Journal of Electromyography and Kinesiology 39 (2018) 99–103

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Factors affecting premature plantarflexor muscle activity during hemiparetic gait

Kazuki Fujita[a,*], Hiroichi Miaki[b], Akira Fujimoto[a], Hideaki Hori[a], Hitomi Fujimoto[c], Yasutaka Kobayashi[d]

[a] Fukui Health Science University, Faculty of Health Science, Department of Rehabilitation Physical Therapy, Japan
[b] Kanazawa University, Faculty of Health Sciences, Institute of Medical, Pharmaceutical and Health Sciences, Japan
[c] Fukui College of Health Sciences, Department of Nursing, Japan
[d] Fukui General Hospital, Department of Rehabilitation Medicine, Japan

ABSTRACT

In hemiparetic stroke survivors, premature plantarflexor muscle activity (PPF) often appears as a gait abnormality from terminal swing to the loading response on the paretic side. This study aimed to discern factors giving rise to PPF. Lower extremity function, spasticity magnitude, and gait electromyograms were assessed in 31 hemiparetic stroke survivors. Mean amplitudes during gait phases were determined for the paretic soleus, tibialis anterior, rectus femoris, and biceps femoris. The subjects were classified into PPF and non-PPF groups based on their relative soleus amplitude at different phases of gait, and group differences in each measurement were calculated and subjected to logistic regression. The PPF group showed less activity of the tibialis anterior during the swing phase but greater activity of the rectus femoris during the swing phase and of the biceps femoris, both prematurely and during the loading response. Logistic regression revealed premature activity of the biceps femoris to be a significant variable related to presence of PPF (odds ratio = 1.054). PPF in hemiparetic gait may work with the biceps femoris to supplement compromised lower extremity extension strength. PPF might be reduced by attaining enhanced strength of the hip and knee extensors at the time of initial contact during gait.

1. Introduction

Ankle plantarflexors normally exhibit increased activity during the single support phase during gait (Perry, 2010). During the loading response, the activity of the ankle plantarflexors is rather subdued while the antagonistic dorsiflexors largely control the movement of the ankle (Perry, 2010). However, in case of hemiparetic patients, premature plantarflexor muscle activity (PPF) on the paretic side occurs from the terminal swing of one gait cycle to the loading response of the following cycle (Perry, 1993). This raises a concern that PPF may interfere with the normal ankle motion from the terminal swing to the loading response phases and thus be considered a potentially important negative factor during hemiparetic gait.

Previous reports on what triggers PPF indicate that in hemiparetic subjects with equinus gait, PPF results from stretch reflex excitability precipitated by ankle dorsiflexion at the moment of initial foot contact during the gait cycle (Hesse et al., 1996; Thomas et al., 1996; Neptune et al., 2007). According to a study on abnormal muscle activity during hemiparetic gait, activity in the soleus increases in conjunction with eccentric contraction of the quadriceps femoris during the terminal swing phase (Dyer et al., 2011). In addition, increased activity of the ankle dorsiflexors during the loading response phase provokes simultaneous increased activity of the ankle plantarflexors (Chow et al., 2012). These are considered to be abnormalities in both recurrent and reciprocal inhibition (Dyer et al., 2011; Aymard et al., 2013), with PPF possibly representing a corresponding emergence of abnormal muscle activity due to disrupted neural pathways at the spinal level. However, one report (Schweizer et al., 2013) has proposed that PPF is not necessarily a matter of neural dysfunction but that the most relevant determinant of PPF is weakness of the lower extremity muscles.

PPF thus appears to involve multiple factors; it is still not clear what triggers it. Remarkably, to date, no studies have examined this problem in a multifaceted manner. In particular, even though the ankle plantarflexor activity during gait by a hemiparetic person is influenced by both synergist and antagonist muscles (Dyer et al., 2011; Chow et al., 2012; Aymard et al., 2013), the specific relation between PPF and these

* Corresponding author.
E-mail address: k.fujita-fchs@kvj.biglobe.ne.jp (K. Fujita).

https://doi.org/10.1016/j.jelekin.2018.02.006
Received 20 July 2017; Accepted 9 February 2018

Table 1
Characteristics of subjects (n = 31).

Age (mean ± SD, in years)	57.1 ± 10.8
Sex (female/male)	11/20
Type of stroke (CI/ICH/SAH)	12/16/3
Paretic side (L/R)	17/14
Months since onset	77.1 ± 74.5
Brunnstrom recovery stage LE (III/IV/V)	3/19/9
Fugl-Meyer assessment LE	21 ± 3.4
Assistive device (none/T-cane/AFO)	6/19/23

Abbreviations: CI = cerebral infarction; ICH = intracerebral hemorrhage; SAH = subarachnoid hemorrhage; LE = lower extremity; AFO = ankle-foot orthosis.

other muscles has thus far remained uninvestigated. Therefore, this study aimed to look at how PPF during hemiparetic stroke gait is related to physical factors affecting gait, as well as the activities of synergists and antagonists, to determine what might precipitate PPF.

2. Methods

2.1. Subjects

The subjects were 31 hemiparetic stroke survivors with a mean ± SD age of 57.1 ± 10.8 years; it was 77.1 ± 74.5 months since the onset of stroke (Table 1). Inclusion criteria were (1) a unilateral cerebral lesion, (2) recovery of at least six months after the onset of the stroke, (3) ability to walk independently or supervised level with or without a cane but no brace, and (4) gait speed in the range of 0.1–1.0 m/s. Exclusion criteria were (1) no positive range of passive ankle dorsiflexion beyond neutral, (2) higher brain dysfunction that might hinder intervention or assessment, and (3) cardiovascular disease that would limit movement activity. Each subject's consent was obtained in writing after a full oral explanation. This study was approved by the ethics committee of Nittazuka Medical Welfare Center (approval no. 29-3 for new projects).

2.2. Assessments

Assessment procedures were selected from methods used in previous studies on PPF (Perry, 1993; Hesse et al., 1996; Thomas et al., 1996; Neptune et al., 2007; Dyer et al., 2011; Chow et al., 2012; Aymard et al., 2013; Schweizer et al., 2013). Motor function of the paretic lower extremity was measured using the Fugl-Meyer assessment (FMA-LE) (Fugl-Meyer et al., 1975), and strength in the paretic lower extremity was evaluated with the Motricity Index (MI-LE) (Collin and Wade, 1990). The modified Ashworth scale (MAS) and clonus score (Kirazli et al., 1998) were used to assess the spasticity of the triceps surae by dorsiflexing the ankle with the subject in the supine position. The range of ankle dorsiflexion motion (ROM-df) was measured with a goniometer to the nearest degree.

Electromyograms of gait were recorded as subjects walked along a straight 16 m walkway three times at a comfortable speed, with data only for the middle 10 m retained for analysis. Each subject walked while wearing shoes and was allowed to use a cane but not a brace. Time to walk the 10 m segment was measured with a stopwatch. Electromyograms were recorded with a Telemyo DTS (Noraxon, USA), digitized at 16-bit resolution, and stored in a personal computer. The sampling frequency was 1500 Hz, and analog signals were filtered with a bandpass of 10–500 Hz. Using the bipolar technique, myoelectric activities of the following four muscles on the paretic side were recorded: soleus, tibialis anterior, rectus femoris, and biceps femoris. After skin impedance was reduced to no greater than 10 kΩ using an alcohol swab and a skinPure preparation (Nihon Kohden), a Dual EMG Electrode (EM-272, Noraxon) with an inter-electrode distance of 2 cm between Ag-AgCl electrodes was applied to the treated skin area. Measurements of the electrode-skin impedance were made between each pair of electrodes using impedance checker (EM-570, Noraxon). Placement of the electrodes followed the guidelines endorsed by the SENIAM project (Surface ElectroMyoGraphy for the NonInvasive Assessment of Muscles) (The SENIAM project, http://www.seniam.org/lowerleg_location.htm). Foot switches (Noraxon) were bilaterally applied to the plantar surface of the great toe, the base of the first metacarpal, the base of the fifth metacarpal, and the plantar surface of the heel. A video camera (running at 30 frames/s) was placed on the side of the walkway 5 m away from its midpoint of the 10 m walkway. Noraxon MyoSync and Sync Light devices were used to synchronize the instruments and ensure alignment of the time frames.

2.3. Data analysis

Electromyograms were analyzed using myoMuscle Master software (Noraxon). From the electromyogram recorded during gait along the middle 10 m segment of the walkway, an excerpt spanning three consecutive gait cycles, determined from the footswitch data, was subjected to analysis. After the electromyogram was full-wave rectified, the excerpt covering three gait cycles was normalized in relation to the mean amplitude, and each of the three cycles was also normalized in time to 100%. The arithmetic mean amplitude of the three cycles was then calculated, with the result expressed as a time series of 1000 points, arranged at intervals of 0.1%. Initial contact was determined as the moment of voltage change from any footswitch on the paretic side, and images from the synchronized video camera were used to confirm gait phases indicated by the footswitches, with care taken to visually account for possible dragging of the foot as the swing phase began. The degree of talipes equinus at the initial contact (Equinus-IC) was recorded in accordance with the Physician's Rating Scale (Boyd and Graham, 1999), using a score of 1 for forefoot contact, 2 for plantigrade contact, and 3 for heel contact. Gait speed was calculated from the time taken to walk 10 m that was measured with a stopwatch.

PPF was determined as the mean normalized amplitude of the soleus electromyogram over a period covering the final 10% of one gait cycle and the initial 10% of the subsequent gait cycle (from the terminal swing through the loading response phases on the paretic side). In addition, functional plantarflexor muscle activity (FPF) was measured by the mean normalized amplitude during 20–50% of the gait cycle (single support phase on the paretic side), as shown in Fig. 1 (Hesse et al., 1996). Electromyograms of the other recorded muscles underwent similar treatment to determine the mean amplitude of premature activity as well as the mean amplitudes during the swing phase and loading response phase.

2.4. Statistical analysis

Each subject was classified into either the PPF group, if the soleus PPF exceeded the FPF score, or the non-PPF group. Assessment variables were subjected to a Mann-Whitney or a *t*-test for comparisons between the two groups. A score of 1+ in the MAS was assigned as 2, and scores of 2 and higher were revised upward by 1. Next, to search for factors influencing PPF, logistic regression analysis was conducted with PPF group assignment, 1 or 0, as the response variable, and items yielding statistically significant differences between the groups as explanatory variables. To avoid the problem of multicollinearity, correlations between various assessment items were examined. SPSS version 20 for Windows (IBM) was used for the statistical procedures, with the level of significance set at 5%.

3. Results

3.1. Comparisons between the PPF and non-PPF groups

Thirteen subjects were assigned to the PPF group (PPF: 151.5% ± 26.2%; FPF: 114.9% ± 21.4%) and the other 18 were