Gait kinematics after forty weeks of use of the Walkaide 2: a case study

Preuss R [1,2], Stein RB[3], Fung J [1,2]

[1] School of Physical and Occupational Therapy, McGill University, Montreal, Canada
[2] CRIR Research Centre, Jewish Rehabilitation Hospital, Laval, Canada
[3] Centre for Neuroscience and Department of Physiology, University of Alberta, Edmonton Canada

richard.preuss@mail.mcgill.ca

Abstract

Functional electrical stimulation (FES) of the common peroneal (CP) nerve is known to have positive orthotic effects for patients with a dropped foot. The Walkaide2 (WA2) is a battery-operated, single channel electrical device that senses the orientation of the leg and stimulates the CP nerve at different phases of the gait cycle. This case study investigates the effects, both orthotic and therapeutic, of 40 weeks of daily use of the WA2 on the kinematics of gait of a 59 y.o. male with a dropped foot following a stroke. Kinematic variables were measured during walking, both with and without the WA2, at 4 separate sessions (following 0, 4, 12 and 40 weeks of use) using a 6-camera Vicon 512 motion analysis system. As expected, an increase in the range of dorsiflexion was observed at the affected ankle with the WA2. More importantly, over the 40 weeks of use, an increase in dorsiflexion was noted even when the subject walked without the WA2. Within the limits of a single-subject design, these results support the therapeutic and orthotic efficacy of FES, with respect to gait kinematics, from prolonged use with the WA2.

1. INTRODUCTION

The WalkAide 2 (WA2) is a battery-operated, single channel electrical stimulator to be used by patients with a dropped foot resulting from a stroke, an incomplete spinal cord injury or some other impairments of the central nervous system. The WA2 is designed to stimulate the common peroneal (CP) nerve where it is closest to the skin surface as it passes posterior to the fibular head. During use, the WA2 is mounted on the lower leg of the paretic limb using a Velcro brace. Stimulation is triggered, during gait, by a programmable tilt sensor, such that stimulation begins at toe-off, and ends at heel strike. By appropriately positioning the surface electrodes, a balanced contraction of the Tibialis Anterior and Peroneal muscles can be achieved, allowing for active dorsiflexion of the ankle during the swing phase of gait, without excessive ankle inversion or eversion.

Functional electrical stimulation (FES) of the CP nerve is known to have a positive orthotic effect (effect occurring during stimulation), improving variables such as walking speed [1] in stroke patients with a dropped foot. Similarly, there is evidence that FES can have a positive therapeutic effect (carry-over) on gait in stroke patients, potentially stimulating some degree of motor recovery [2].

The purpose of the current study was to evaluate the gait kinematics of a single subject for any orthotic and therapeutic effects derived from 40 weeks of use of the WA2.

2. METHODS

2.1. Subject

The subject for this case study was a 59 y.o. male with a right sided hemiparesis, including a dropped foot, resulting from a stroke 2 years prior to testing. At the time of the first testing session the subject used both an ankle-foot orthosis (AFO) and a cane for ambulation, but was able to walk independently over short distances without ambulatory aids or bracing. Informed consent was provided by the subject prior to participation.

2.2 Acquisition and Analysis

Data were collected at 4 separate testing sessions - an initial session (session 1), after 4 weeks (session 2), 12 weeks (session 3) and 40 weeks (session 4) - with the subject instructed to use the WA2 as much as possible during his day-to-day activities between sessions. During testing, the subject was asked to walk along a

pathway, at a self selected pace, both with and without the WA2. For each session, between 6 and 19 complete gait cycles were collected for both the left and right lower extremities.

Three-dimensional kinematic data was acquired using a 6-camera Vicon 512 motion analysis system (Vicon Motion Systems Ltd.), with marker position sampled at 120Hz. Gait kinematics were determined using Vicon Plug-in-Gait marker placement and software. The gait variables evaluated included, bilaterally: ankle, knee and hip angles in the sagittal plane, centre of mass (CoM) position in the frontal plane, and ankle marker position in the frontal plane as a measure of circumduction. Prior to modelling and analysis all marker position data was low pass filtered using a dual pass, 4th order digital Butterworth filter at a cutoff frequency of 8Hz. Filter frequency was based on the maximum frequency obtained from a residual analysis of all marker position data.

3. RESULTS

3.1. Orthotic Effects

A comparison of the average gait kinematics over the 4 testing sessions revealed an increase in right (paretic) ankle dorsiflexion at toe-off, and throughout the swing phase of gait, with the WA2 (Figure 1).

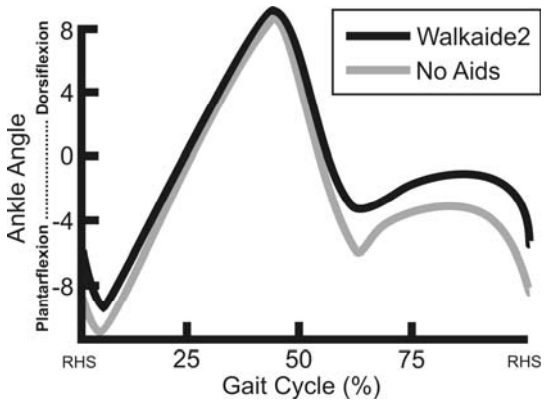

Figure 1 - Average ankle angle over the gait cycle with and without the WA2.

A minor decrease in right knee flexion was also noted at toe-off, and in the early swing phase, when using the WA2. The right hip angle in the sagittal plane, as well as the degree of circumduction and the lateral movement of the CoM, were unaffected, as were all variables investigated on the left (non-paretic) side.

3.2. Therapeutic Effects

The main therapeutic effect noted was an increase in right (paretic) ankle dorsiflexion during the swing phase, normalized to the ankle angle at toe-off, even without the WA2 turned on. This increase was noted in both sessions 2 and 3, with a further increase noted in session 4 (Figure 2).

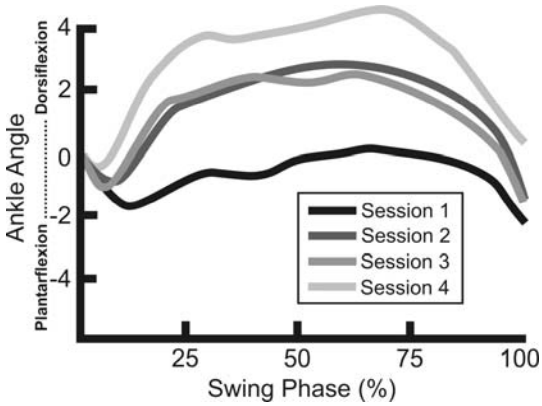

Figure 2 - Average ankle angle over the swing phase of gait, normalized to the angle at toe-off, for the 4 testing sessions, without the WA2.

A slight decrease in right knee flexion was also noted at toe-off during sessions 3 and 4. No other changes in gait kinematics were noted between testing sessions.

4. DISCUSSION AND CONCLUSIONS

As described previously, the WA2 is a functional electrical stimulator designed to stimulate the common peroneal nerve during the swing phase of gait in order to achieve an increase in dorsiflexion for patients suffering from a dropped foot. This is well demonstrated in the observed orthotic effect at the ankle (Figure 1).

Perhaps of more importance, however, is the apparent therapeutic effect noted at the ankle between testing sessions over the 40-week period of use. The improved dorsiflexion at the ankle, observed in the absence of external stimulation (Figure 2), suggests that the stimulation provided by the WA2 may promote a degree of motor recovery, either neurological, by training the individual to better recruit the muscles in question, or mechanical, by strengthening these muscles through use thus allowing the patient to make better use what residual recruitment remains.

Kottink et al [1] suggest a number of theoretical advantages to FES over the use of an AFO for

patients suffering from a dropped foot. These include stimulation of blood circulation due to the muscle contraction achieved by FES, improved afferent feedback, cosmesis, and the fact that electrical stimulators need not be custom made. These advantages, however, may at present be outweighed by the increased task complexity of applying FES versus an AFO. If it could be demonstrated, however, that the benefits of FES were therapeutic in the long term, as well as orthotic, this would certainly tip the scales in favour of FES over bracing, even as the practicality of this technology remains in development.

The limitations of the current study are clear. The use of a single subject design precludes generalizing these results, or drawing conclusions about the orthotic and therapeutic effects of the WA2. Further, the limitations of the cinematographic technology and methods used to measure the gait kinematics may introduce errors in the measured values, skewing these results either positively or negatively. As such, further study, using a randomized, placebo-controlled study design, is required before any conclusion can be drawn with respect to the beneficial effect of the WA2 on gait kinematics. In addition, future studies should be designed in such a manner as to shed greater light on the potential mechanisms of the improvements observed in the current study: in particular whether these improvements result from neurological or mechanical adaptations, or from some combination of these.

Despite these limitations, the results of this case study are promising, providing further insight into the potential benefits of FES. Specifically, these results imply that the WA2 may provide both orthotic and therapeutic benefits for increasing dorsiflexion during the swing phase of gait for stroke patients with a dropped foot.

References

[1] Kottink A, Oostendorp L, Buurke J, *et al* The orthotic effect of functional electrical stimulation on the improvement of walking in stroke patients with a dropped foot: a systematic review. *Artificial Organs* 28, 577-586, 2004.

[2] Yan T, Hui-Chan C, and Li L. Functional electrical stimulation improves motor recovery of the lower extremity and walking ability of subjects with first acute stroke: a randomized placebo-controlled trial. *Stroke* 36, 80-85, 2005.

Acknowledgements

We would like to thank Ms. Su Ling Chong, at the University of Alberta, for her assistance with the WA2. We also acknowledge the support of the JRH Foundation and CRIR. RP is a PhD candidate supported by the CIHR and a McGill Tomlinson award. JF is a senior research scholar supported by the FRSQ and the McGill William Dawson endowment.