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Gait patterns in ischemic and hemorrhagic post-stroke patients with delayed access to physiotherapy

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Objectives: (1) To assess the effects of a conventional, delayed physiotherapy protocol used by Ischemic Stroke (IS) and Hemorrhagic Stroke (HS) post-stroke patients, in their electromyographic activation patterns during hemiparetic gait; and (2) to study whether this protocol may improve the functional abilities in this population.

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Methods: This is an observational, descriptive, and analytical quasi-experimental trial. Forty patients with unilateral IS ($n = 25$) and HS ($n = 15$) stroke were recruited; the stroke involved the motor cortex or subcortical areas, and the patients were able to walk independently. Interventions with standard protocols of physiotherapy were carried out. Evaluations (clinical and gait assessment) were performed at the time of admission and at the end of the protocol. Outcome measures include Stroke Impact Scale, Timed Up and Go Test, and gait electromyographic evaluation.

Results: Only IS patients (with an average of 124.4 ± 45.4 months delayed access to physiotherapy rehabilitation) had improvements in Timed Up and Go Test (change in speed $= -8.0$ seg $p < 0.05$) and presented an anticipation of the onset in Upper leg muscles after the intervention. BF ($p = 0.05$), ST ($p = 0.001$), and RF ($p = 0.024$), started their recruitment (onset) earlier at the swing phase of the gait cycle, which is more similar to the normal pattern (grey shadow). IS and HS (120.4 ± 28.4 months since last stroke) patients presented higher electromyographic activation, after physiotherapy, of the posterior leg muscles (gastrocnemius, semitendinosus and biceps femoris) during stance phase ($p < 0.05$).

Conclusion: IS patients had improvements after delayed conventional physiotherapy. For HS limited response to intervention was observed.

Keywords: Stroke; age; surface electromyography; gait; physiotherapy.

Introduction

Stroke is the second highest cause of death and contributes significantly to motor disability and compromised quality of life. Its consequences depend on its severity, brain location, and type.[1] Since stroke is a long-term condition with long-term needs, it is important to quantify the impact of differing stroke sub-types; Ischemic Stroke (IS) or Hemorrhagic Stroke (HS); and also, to identify important prognostic variables.

Post-stroke gait, known as hemiparetic gait, is altered compared to normal gait, as measured by spatiotemporal parameters, kinematic and kinetic profiles, and energy costs.[2,3] Abnormal electrical activity is associated to these clinical impairments during the gait cycle.[4–6,38,39] Some features include the absence or reduced electromyographic (EMG) amplitude with premature or delayed activation in lower leg muscles during the terminal swing and early stance phase. We have reported the electromyographic findings of a quasi-experimental trial that demonstrated changes in the hemiparetic gait cycle after physical rehabilitation in patients with delayed access to treatment.[7] Without considering the type of stroke, we found that although chronic stroke patients continued to exhibit abnormalities in the temporal characteristics of muscle activity, they anticipated Tibialis Anterior (TA) and Rectus Femoris (RF) activation in the swing phase, after rehabilitation. But no association with clinical features or with stroke type was described

in that occasion. Thus, in this paper, that included some additional participants, we are reporting the correlation of this changes with some clinical outcomes and the type of stroke.

Balance improvements (i.e., better control of the body center of pressure) in stroke patients after a late physiotherapy conventional intervention were also recently reported and were observed only in IS patients, when compared to HS, besides all patients had delayed access for the treatment.[8] In addition to this reference, as far as the authors know, the effects of time after stroke (chronicity) associated with delayed access to recovery in the follow-up of patients have not been fully investigated.

Physical rehabilitation is strongly recommended as an early intervention due to its ability to improve the brain organization and plasticity. Around six months after the stroke episode, it is recommended to start the rehabilitation program.[9–12] However, the public health system in developing countries are under high demand and with limited infrastructure. Long periods waiting for treatment often makes patients become chronic and worse, compared to patients who get the recommended ideal scenario of an early intervention.[9] Moreover, as a long-term condition, it is important to quantify the impact of differing stroke subtypes to identify the prognostic. Thus, some questions remain unclear, and we intend to explore in this new study: How effective are these

late intervention for IS and HS patients? Have these patients better function scores after intervention? Do they learn effective patterns when recruiting muscles during walking?

In this study, we aimed to determine whether it is still possible to improve electromyographic gait patterns in chronic patients after later intervention. For that, we quantified the amplitude of the electromyographic activation in the lower limb muscles and timing of muscle activation during the gait cycle. We hypothesized that limited response to intervention will be observed, due to the long-time post-stroke and delayed access to treatment, turning the financial efforts not effective. We further hypothesized that among these chronic patients, and due to its severity according to the type, those that had HS could show worse results compared with subjects affected by IS stroke when receiving the same physical therapy protocol.

Methods

This is an observational, descriptive study and analytical quasi-experimental trial, that evaluated stroke patient cases referred for rehabilitation from the public health system. The treatment took place at the Demetrius Medrado Reference Center and Unit of Education and Care in Physical Therapy at the State University of Pará, Belém, Pará, Brazil. This study followed the STROBE statement and has been approved by the internal ethics committee of the Federal University of Pará

(report #141.605). Participants gave their written informed consent.

Participants

We enrolled for this study 40 stroke patients. They had experienced a unilateral stroke (HS or IS), involving the motor cortex or sub-cortical areas and were able to walk independently (10 meters without any supervision or assistive devices). No physical therapy and or exercise program 24 months prior to the enrolment in the study was permitted.

Participants with no cognitive ability to understand the tasks, with other neurological or orthopedic comorbidities or under antispastic medication at the time of the study were excluded. An experienced physiotherapist performed a clinical examination to assess the baseline characteristics before any experimental procedure. The baseline characteristics were age, sex, height, weight, time since last stroke onset episode, time since last physical therapy intervention, Stroke Impact Score,[13] Timed up and Go test,[14] Berg Balance Score[15] and Brunnstom Score[16] and stroke type (Table 1).

Procedures

Clinical assessment

Researchers were blinded to the type of stroke when performing all procedures and assessed the

Table 1. Sample baseline characteristics.

	IS group ($n = 25$)	HS group ($n = 15$)	p-Value
Sex	16 M/9 F	10 M/5 F	
Age (years)	58.56 ± 10.22 (54;74)	55.0 ± 10.27 (39;71)	0.29
Height (cm)	159.1 ± 8.5 (156;175)	161.1 ± 8.0 (148;175)	0.47
Weight (kg)	69.0 ± 11.1 (60;94)	69.6 ± 10.2 (52;88)	0.66
Time of stroke (months)	124.4 ± 45.4 (84;36)	120.4 ± 28.4 (84;152)	0.94
Time since last physical therapy intervention (months)	31.68 ± 7.93 (25;48)	29.53 ± 5.24 (21;39)	0.71
Brunnstrom stage	3.44 ± 0.5 (3;4)	3.6 ± 0.5 (3;4)	0.96
SIS Movement domains	43.64 ± 17.64 (31;51)	43.53 ± 21.15 (28;53)	0.82
Timed Up and Go Test (s)	30.36 ± 10.79 (22;41)	29 ± 7.00 (25;34)	0.47
Berg Balance Scale	43.00 ± 5.01 (39;46)	42 ± 3.8 (35;47)	0.95

Notes: Values are mean $\pm$ SD. Statistical comparisons were made with unpaired t test (Stroke Impact Scale, Age, Height and Weight) and Mann–Whitney test (Timed Up and Go Test, Last Episode, Last Physio, Brunnstom stage and Berg Balance Scale). The level of significance was $p \leq 0.05$. Abbreviations: Ischemic Stroke (IS); Hemorrhagic Stroke (HS); Stroke Impact Scale (SIS).

Table 2.   Standardized rehabilitation protocol implemented by physiotherapists at public treatment centers.

Intervention	Procedures	Major goal
Stretching Passive range of motion (ROM)	3 series of stretches, sustaining the position 20 s, for the main lower and upper limbs muscle groups. 10 series of passive movements, for the main lower and upper limbs muscle groups.	Increase ROM of involved extremities Reduce spasticity Maintain flexible joints and prevent contracture
Active assistive ROM Active ROM Resistance training: isometric exercise Free weights, weight machines Functional electrical stimulation of the upper and lower limb which practicing functional tasks	10 series active assistive movements (active progression), for the main lower and upper limbs muscle groups 15 minutes of Functional electrical stimulation for weak muscle during functional tasks (squat, climb step)	Increase strength and improve muscular endurance
Coordination and balance activities while sitting and standing	10 minutes of exercises: Lateral Leg Swings, Knee Raises, Bridging, Clams Exercise	Increase core or trunk musculature strength Help prevent falls Improve proprioception
Large-muscle activities such as walking, treadmill, stationary cycle, combined arm-leg ergometry, arm ergometry, seated stepper Circuit training	10 minutes walking, treadmill or stationary cycle	Reduce risk of cardiovascular disease Improve gross motor skills coordination Improve tolerance for prolonged physical activity Increase walking speed/efficiency Improve independence in ADLs
Fine- motor exercises	10 minutes picking up objects, feeding oneself, buttoning clothes and/or writing	Improve gross motor skills coordination Improve independence in ADLs
Wrist, hand or ankle splints	Continuous use, if necessary	Maintain joint range and alignment Facilitate function and increase comfort

Note: As the standard for the program, all patient received the interventions with the volume, intensity and frequency described.

patients on the Stroke Impact Scale and with Timed Up and Go Test, by the time of admission to physiotherapy (pre-physiotherapy) and after the treatment (post-physiotherapy). Only one therapist performed all baseline, clinical and gait evaluations. All subjects completed the physiotherapy intervention that totalized 20 sessions of 60 minutes carried out in 8 weeks, following the standard protocols of the public health system without any intervention from the researchers. Two therapists of the public health system provided treatments (summarized in Table 2).

Stroke impact scale

Health-related quality of life was measured using a stroke-specific, self-reported patient-perspective assessment tool called Stroke Impact Scale. This scale measures eight factors: strength, hand function, mobility, physical and instrumental activities of daily living (ADLs/IADLs), memory and thinking, communication, emotion, and social participation.[13] The Stroke Impact Scale score for each factor ranges from 0 to 100, with higher scores indicating better results. The patient's strength, hand function, mobility, ADLs/IADLs scores were combined into a composite movement Stroke Impact Scale score to demonstrate the impact of functional change as it relates to the international classification of functioning, disability, and health.

Functional assessments

Participants were evaluated using the Time Up and Go test to assess dynamic ability in this study.[14] Participants were asked to rise from a chair, walk forward for three meters, turn around, walk back, and sit in the same chair as fast as possible. The average time to complete the Timed Up and Go Test over two trials was calculated.

Gait evaluation

Volunteers walked with natural self-paced speed along a 7-meter, ethylene vinyl acetate made walkway. The following muscles were assessed: gastrocnemius lateralis (GAS), TA, semitendinosus

(ST), biceps femoris (BF), and RF muscles on the paretic side. 18 steps were used for the calculations.

An eight channel electromyographer with a 16 bits of resolution analog–digital converter (EMG System do Brasil™, São José dos Campos, Brazil) was used for acquisition of muscle activation. The signal was amplified 20 times, band-pass filtered (20–500 Hz), and sampled with a rate of 2 kHz. Active bipolar Ag/AgCl, 10 mm, electrodes were used in all channels (Meditrace, Mansfield, USA), placed in pairs, separated by 2 cm. The reference electrode was positioned on the spinous process of C7. All procedures were taken according to the standard recommendations.[17] A custom developed routine in MATLAB (Matlab 2008a, MathWorks Inc., MA, USA) was employed to quantify the electromyographic root mean square (RMS) over a 300 ms window. Tests of maximum voluntary isometric contraction (MVC) for each muscle were performed and used to normalize gait signals. Three tests of MVC were performed, where the contractions were maintained for five seconds, with a one-minute rest between contractions. The average values obtained during the MVC tests was used for normalization of each muscle's activation signal.[18] Finally, we used a second-order Butterworth low-pass filter (6 Hz cut-off), to get the linear envelope of each muscle. Timing normalization was also made using MATLAB. All steps were calculated to a percentage of the total gait cycle, using a foot switch (Heel/Toe strike transducer, Emgsystem, São Jose dos Campos, Brazil). This device was synchronized to the EMG channels and triggered the time of initial and loss of foot contact with the ground, thereby determining cycle phases, ranging from 0% and 100% of the gait cycle. Muscular onset was established based on the moment when the EMG signal exceeded 30% of the minimum amplitude of the signal average per individual.[18] Data were analyzed using the periods of muscle activation during the gait phases (as a percentage of the cycle, and the electromyographic activation (as a percentage of MVC) during the stance and swing phases. Variables were compared for the initial and final evaluation stages. When a muscle became onset earlier compared to the baseline evaluation, we considered it as an anticipation (if it was statistically significant).

Statistical analysis

Statistical procedures were carried out in RStudio (R version 3.3.2, R Core Team (2016). Shapiro–Wilk test was performed to test the data normality. Parametric variables were compared between groups using the Student's t-test (i.e., Stroke Impact Scale, Sex, Age, Height, Weight and Berg Balance Scale). Non-normally distributed Outcomes were compared using Wilcoxon–Mann–Whitney (i.e., Timed Up and Go test, Last Episode, Last Physio and Brunnstom stage). In addition, a two-way analysis of variance (ANOVA) was conducted on the influence of the group and stage on the Stroke Impact Scale, Timed Up and Go Test and all electromyographic gait variables. Group included in two levels (HS or IS) and stage consisted in two levels (pre or post-physiotherapy). *Post-hoc* analyses were done with Tukey HSD tests when necessary. For all these statistical treatments, the significance level was set at $p < 0.05$.

Results

Clinical outcomes

Clinical outcomes are depicted in Table 3. No significant difference was observed on movement

Table 3.   Clinical outcomes measured before and after physiotherapy intervention.

Clinical outcomes	IS group ($n = 25$)	HS group ($n = 15$)
Stroke International Scale Movement (domains combined)		
Pre-physio	43.64 ± 17.64 (31;51)	43.53 ± 21.15 (28;53)
Post-physio	49.88 ± 15.15 (41; 61)	$53,33 \pm 17.49$ (45;56)
Timed Up and Go Test (s)		
Pre-physio	30.36 ± 10.79 (22;41)*#	29 ± 7.00 (25;34)
Post-physio	23.64 ± 4.63 (21;25)	33.93 ± 11.45 (26;42)

Notes: Values are mean $\pm$ SD. Statistical comparisons were made with unpaired t test and Mann–Whitney test. The level of significance was 0.05. Abbreviations: Ischemic Stroke (IS); Hemorrhagic Stroke (HS). #$p < 0.05$ difference between Pre-physio and Post-physio. *$p < 0.05$ interaction group x stage.

domain in the Stroke Impact Scale neither between groups, nor between pre and post-physiotherapy stages. For Timed Up and Go Test, there was a significant group effect that yielded an F ratio of F $(1,76) = 4.75$, $p = 0.032$ and significant interaction F $(1, 76) = 4.5$, $p = 0.036$. Thus, IS group showed reduction in Timed Up and Go Test score after physiotherapy, not observed in HS.

Gait assessment

No differences were found in the duration of the gait cycle in any phase neither between the pre- and post-physiotherapy, nor between groups. Stance phase in the pre physiotherapy stage

(IS $41.9 \pm 11.9\%$; HS $43.7 \pm 11.7\%$) and post-physiotherapy moment (IS $40.9 \pm 10.5\%$; HS 46.7 ± 11.4) were similar as well as the swing phase duration pre-physio moment (IS $57.1 \pm 12.2\%$; HS $54.3 \pm 12.7\%$) and post-physio moment (IS $60.5 \pm 9.0\%$; HS $54.9 \pm 11.7\%$).

Posterior leg muscles (BF, ST, and GAS) presented significant group, stage effect, and interaction. *Post-hoc* analysis revealed that the electromyographic amplitude from these muscles was higher during the stance phase after the physiotherapy, only in IS group (Fig. 1). HS group only increased BF electromyographic amplitude after the intervention. Moreover, the BF and ST muscle activation after the physiotherapy were
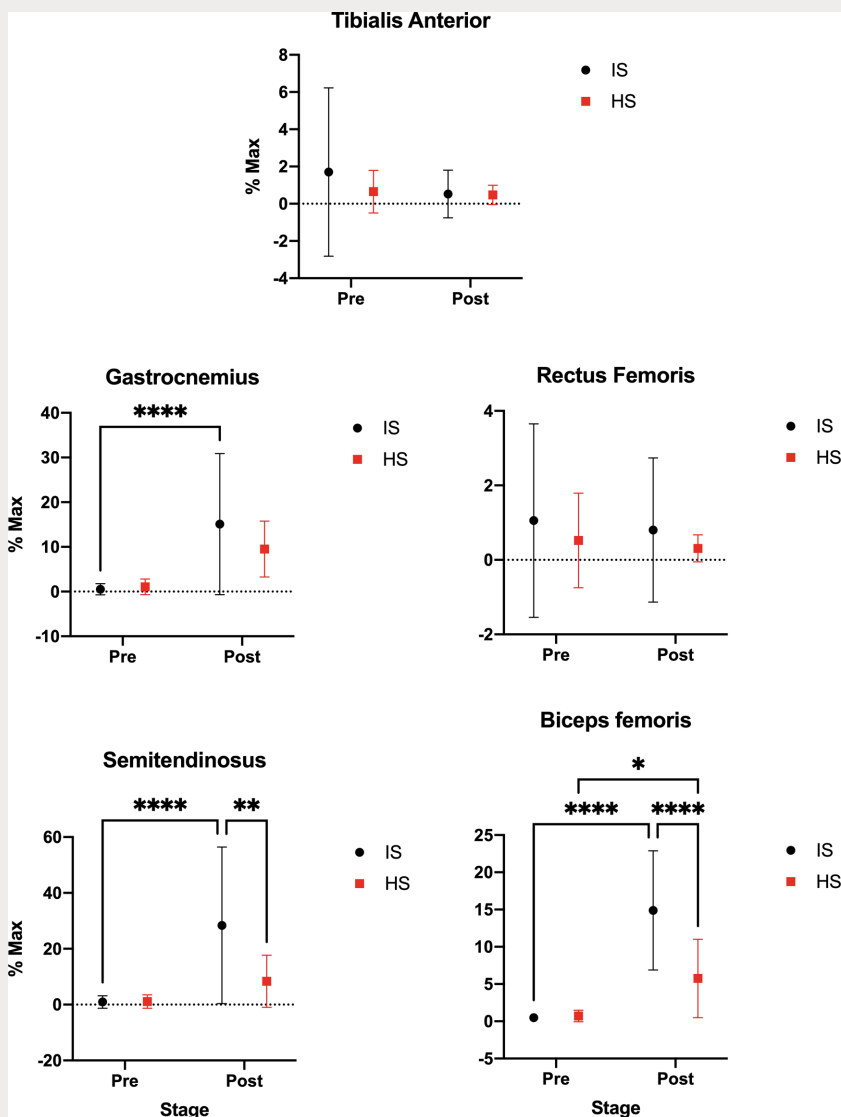
Notes: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$ and $****p < 0.0001$.

Fig. 1.   Muscles electromyographic amplitude during the gait stance phase at the pre-physiotherapy and post-physiotherapy stage, respectively.

Table 4.   ANOVA effects for muscles activation during stance and swing phases of gait.

Muscles	Stage (Pre/Post)	Group (IS/HS)	Interaction
		ANOVA	
BF			
Stance	$\boldsymbol{F(1,76) = 14.55; p = 0.0003^*}$	$\boldsymbol{F(1,76) = 69.50; p < 0.0001^{****}}$	$\boldsymbol{F(1,76) = 16.10; p = 0.0001^{***}}$
Swing	$F(1,76) = 0.871; p = 0.35$	$F(1,76) = 0.003; p = 0.953$	$F(1,76) = 0.026; p = 0.871$
Onset	$\boldsymbol{F(1,76) = 7.03; p = 0.009^{***}}$	$\boldsymbol{F(1,76) = 3.73; p = 0.05^*}$	$\boldsymbol{F(1,76) = 4.19; p = 0.04^*}$
ST			
Stance	$\boldsymbol{F(1,76) = 6.90; p = 0.010^{***}}$	$\boldsymbol{F(1,76) = 21.181; p = 0.0001^{****}}$	$\boldsymbol{F(1,76) = 7.15; p = 0.009^*}$
Swing	$F(1,76) = 0.000; p = 0.989$	$F(1,76) = 0.351; p = 0.555$	$F(1,76) = 0.000; p = 0.986$
Onset	$\boldsymbol{F(1,76) = 15.62; p = 0.0001^{****}}$	$F(1,76) = 0.494; p = 0.48482$	$F(1,76) = 9.37, p = 0.003^{***}$
GAS			
Stance	$\boldsymbol{F(1,76) = 28.66; p = 0.0001^{****}}$	$\boldsymbol{F(1,76) = 0.331; p = 0.0001^{****}}$	$\boldsymbol{F(1,76) = 0.285; p = 0.0001^{***}}$
Swing	$F(1,76) = 0.730; p = 0.396$	$F(1,76) = 0.765; p = 0.384$	$F(1,76) = 0.479; p = 0.491$
Onset	$F(1,76) = 1.502; p = 0.2245$	$F(1,76) = 3.714; p = 0.0581$	$F(1,76) = 0.803; p = 0.3733$
RF			
Stance	$F(1,76) = 0.311; p = 0.578$	$F(1,76) = 1.364; p = 0.246$	$F(1,76) = 0.002; p = 0.963$
Swing	$F(1,76) = 0.912; p = 0.343$	$F(1,76) = 2.244; p = 0.138$	$F(1,76) = 0.228; p = 0.634$
Onset	$\boldsymbol{F(1,76) = 15.25; p = 0.0001^{****}}$	$\boldsymbol{F(1,76) = 10.10; p = 0.002^{***}}$	$\boldsymbol{F(1,76) = 4.67; p = 0.034^*}$
TA			
Stance	$F(1,76) = 1.787; p = 0.185$	$F(1,76) = 0.787; p = 0.378$	$F(1,76) = 0.652; p = 0.422$
Swing	$F(1,76) = 1.304; p = 0.257$	$F(1,76) = 0.022; p = 0.881$	$F(1,76) = 0.136; p = 0.713$
Onset	$F(1,76) = 1.297; p = 0.258$	$F(1,76) = 1.589; p = 0.211$	$F(1,76) = 0.730; p = 0.396$

Abbreviations: Ischemic Stroke (IS); Hemorrhagic Stroke (HS); Muscle abbreviations: RF — rectus femoris, BG — Biceps femoris, ST — semitendinosus, GAS — gastrocnemious and TA — tibialis anterior. *Notes*: $^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$ and $^{****}p < 0.0001$.

significantly higher in IS group. No changes in leg muscle were observed during the swing phase (Table 4).

Figure 2 depicts the muscle activation during the gait cycle, before and after the intervention, in both groups (A: IS; B: HS), as well as the literature normal pattern (grey shadow).[19] Upper leg muscles presented an anticipation of the onset after physiotherapy, only in IS group. The RF onset during the initial swing phase showed a main group and stage effects, and interaction indicating an anticipation of the activation in IS compared to HS, BF, and ST onset during the swing phase presented the same behavior. Therefore, these results showed that RF, ST, and BF started their recruitment (onset) earlier at the swing phase of the gait cycle, which is more similar to the normal pattern (grey shadow). No differences were observed in lower leg muscles.

Discussion

In this study, we have measured some clinical outcomes and electromyographic features during the gait cycle and made a follow up in a group of post-stroke patients with delayed access to a rehabilitation program. Our main findings suggest some answers to our initial questions. Firstly, late intervention was more effective for IS than for HS patients, since they present higher changes in Timed Up and Go Test speed and changes in Muscle patterns and activation after the intervention. Indeed, IS patients, when recruiting muscles, were more similar to the normal standard in human walking, while no changes showed up in HS group after the intervention.

Physiotherapy intervention led to greater activation of the posterior muscles (BF, ST, and GAS) in IS patients while HS group only increased BF. IS group also presented changes in muscles onset during the gait cycle. Indeed, the thigh muscles (RF, BF, and ST) had better anticipation of muscle onset activity in post-physiotherapy stage. Patients have been reported to exhibit abnormalities in the temporal characteristics of muscle activity compared to normal gait[19] and these changes in IS group maybe an strategy in an attempt to deal with the non-functional gait.[10,20–22] As BF muscle helps the hip extension, and ST — RF co-contraction keeps the knee extension during the
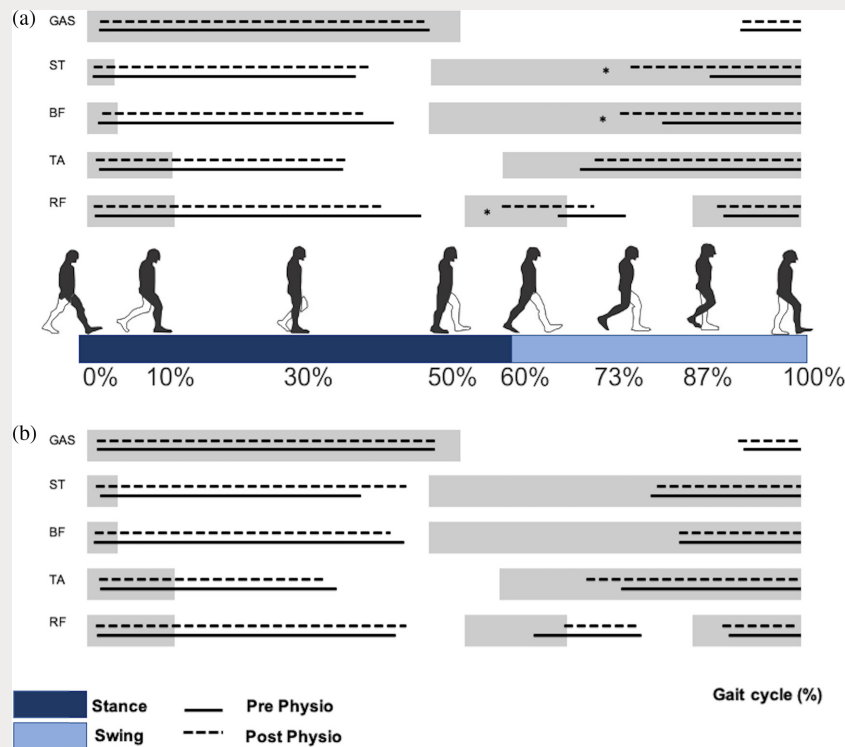
Fig. 2.   Muscles onset during the gait cycle where continuous and dashed lines represent muscle activation at the pre-physiotherapy and post-physiotherapy stage, respectively. A represents IS group; B represents Hs groups. Grey shadow represents the literature normal pattern.

gait cycle,[4] the anticipation of these three muscles increases the stiffness theses joints in order to help supporting full body weight. Moreover, the weakness of the calf muscles contributes to this.[4] Compared to normal gait, IS and HS showed TA-GAS co-activation at the early stance phase.[23] This prolonged and simultaneous activation of the lower leg muscles contributes helps to maintain dorsiflexion for the initial contact, and to control foot drop[4] but lead to inversion positioning of the ankle, as previously reported.[5,24] It was observed that the physiotherapy intervention did not change the TA-GAS co-activation patterns in any group during stance, aside from the earlier onset of thigh muscles (BF-ST-RF co-activation) presented by IS in swing phase. Longer BF, RF, and GAS activity during stance phase, associated to longer duration of BF-RF co-activation were previously described in the paretic patients compared to controls[25] in an investigation during early rehabilitation (35–90 days after stroke). But, curiously, these abnormal electromyographic activation patterns remained unchanged after 60 days of physiotherapy besides these patients showed better spatiotemporal and clinical measures of mobility and function. This was attributed to a paradigm where normal patterns of muscle activity are not directly linked to functional gait recovery.[25] In our results, the changes in Timed Up and Go Test speed were found only in IS group and, on the contrary of this unlinked paradigm, IS group also showed changes in muscle patterns after delayed access to rehabilitation. However, other factors, apart from the muscle temporal organization, such as force and spasticity, are also strictly related to gait performance and even improving the muscles timing, stroke patients remained much different to the normal pattern.[25]

Authors stated that the rehabilitation program should start early to be more efficient.[11,12] although no optimal time window have been defined.[11] Some authors suggest a period within three to 30 days post-stroke.[22,26,27] while others[28] reported that even chronic patients had improvements.[29] These last studies describing "late plasticity" may be the reason why we observed changed electromyographic activation patterns in our patients. However, as we hypothesized, this was only evident in IS patients.

The type of stroke is highly related to the severity of the impairments. IS is seven times more common but it tends to be less severe since it leads to a loss of neurologic function that depends to the extension of the brain area that the obstructed vessel supplies.[30] HS is highly associated with deaths and those that survive often have major neurological impairments. The diameter of lesions in HS patients was by 20% larger compared to IS. This may reflect differences in recovery and may explain partially our results.[31]

Possibly, other factors, as the intervention techniques may be also involved. Common gait retraining techniques, currently in clinical use,[32] includes strength training, functional electrical stimulation (FES),[33] treadmill training (with or without partial body-weight support),[34] EMG biofeedback[35] and splinting of the lower extremity.[36] Conventional physiotherapy, as offered to our patients, seems to be more effective with early intervention while more other registered clinical trials support that more expensive and elaborate techniques such as the partial bodyweight support and treadmill training, or biofeedback training resulted in improved gait performance.[37] Unfortunately, these treatments are not available in the public health system.

In our study, assessment of stroke recovery has been limited by the measures used to evaluate recovery (Stroke Impact Scale and Timed Up and Go Test). These are functional measures and individuals may continue to recover both neurologically and achieve higher levels of functional status, but these scales are not sensitive to these changes. In order to advocate for the most appropriate rehabilitation programs for stroke patients, health professionals must understand patterns of recovery and know the limitations of existing studies. This is the main reason why we performed the EMG measurements before and after delayed physiotherapy treatment of stroke patients. However, due to the number of channels of our EMG equipment, only five muscles were accessed and only on the paretic limb, which consists in a study limitation. Another limitation is the small number of subjects with HS stroke what might have effects in the differences observed.

Conclusion

IS patients, submitted to delayed physiotherapy treatment, had greater activation of the measured posterior muscles during stance phase. Timing analysis of the swing phase found that these patients had earlier ST, BF, and TA muscle onset anticipation. These physiological modifications improved Timed Up and Go Test speed but had limited effect in Stroke Impact Scale.

Conflict of Interest

Funding/Support

Author Contributions

ASSCA, GSS and BC conceived and designed the experiments. ASSCA, ATVCJ, SRAC, NICN, KJSC, RCL and TGCPB performed the experiments. AACS, DRG, GSS and BC analyzed the data. ASSCA, ATVCJ, SRAC, NICN, KJSC, RCL and TGCPB contributed reagents/materials/analysis tools. AACS, DRG, GSS and BC wrote the paper. All authors revised the final paper.

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