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Reciprocal versus swing-through gait using implanted functional electrical stimulation in motor complete SCI. A case report.

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Abstract

Most of the studies on lower extremity functional electrical stimulation focus on the use of a reciprocal gait pattern. However, a swing-through pattern is another option. The purpose of this study was to compare a reciprocal and a swing-through gait pattern using an implanted FES system with 18 lower extremity channels in a young man with a thoracic spinal cord injury. After training, the subject underwent instrumented gait analysis using both patterns, and the results showed that the subject could walk faster and take larger steps when using a swing-through pattern as compared to a reciprocal pattern. The subject also reported preferring the swing- through pattern as it was faster. Due to the subject's preference for the swing-through gait pattern, less emphasis was placed on the reciprocal gait pattern during training. Therefore, further training and altering of patterns of muscle stimulation may have allowed the subject to walk faster with a reciprocal pattern.

1. INTRODUCTION

The majority of studies using functional electrical stimulation (FES) for standing and walking in individuals with spinal cord injury (SCI) have focused on the use of a reciprocal gait pattern for ambulation, in which right and left steps are taken individually. However, some studies have instead studied the outcomes of upright mobility using FES and a swing-through gait pattern, in which the user advances both legs simultaneously, supporting all of the body weight through the upper extremities using an assistive device.[1,2] In all of these studies using FES, stimulation has been provided through electrodes placed on the skin surface, through percutaneous intramuscular electrodes that are implanted directly into the muscle and exit at the skin surface, and through completely implanted systems.[2] Studies using primarily a swing-through pattern utilize either percutaneous or implanted FES using fewer electrodes/channels (typically 4 per leg),[1,2] while those focusing on a reciprocal gait pattern have used surface, percutaneous, or implanted FES with the number of electrodes/channels ranging from 6 using surface electrodes[3] to 48 using percutaneous electrodes.[4]

Collectively, these studies have shown that FES is feasible using both types of gait patterns. However, no study has compared these two types of gait patterns within an individual user. The purpose of this report is to compare a reciprocal and a swing-through gait pattern in a young man with an SCI and an implanted FES system.

2. METHODS

A 21-year-old young man with a T8 ASIA A SCI of 2 years duration underwent implantation of the Praxis FES System (Cochlear Ltd, Lane Cove, NSW, Australia), which consists of a 22-channel implant stimulator placed subcutaneously in the lower chest. Insulated stretchable leads

Table 1: Muscles stimulated bilaterally during swing-through gait*, the stance phase of reciprocal gait #, and the swing phase of reciprocal gait^.

Posterior adductor magnus*#
Biceps femoris – long head*#
Gluteus maximus*#
Gluteus medius, minimus, tensor fascia lata*#^
Vastus lateralis, vastus intermedius*#
Vastus medialis, vastus lateralis*#
Tibialis anterior, extensor digitorum longus^
Iliopsoas^

were connected to 18 epineural electrodes to stimulate nerves in the lower limbs (Table 1). The available stimulation parameters are 0.2-8.3 mA amplitude, 25-600 μsec pulse duration, and 2-500Hz pulse frequency per channel. Stimulation patterns were delivered to the implanted stimulator using a hand held pocket personal computer that communicates with the internal stimulator via a transmit coil placed on the skin.

Upright mobility was achieved through either continuous stimulation to the lower extremities for standing and bilateral swing-through gait or through alternating extension and flexion for reciprocal gait using open loop control. Transitions between sitting and standing were achieved by ramping stimulation up or down and were activated through the use of push button switches. For reciprocal gait, swing was achieved through stimulation to the iliopsoas and the tibialis anterior to create a flexor withdrawal response and each step was initiated through a push button switch on the walker. Bilateral articulating ankle foot orthoses were worn for all upright mobility activities.

Four weeks post implantation of the Praxis FES System, the subject participated in 4 weeks of strengthening and conditioning of the implanted muscles followed by 17 weeks of upright mobility training. Upright mobility training focused on programming of the upright mobility strategies and training on their functional use. Goals included achievement of the transitions between sitting and standing, and swing-through and reciprocal gait.

Following training, the subject underwent instrumented gait analysis using a reciprocal gait pattern with a wheeled walker and a swing-through gait pattern with forearm crutches. Self-selected gait speed, step length, cadence, and joint kinematics during gait were assessed via motion analysis utilizing a 7-camera system (Vicon Motion Systems, lake Forest, CA). For assessment of lower extremity kinematics, retroreflective spherical markers of 25 mm diameter were placed midway between the two posterior superior iliac spines and bilaterally on the anterior superior iliac spine, greater trochanter, lateral femoral condyle, lateral malleolus, and dorsum of the foot between the 2nd and 3rd metatarsal heads. Retroreflective spherical markers positioned on 35 mm long wands were placed laterally on the mid-thigh and mid-shank in a position of neutral segment rotation with the axis aligned with the flexion/extension axis of the joint immediately distal to the wand.

3. RESULTS

Walking with a swing-through gait pattern was faster with a higher cadence and a longer step length as compared to the reciprocal pattern (Table 2). Step length was longer with the swing-through pattern than that seen with typical gait, but cadence and velocity were lower.

Table 2: Spatial-temporal gait parameters

Gait Pattern	Velocity (m/s)	Cadence (steps/min)	Step Length (m)
Swing-through	0.6 ± 0.02	65.7 ± 3.8	1.0 ± 0.1
Reciprocal	0.1 ± 0.01	14.0 ± 0.9	0.4 ± 0.1
Typical Gait	1.3 ± 0.2	96.9 ± 5.7	0.6 ± 0.1

The sagittal plane kinematics (Figure 1) showed greater excursion of the pelvis with the swing-through pattern, showing that this was a unique strategy for this type of gait pattern. As expected, the sagittal plane excursions at the hip and the knee were greater with the reciprocal pattern. However, these were different from what is seen during typical gait for both excursion and timing. Interestingly when comparing toe-off between the two gait patterns and typical gait, toe-off occurred at a similar point in the gait cycle (around 60%) during swing-through and typical gait. With reciprocal gait, toe-off occurred much later (around 80% of the gait cycle).

4. DISCUSSION

Swing-through gait with FES was faster than reciprocal gait with FES for this subject, and both patterns differed in sagittal plane kinematics as compared to typical gait. The subject reported preferring the swing-through gait pattern to the reciprocal pattern, despite the fact that he needed to lift his entire body weight to advance his legs simultaneously. He preferred walking quickly as opposed to walking taking individual steps. Although not studied in the motion analysis lab, the subject did report preferring a reciprocal pattern for ascending stairs, as the reciprocal motion assisted with the lift onto a step.

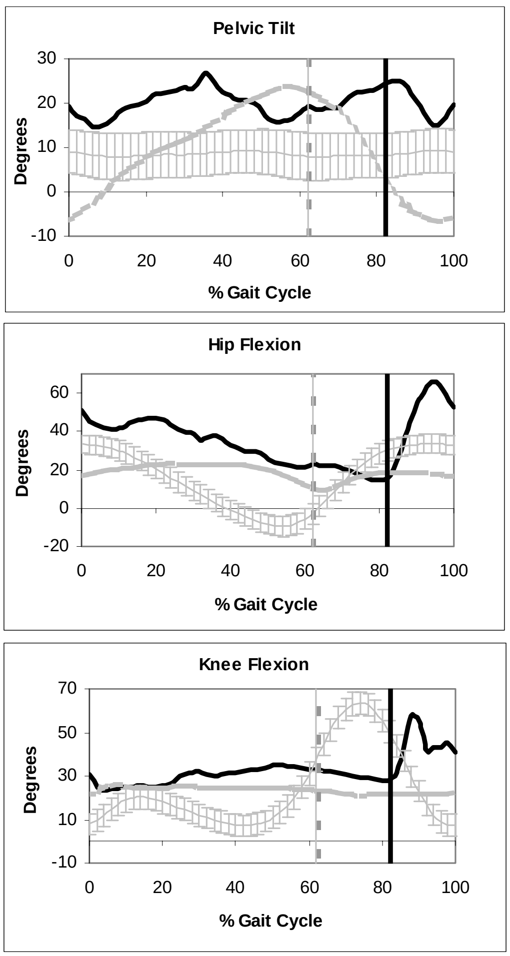

Figure 1: Sagittal plane joint kinematics for reciprocal (black line) and swing-through gait (gray line) as compared to typical gait (gray line with bars representing one standard deviation). The positive direction indicates anterior pelvic tilt, hip flexion, and knee flexion. 0% of the gait cycle represents the beginning of stance. The vertical lines indicate when toe-off occurs for reciprocal (black line) and swing-through gait (gray line with dashes) as compared to typical gait (gray line). Note that toe-off occurs at the same point for swing-through and typical gait just after 60% of the gait cycle, but that toe-off during reciprocal gait occurs much later in the gait cycle.

Due to the subject's preference for the swing-through pattern throughout the training period, more focus was directed toward perfecting this pattern instead of the reciprocal pattern. The subject may have learned to walk faster with greater hip and knee extension using the reciprocal pattern with more training and continued work with attempting to perfect the timing of the stimulated muscles.

This subject did undergo extensive surgery to place the 18 electrodes to the lower extremity muscles to allow a reciprocal gait pattern. A swing-through gait pattern can be provided with fewer channels of stimulation, with studies reporting success with the use of 8 channels.[1,2] However, with 8 channels, this subject would not have been able to ascend stairs reciprocally, one benefit that he saw of the reciprocal pattern. Further research is needed to optimize reciprocal walking and to determine the advantages and disadvantages of each gait pattern.

References

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