Gait & Posture 39 (2014) 1092–1096

Contents lists available at ScienceDirect

Gait & Posture

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

Gait kinematics of people with Multiple Sclerosis and the acute application of Functional Electrical Stimulation

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ARTICLE INFO

Article history:
Received 19 August 2013
Received in revised form 13 December 2013
Accepted 22 January 2014

Keywords:
Multiple Sclerosis
Walking speed
3D gait analysis
Functional Electrical Stimulation

ABSTRACT

This study aimed to (i) compare the gait characteristics of people with Multiple Sclerosis (pwMS) to those of healthy controls walking at the same average speed, and (ii) assess the effects of the acute application of Functional Electrical Stimulation (FES) to the dorsiflexors.

Twenty-two people with pwMS (mean age 49 years), prescribed FES, and 11 age matched healthy controls participated. Three dimensional gait kinematics were assessed whilst (i) pwMS and healthy controls walked at self-selected speeds (SSWS), (ii) healthy controls also walked at the average walking speed of the pwMS group, and (iii) people with MS walked using FES.

Compared to healthy controls walking at their SSWS, pwMS walked slower and showed differences in nearly all gait characteristics ($p < 0.001$). Compared to healthy controls walking at the same average speed, pwMS still exhibited significantly shorter stride length ($p = 0.007$), reduced dorsiflexion at initial contact ($p = 0.002$), reduced plantar flexion at terminal stance ($p = 0.008$) and reduced knee flexion in swing ($p = 0.002$). However, no significant differences were seen between groups in double support duration ($p = 0.617$), or hip range of motion ($p = 0.291$). Acute application of FES resulted in a shift towards more normal gait characteristics, except for plantar flexion at terminal stance which decreased.

In conclusion, compared to healthy controls, pwMS exhibit impairment of several characteristics that appear to be independent of the slower walking speed of pwMS. The acute application of FES improved most impaired gait kinematics. A speed matched control group is warranted in future studies of gait kinematics of pwMS.

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Introduction

A common gait problem even in minimally impaired people with Multiple Sclerosis (pwMS) is reduced dorsiflexion or increased plantar flexion at initial contact which is associated with 'foot-drop' in swing [1–3], which increases the risk of tripping and falling. The conventional treatment approach to manage foot-drop is the prescription of an Ankle Foot Orthosis (AFO) although, increasingly, Functional Electrical Stimulation (FES) to the pre-tibial muscles to aid dorsiflexion in swing, is also prescribed. There are some indications that FES may have some advantages over AFO as it is an active rather than passive approach to treat foot drop [4].

The need for, and effect of, these assistive devices can be assessed through measures of walking ability, either using standardised tests such as the 10 m walk tests [5–10] or self-reported measures such as the MS walking scale [11]. However, these measures provide limited information on the 'gait quality' which is best described and quantified by gait characteristics such as joint kinematics and spatio-temporal stride parameters. Gait characteristics of people with MS have been described previously, with the majority of studies reporting the spatio-temporal stride parameters both in absolute terms [5,12,13] and their variability [14–16].

However, few studies characterised the lower limb joint kinematics of people with MS [1–3,17,18] in comparison to age matched healthy controls. Such an approach may provide insight into the underlying gait problems associated with MS whilst also facilitating a more comprehensive assessment of the effects of devices such as FES or AFOs upon the gait of pwMS.

Benedetti et al. [1] studied the gait of seven very mildly affected people with MS (EDSS 0–2) and reported a slower walking speed,

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http://dx.doi.org/10.1016/j.gaitpost.2014.01.016

increased double support, reduced peak ankle plantar flexion in terminal stance compared to a control group of 10 healthy volunteers. The authors concluded that this gait pattern indicated a lack of fine motor control, which was also suggested by Kelleher et al. [18] and Huisinga et al. [17].

In previous studies, in which the lower limb kinematics of people with MS were compared with those of people without impairments, the non MS group were observed to walk with a faster self-selected walking speed than those with pwMS. A few reports [1,19,20] have recognised that gait kinematics and spatial–temporal stride parameters are influenced by walking speed, and in so doing, used walking speed as a covariate in their statistical analysis. However, such an approach may be problematic as some of the effects of walking speed on gait kinematics are both non-linear and dependent on the range of walking speeds studied [21–23]. In order to assess whether an intervention such as FES or another assistive device results in a 'normalisation' of the person's gait pattern it is of importance to have a group of age and gender matched healthy controls as a reference population. Based on previous studies [21–23], we hypothesised that although significant differences in gait kinematics between such groups may exist, some of the differences in gait kinematics between pwMS and healthy controls would be attributable to differences in self-selected walking speed. The primary aim of this study was to describe the gait characteristics of pwMS by comparing these to the gait characteristics of an age matched group of control participants walking at a range of slower walking speeds. Secondly, we investigated whether that the acute application of FES to the dorsiflexors of the pwMS would produce an improved gait kinematic pattern which is closer to that of a group of age and walking speed matched people without MS.

Methods

Participants in the MS group were recruited through a community NHS (National Health Service) physiotherapy service. People with a positive diagnosis of MS between the ages of 18 and 75 who were considered by a clinical specialist physiotherapist to be suitable for FES to manage foot drop were eligible for participation in this study. Only people who had not been using FES for more than three weeks were included in the study. The age matched participants in the healthy group were a convenience sample of colleagues and family without any neurological or orthopaedic conditions affecting their gait. The study received approval from both by the University and National Health Service research ethics committees. In accordance with the Declaration of Helsinki, all participants provided written informed consent before taking part in the study.

Protocol

Three dimensional gait analysis of barefoot walking was performed for both groups. It was decided to perform barefoot gait analysis and attach the ODFS footswitch under the heel of the participants in the MS group using tape to avoid having to attach markers to the footwear which may lead to inaccuracies in the calculation of the ankle kinematics.

Participants were requested to walk a distance of about 6–7 m during which their gait was recorded. In the MS group the first six trials were performed with the FES switched off, followed by six trials with the FES switched on. Participants were able to use additional walking aids (walking sticks) during testing if required and used these for both 'FES off' and 'FES on' conditions. Participants in the healthy control (HC) group were asked to walk at their self-selected walking speed for the first six trials. Following these trials, participants were instructed to walk at a slower speed. The researcher timed the walk over 5 m and informed the participant whether this was faster or slower than the target speed of 0.74 m/s which was the average speed of the MS group. After a few practice trials, the participants in the HC group then performed six trials at the slower speed. Walking speed for both groups was derived from the Vicon Plug-In-Gait Model output.

Gait analysis

Three dimensional gait analysis was undertaken using a 100 Hz eight camera Vicon Nexus three dimensional motion analysis system (Vicon Motion Systems, Oxford, UK). Participants had 14 mm diameter passive reflective sphere makers attached to anatomical landmarks of their lower limbs and the pelvis according to the Vicon Plug-In-Gait manual which is based on the Helen Hays marker system [24]. A static trial was conducted using a Knee Alignment Device (KAD) to derive the orientation of the knee flexion extension axis.

Functional Electrical Stimulation

The single channel Odstock Drop Foot Stimulator (ODFS III, Biomedical Engineering and Medical Physics, Salisbury, UK) was used to administer FES. The intensity of the current amplitude ranged from 20 to 70 mA and was determined by the amplitude required to achieve adequate foot clearance during the swing phase of the gait. One surface electrode was placed over the common peroneal nerve as it passes over the head of the fibula and another over the motor point of the Tibialis Anterior. The stimulation frequency was 40 Hz and output time, extension time and ramp were adjusted for each subject to optimise the amount and timing of dorsiflexion. After being taught by their physiotherapist how to use the stimulator and attach the electrodes prior to taking part in the study, participants had set up the stimulator themselves before attending the gait analysis laboratory. This set-up was not changed for gait assessments as the researcher responsible for data collection was not qualified to fit the ODFS.

Kinematic data processing

Three-dimensional kinematics of the ankle, knee, hip and pelvis and stride parameters were derived from the Plug-in-Gait software (Vicon Motion Systems, Oxford, UK). Kinematic data were time normalised so that every trial included the data between two consecutive foot strikes which was defined as one gait cycle. The following angles were derived from each trial: ankle dorsiflexion at initial contact, peak plantar flexion in terminal stance, peak dorsiflexion in swing, peak knee flexion in swing, sagittal hip range of motion and peak pelvic obliquity in swing. Data from the most affected limb in the MS group, to which FES was applied, and from both the left and right leg of the HC group were analysed.

The average value of each of these angles was calculated over the six trials for each participant. The Gait Profile Score (GPS) was derived from the ankle, knee, hip and pelvis kinematics of the most affected leg in the MS group as this is an index of overall gait pathology and has been mostly used to describe the children with Cerebral Palsy [25]. The GPS in this study was calculated from Gait Variable Scores for the sagittal ankle, knee and hip kinematics and frontal plane hip and pelvis kinematics. Gait Variable Scores were calculated as the RMS differences over the whole gait cycle of each individual participant in the MS group and the average data from the HC group walking at the slower speed. A higher GPS score indicates a greater deviation from normal gait.

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