below expected in A1. After physiotherapy, gait speed, cadence, swing phase and single support increased, while stance phase and double support phase decreased, showing improvements. Against expectations, step length decreased and step width increased. Both GPS and GDI improved (Table 1). In A1 the patient presented high trunk flexion and anterior pelvic tilt (Figure 2). A normalized trunk kinematics and reduced pelvic tilt was seen in A2 (Figure 2). From A1 to A3, decreased flexion angle of the hips can be observed (Figure 2) with persistent extensor moment during mid-stance (Figure 3). In A3, there was an incipient hip flexor moment and power (Figures 3 and 4, respectively). Persistent knee flexion during stance and delayed peak flexion during swing phase (Figure 2) associated with persistent knee extensor moment was noted in all assessments (Figure 3). Despite the incresead knee flexion angle, rectus femoris showed a better pattern in A2 and A3 compared to A1 (Figure 5). Simultaneously, hamstrings were coactivated during initial contact and load response (Figure 5).

All assessments showed inadequate ankle pre-positioning, increased dorsiflexion, delayed plantar flexion (Figure 2) and low production of plantar flexor moment (Figure 3). However, we observed a great gain in muscle power and EMG (Figures 4 and 5, respectively).

Table 1 - Results of the spatiotemporal gait parameters, scores and gait indexes of the patient during the three evaluations

Spatiotemporal Gait Parameters	Assessment 1		Assessment 2		Assessment 3		Normal values*
	RL	LL	RL	LL	RL	LL	
Stride time (s)	3.62 ± 0.15	3.40 ± 0.47	1.76 ± 0.07	1.74 ± 0.08	1.41 ± 0.07	1.42 ± 0.06	1.10 ± 0.09
Stance time (s)	2.81 ± 0.17	1.28 ± 0.09	1.28 ± 0.09	1.24 ± 0.10	0.95 ± 0.05	0.95 ± 0.07	0.65 ± 0.07
Swing time (s)	0.81 ± 0.02	0.47 ± 0.04	0.47 ± 0.04	0.50 ± 0.08	0.46 ±0.05	0.47 ± 0.05	0.44 ± 0.05
Stance phase (%)	77.66 ± 1.40	72.52 ± 2.55	72.52 ± 2.55	71.06 ± 4.26	67.59 ± 2.43	66.63 ± 3.27	59.98 ± 1.97
Swing Phase (%)	22.34 ± 1.40	26.75 ± 2.72	26.75 ± 2.72	28.87 ± 4.63	32.41 ± 2.43	33.39 ± 3.27	40.03 ± 3.56
Single support phase (%)	23.48 ± 1.71	28.49 ± 4.66	28.49 ± 4.66	27.14 ± 2.84	33.79 ± 3.99	32.13 ± 2.95	38.87 ± 2.57
Double support phase (%)	28.90 ± 2.73	22.49 ± 1.63	22.49 ± 1.63	21.97 ± 3.61	18.26 ± 0.74	15.74 ± 2.16	10.27 ± 3.09
Stride length (m)	0.56 ± 0.04	0.45 ± 0.06	0.45 ± 0.06	0.44 ± 0.04	0.65 ± 0.06	0.66 ± 0.05	1.36 ± 0.11
Stride length (%height)	34.76 ± 2.37	28.20 ± 3.57	28.20 ± 3.57	27.03 ± 2.70	40.47 ± 3.55	40.87 ± 3.01	80.00 ± 0.10
Step length (m)	0.25 ± 0.02	0.22 ± 0.04	0.22 ± 0.04	0.23 ± 0.02	0.34 ± 0.03	0.32 ± 0.07	0.62 ± 0.05
Mean velocity (m/s)	0.20 ± 0.00		0.30 ± 0.00		0.50 ± 0.00		1.20 ± 0.20
Mean velocity (%height/s)	9.50 ± 0.73		16.00 ± 2.50		28.80 ± 2.70		80.00 ± 5.00
Cadence (steps/min)	34.65 ± 3.24		68.70 ± 3.99		85.00 ± 4.05		114.00 ± 4.20
Step width (m)	0.17 ± 0.01		0.24 ± 0.01		0.19 ± 0.01		0.08 ± 0.05
Propulsion	0.60	0.70	1.00	1.50	2.80	3.40	-
Gait profile score	15.80 ± 0.20	14.60 ± 0.20	13.50 ± 0.60	10.80 ± 0.30	12.20 ± 0.30	10.40 ± 0.40	< 7
Gait deviation index	70.36 ± 0.48	72.72 ± 0.56	76.63 ± 1.51	85.58 ± 1.41	81.37 ± 1.35	86.66 ± 1.29	> 100
TUG (s)	63.71		23.37		15.66		< 15s

Note: RL = right limb; LL = left limb; TUG = Timed Up and Go test; m = meters; s = seconds. Results presented in average ± standard deviation.
*Normality values are offered by the manufacturer of the acquisition system (BTS Bioengineering, Milan Italy).

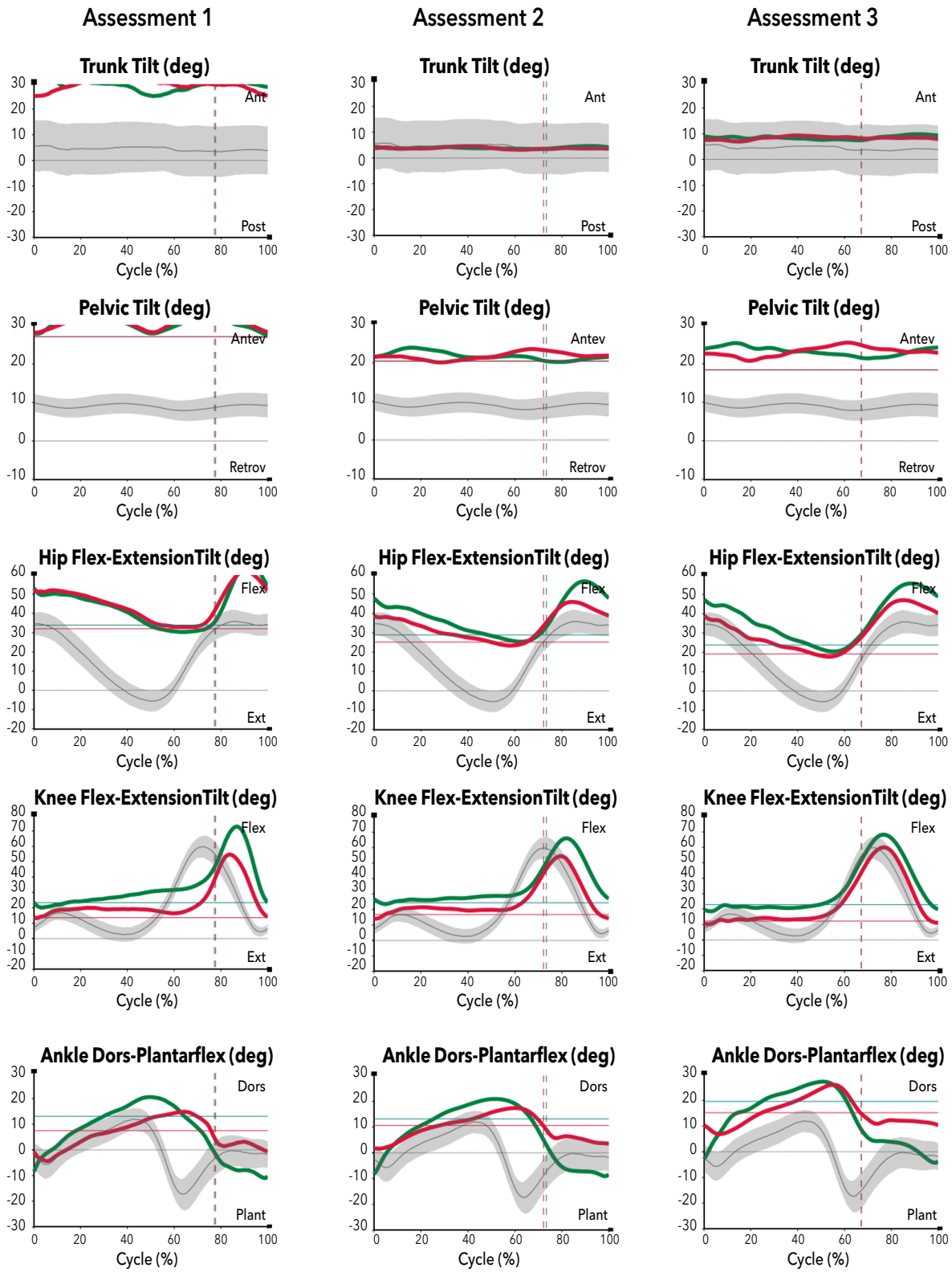

Figure 2 - Joints kinematics results during the three assessments. The red line represents the left lower limb, and the green line represents the right lower limb, while the gray-filled area represents the normal gait pattern described by the system.

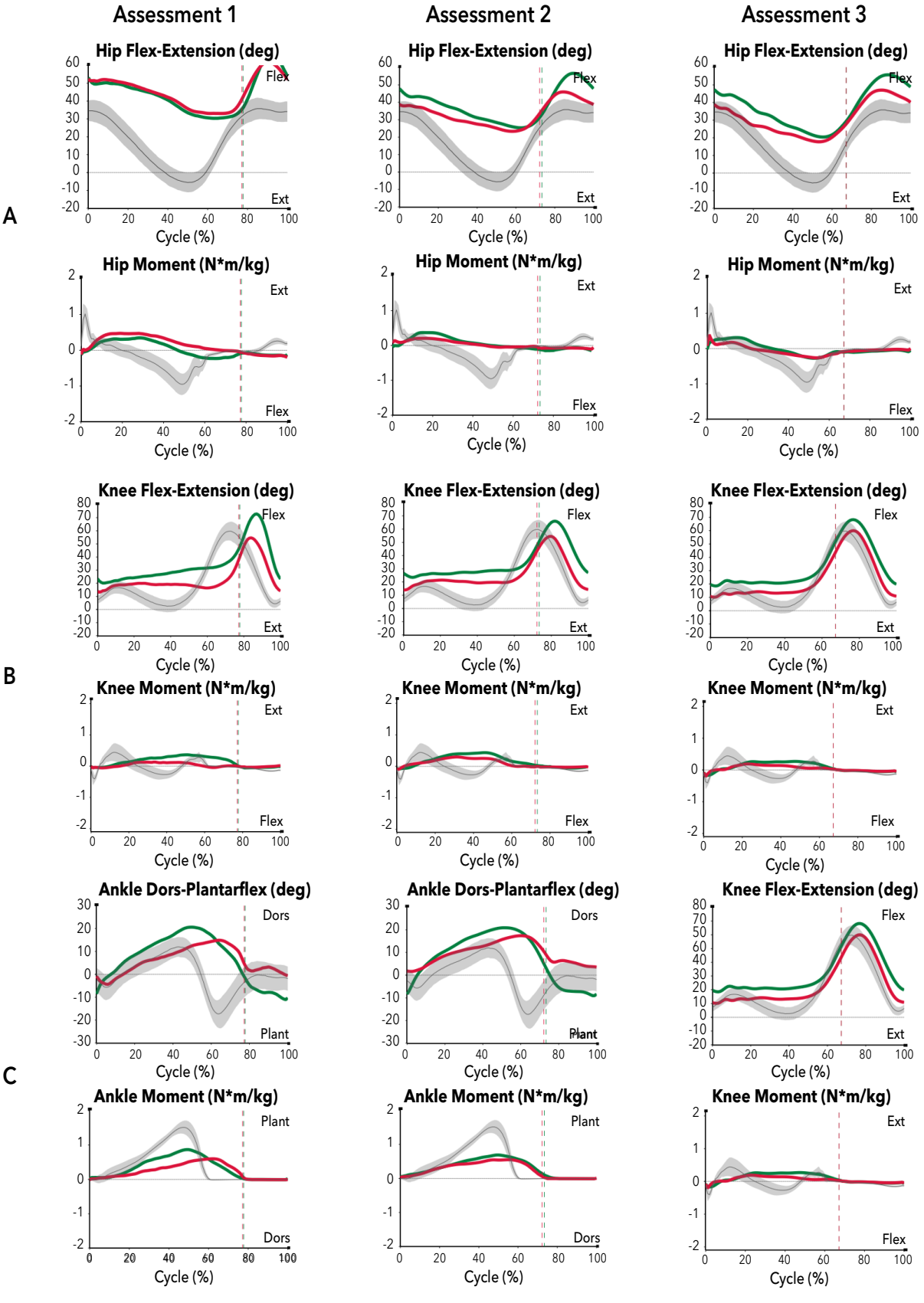

Figure 3 - Results of kinetics of the hips (A), knees (B) and ankles (C) during the three assessments. The first row shows the results of kinematics (same as figure 2, for better visualization) and the second row shows joint internal moment. The red line represents the left lower limb, and the green line represents the right lower limb, while the gray-filled area represents the normal gait pattern described by the system.

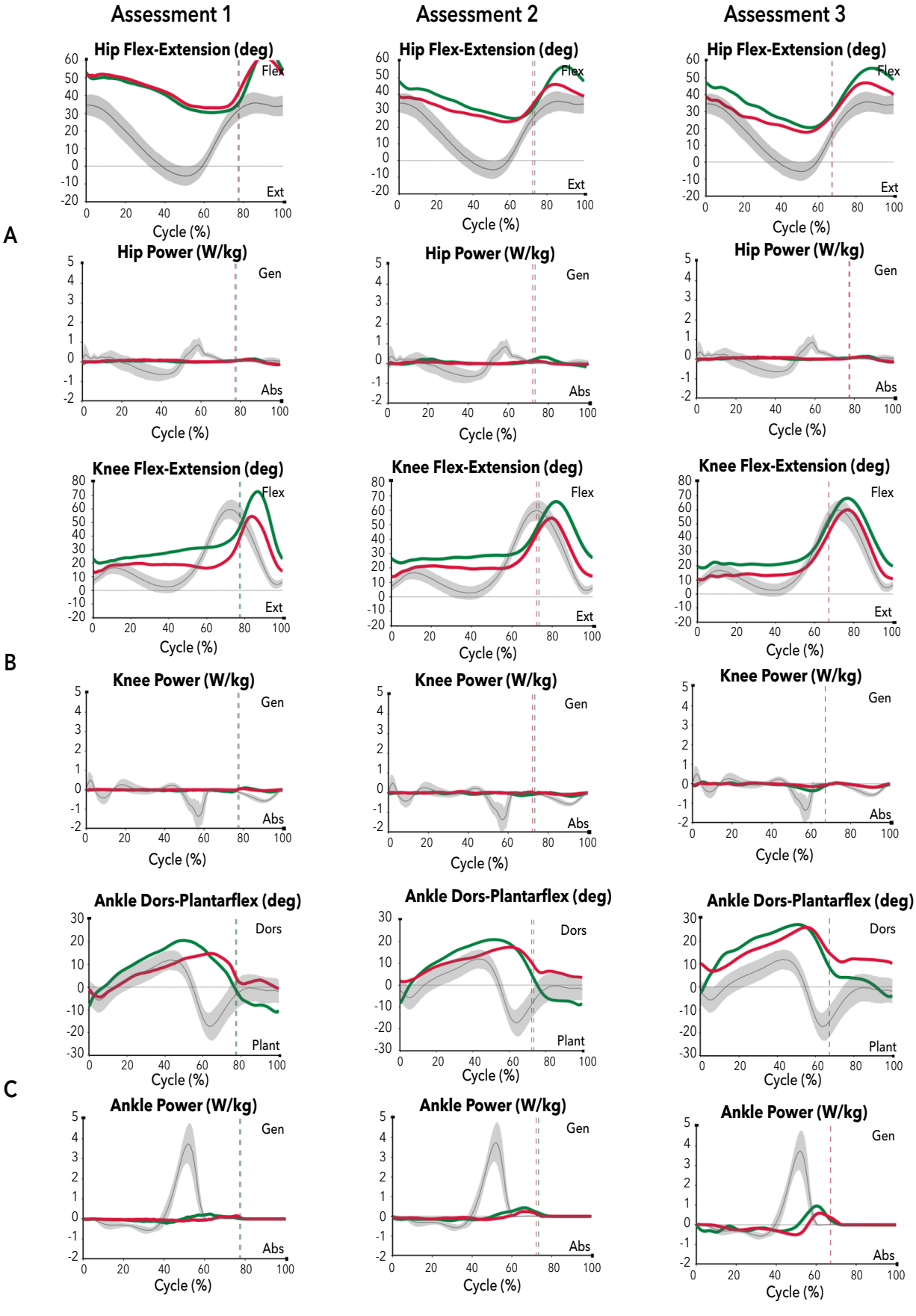

Figure 4 - Results of kinetics of the hips (A), knees (B) and ankles (C) during the three assessments. The first row shows the results of kinematics (same as Figure 2, for better visualization) and the second row shows joint muscle power. The red line represents the left lower limb, and the green line represents the right lower limb, while the gray-filled area represents the normal gait pattern described by the system.

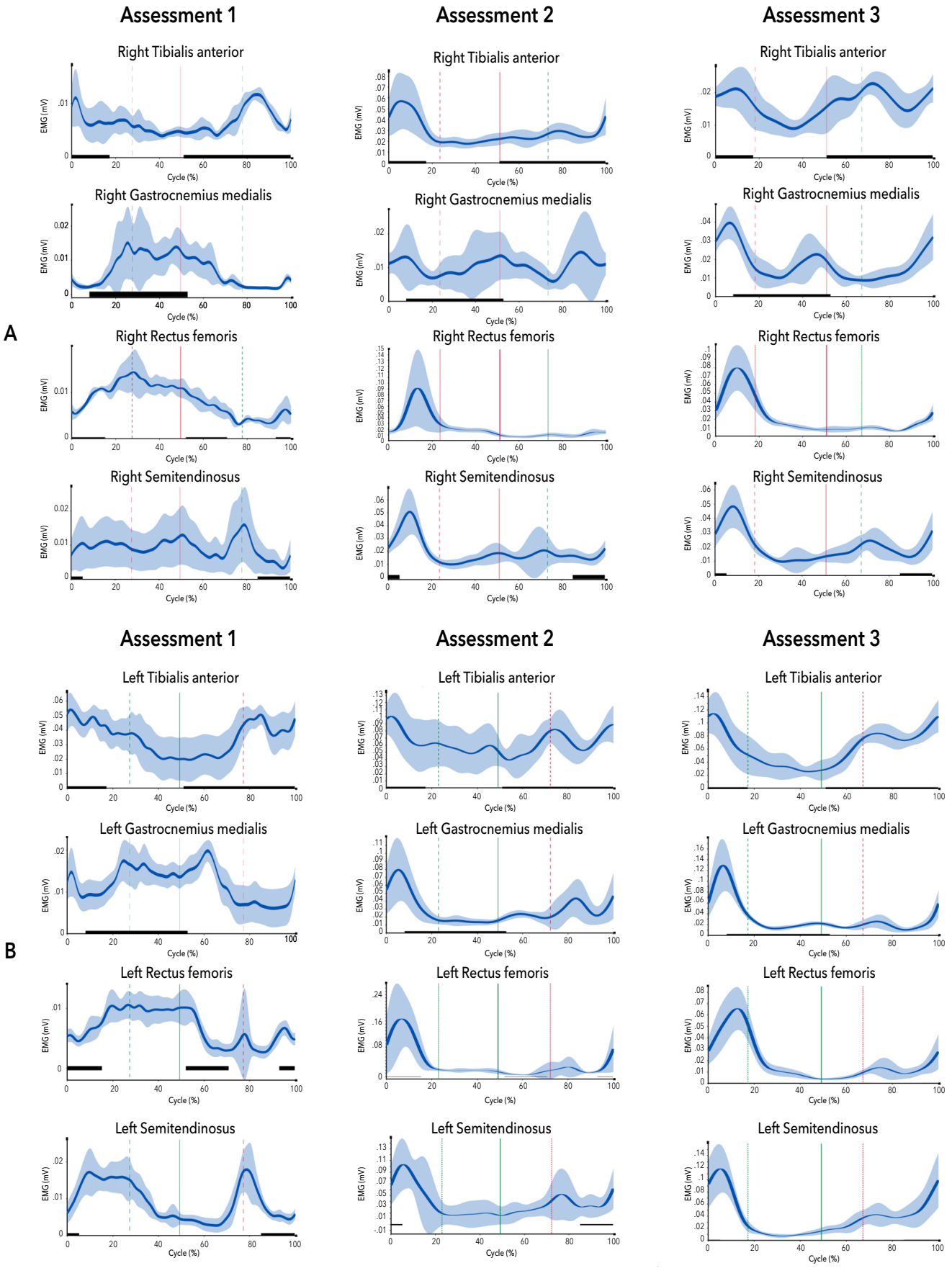

Figure 5 - Surface electromyography of the tibialis anterior, gastrocnemius medialis, rectus femoris and semitendinosus muscles during the three assessments of the right lower limb (A) and the left lower limb (B). The blue line represents mean EMG activation while the blue-filled area represents the standard deviation.

Discussion

SARS-CoV-2 patients may present peripheral nervous system impairments such as polyneuropathy.[5] It is possible that the viral infection itself can affect fundamental aspects of gait biomechanics, but this effect can be overlapped by PICS[13,19] and by hyperglycemia comorbidities.[8,10] It is known that hyperglycemia is associated with a poor prognosis and severe COVID-19 even without diabetes diagnosis prior to admission.[20,21] We do not have a gait analysis prior to patient's admission, however, as reported by the patient and family, he was functional and active before COVID-19. Therefore, it can be inferred that the disease, hospitalization, and their associated complications were responsible for the severe motor impairments observed.

Three assessments were conducted post-discharge, including spatiotemporal, electromyographic, kinetic, and kinematic evaluations of gait. It is worth noting that the most significant improvements in electromyographic, kinetic, and kinematic variables were already observed at A2 and remained consistent at A3. However, various spatiotemporal variables such as stance time, stance phase, single support phase, stride length, velocity, cadence, and TUG continued to show progress from A1 to A2 and from A2 to A3, even without notable changes in the kinetic, kinematic, and electromyographic graphs.

In A1, stance phase, double support phase, gait speed, cadence, step length, variables commonly associated with gait stability and functional capacity were far below normal.[22-25] Individuals with diabetic neuropathy may present alterations in gait speed, cadence, and step length.[10,26] Changes in the stance phase and double support phase may be attributed to central nervous system impairments caused by COVID-19.[10,27] Step length and gait speed are associated with lower limb weakness, while time variables may indicate balance impairments due to neuropathology.[28] During A3, despite the improvement compared to A2, a reduction in velocity was still observed, indicating the need for further intervention (physiotherapy or exercises) in this variable as it is highly related to the patient's life expectancy.[29] Additionally, step width, cadence, and stance time still deviated from normal values in A3, suggesting the persistence of deficits in balance control and residual motor control impairments even after the rehabilitation period.[30,31]

Patients discharged from intensive care unit may present a "cautious" gait pattern due to decreased joint range of motion and power deficits related to limb weakness and stiffness.[13] Physiotherapy program increased speed, stance time and cadence[9] attributable to improvement of joint range of motion,[32] as well as lower limbs strength gains[13] in the early weeks of intervention.[33-35] Furthermore, the progression of TUG test results over assessments indicates functional gains, similar to what is observed in cases of peripheral neuropathy.[11]

Patients´ hip gait kinematics is similar to patients with other neuropathy, showing a reduced range of motion and increased hip flexion.[36,37] Similar hip moments can be found in diabetic patients.[37,38] These similarities in gait alterations can be due to similar neuromotor issues between pathologies. In A2 and A3, the slight increase in hip flexor moment may have occurred by psoas and iliac muscles action.[39,40]

The decreased knee range of motion may be associated with stiffening of the joint in order to maintain postural balance.[10] In A2 and A3, rectus femoris EMG demonstrated a clear peak during stance, possibly caused by increase in gait speed, once the quadriceps has the function of deceleration during stance phase. [41]

Contrary to expected, hamstrings presented recruitment during initial contact and loading response in A2 and A3.[39,41,42] Four mechanisms may explain the increased hamstring activity: coactivation caused by increased knee flexion; hip and knee flexion acceleration deficits during stance to swing transition, caused by the plantar flexion weakness; the need to generate an exaggerated knee flexion during the swing phase; the performance as synergists in attempt to extend the hips.[39,42,43] By Ockham's razor, the first mechanism is the most likely.

Recruitment deficits of distal musculature such as tibialis anterior and gastrocnemius medialis can cause changes in proximal joints kinematics.[42,44] This may partly explain certain kinematic changes in A1 and A2, such as decreased knee flexion peak during the transition from stance to swing, and increased knee and hip flexion during the stance phase.[41-43] In addition, the triceps surae contributes to the upright posture,[39,40] extending all three joints and providing a large contribution to body weight support,[41] which may have also contributed to important trunk and hip flexion at A1. These are similar alterations found in patients with diabetic polyneuropathy who adopt a gait pattern with propulsion generated predominantly by the hips.[10]

During A1 and A2, the recruitment of tibialis anterior was affected, as it failed to provide clearance of the foot during the swing phase.[39,40] This recruitment deficit justifies the foot drop during A1, A2 and A3, a recurrent condition in patients with neurological lesions,[45,46] which reinforces the hypothesis of COVID-19 and PICS impact on patients important neurological aspects.

The patient presented slightly flexed hip and knees throughout evaluations, similar to crouch knee gait,[41,43] which can be explained by the persistent insufficiency of the plantar flexor mechanism,[40,41,43,47] usually related to muscle weakness, motor control deficits and lack of proprioceptive feedback.[48]

This study has limitations, once we had limited information on patient's previous gait condition, drug treatments and diagnoses. Nonetheless, this report has great clinical importance as it describes complete clinical gait analysis evolution of a patient with PICS due to COVID-19.

Conclusion

We observed important improvements in gait kinematics, kinetics, and electromyography of a patient with severe motor impairment post-COVID-19, after 12 months of follow-up, and the results are similar to other neurological diseases already known.

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Authors' contributions

AFFS protocolled the project, coordinated the study, and gathered the patient history information with MAFSF, HMLAV and EMG. GAB performed the statistical analysis and, along with AFFS, the data analysis and manuscript reviews. TNA treated and performed patient evaluations. MAFSF, HMLAC and EMG performed clinical tests and gait analysis. All authors contributed to the discussion of the results and preparation of the manuscript.

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