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# Spatiotemporal, Kinematic, and Kinetic Effect of a Peroneal Nerve Stimulator Versus an Ankle Foot Orthosis in Hemiparetic Gait

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## Abstract

**Background—**The relative effect of a transcutaneous peroneal nerve stimulator (tPNS) and an ankle foot orthosis (AFO) on spatiotemporal, kinematic, and kinetic parameters of hemiparetic gait has not been well described.

**Objective—**To compare the relative neuroprosthetic effect of a tPNS to the orthotic effect of an AFO using quantitative gait analysis (QGA).

**Design—**Twelve stroke survivors underwent QGA under three device conditions, 1) no device (ND), 2) AFO, and 3) tPNS. A series of repeated measures ANOVA (rmANOVA) were performed with dorsiflexion status (presence or absence of volitional dorsiflexion) as a covariate to compare selected spatiotemporal, kinematic, and kinetic parameters for each device condition. Post-hoc pairwise comparisons and/or subset analysis by dorsiflexion status were performed for significant effect.

**Results—**Stride length was improved with both the AFO (p=.035) and the tPNS (p=.029) relative to ND. Subjects without dorsiflexion (DA) had longer stride length with the tPNS relative to ND (p=0.034) and a higher walking velocity with a tPNS relative to the AFO (p=0.015). There was no device effect on dorsiflexion angle at initial contact (DFIC), however, a significant device×dorsiflexion status interaction effect favored the AFO relative to ND (p=0.025) in subjects with dorsiflexion present (DP).

**Conclusion—**This study suggests that level of motor impairment may influence the relative effects of the tPNS and AFO devices in chronic hemiparetic gait; however, the small sample size limits generalizability. Future studies are necessary to determine if motor impairment level should be considered in the clinical prescription of these devices.

### Keywords

hemiparesis; gait; peroneal nerve stimulation

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## Introduction

The neuroprosthetic effect of a transcutaneous peroneal nerve stimulator (tPNS)[1–4] and the orthotic effect of an ankle foot orthosis (AFO)[5] on various gait parameters in hemiparetic gait have been previously described. However, while the tPNS is a clinically accepted alternative device, the rehabilitation intervention considered standard of care for post-stroke footdrop in the United States remains the AFO.[1,2] A paradigm shift in stroke rehabilitation clinical care requires evidence-based research demonstrating, at a minimum, an equivalency of effect between the two devices. The few studies which have directly compared the neuroprosthetic effect of a tPNS to the orthotic effect of an AFO suggest equivalency in walking speed[6–9], activity level[9], and functional mobility[6] and a superior effect of a tPNS on balance control[7] and device satisfaction[9].

The relative effect of a tPNS and an AFO on spatiotemporal, kinetic, and kinematic parameters of hemiparetic gait using quantitative gait analysis (QGA) has not been well described in the literature. Voigt et al[10] presented a case series of eight hemiparetic stroke subjects, comparing kinematic and kinetic gait parameters with and without a tPNS device, but did not compare performance to an AFO. Van Swighem et al[11] presented a single case study of within-subject AFO, transcutaneous, and implanted PNS device performance in a subject who had not tolerated a tPNS device due to skin breakdown. Kottink et al[12] randomized subjects to receive either an implantable PNS device or standard of care intervention (defined as either an AFO, shoe, or no device). Baseline and end of treatment spatiotemporal and kinematic gait parameters were compared but neither relative device effects, using an intrasubject study design, nor kinetic parameters were studied. Secondly, spatiotemporal, kinematic, and kinetic analysis of an implantable PNS device performance would not necessarily be expected to yield the same results as tPNS performance because of variability of placement (stimulating electrode, heel switch or tilt sensor) and specificity of muscle stimulation between devices. Stroke rehabilitation physicians in the US do not have the clinical option of having their patient implanted with a PNS device as the device is not presently FDA approved, thus the relative effect of an implantable PNS device to a standard of care device is less clinically relevant. Presently, there are three FDA approved tPNS devices being prescribed by physicians providing clinical care of stroke rehabilitation patients in the US yet the relative effect of a tPNS device and AFO is not well understood for any given patient.

Our primary study hypothesis was that the tPNS and AFO devices would have equivalent effects on the selected spatiotemporal gait parameters (walking velocity, stride length, cadence, and double support time). Our second hypothesis was that ankle dorsiflexion angle at initial contact (DFIC) would be improved by both the tPNS and AFO devices but that peak dorsiflexion, knee flexion, and hip flexion during swing would be greater in the tPNS device condition due to a lower extremity flexion withdrawal response[13] elicited specifically by the tPNS. Our third hypothesis was that peak ankle power at push-off would be less in the AFO device condition, relative to the tPNS device condition, due to inhibition of active ankle movement by the AFO.

## Methods

### Study Design

This case series evaluated 12 chronic hemiparetic stroke survivors who were participating in a randomized controlled trial (RCT) which compared the lower limb motor relearning effect of a tPNS to usual care treatment. The 110 subjects enrolled in the RCT were stratified by motor impairment level as evidenced by the presence (≥ 1/5 on the Medical Research Council (MRC)scale) or absence (0/5 MRC) of volitional ankle dorsiflexion while non-

weightbearing prior to being randomized to either a tPNS or usual care group. Fifty-four subjects were randomized to the tPNS group and 56 were randomized to usual care. The subjects then participated in a 12-week ambulation training treatment period using the assigned device in their home and community setting up to 8 hours per day. All subjects randomized to the tPNS group who had used an AFO prior to enrollment in the RCT were offered the opportunity to participate. This present study evaluated the 12 subjects in the tPNS group who met that criterion and agreed to participate in this additional analysis. These subjects underwent one QGA session near the end of the 12-wk tPNS treatment period under the three device conditions in the same device order (no device (ND), AFO, and tPNS).

## Participants

The protocol of the larger RCT included this optional protocol, which was available to subjects randomized to the tPNS group only, and was approved by the Institutional Review Board(s) of the involved academic medical center(s). Each subject gave written consent prior for participation. All subjects were ≥ 18 years of age, > 3-months post-stroke, and medically stable. Subjects demonstrated unilateral hemiparesis with ankle dorsiflexion strength of no greater than 4/5 on the Medical Research Council (MRC) scale. Each subject demonstrated dorsiflexion weakness during ambulation such that gait instability or inefficient gait patterns were exhibited. Each subject was required to ambulate 10 meters with minimal assistance or less and scored ≥ 24 on the Berg Balance scale due to safety considerations in performing the QGA. Subjects were excluded for concomitant neurological diagnoses, uncompensated hemineglect, severely impaired cognition and communication, fixed ankle contracture, peroneal nerve injury, genu recurvatum, or history of Botulinum toxin injection to the affected lower extremity in the preceding 3 months. The subjects enrolled in this protocol were near completion of the 12-wk treatment period of the RCT, independently using the PNS device for daily ambulation, and also had in their possession a custom AFO which was being used for correction of footdrop prior to enrollment in the RCT. None of the subjects required an ambulatory assist device (ie cane) for safe participation in the QGA procedure.

## Devices

The tPNS device was the Odstock Dropped-Foot Stimulator (ODFS)[2] (Odstock Medical Limited, Salisbury, U.K.), which is a single-channel device consisting of a 9V battery-powered stimulator and skin surface electrodes. Stimulation is initiated at pre-swing with detection of heel rise by the 3-mm insole pressure sensing footswitch. Each subject used his own physician-prescribed AFO which was in his possession prior to entry into the study and thus the AFOs were not standardized. Each AFO was custom molded, hinged, and fabricated using conventional, clinically accepted techniques.

## Outcome Measures

Quantitative gait analysis was performed using a Vicon system (Vicon Motion Systems Limited, Oxford, United Kingdom), a motion measurement and analysis system which tracked the trajectories of reflective markers in the field of view of multiple cameras mounted around the periphery of the lab. All subjects wore low-heeled, laced shoes during the trials. Retro-reflective markers were adhered to the skin at anatomical locations following a modified Helen Hayes marker set[14–15]; the second metatarsal and calcaneal markers were secured directly to the shoe and thus all marker positions were consistent between trials. Subjects were asked to ambulate 10 meters at a self-selected comfortable rate. A minimum of 20 strides (approximately 10 trials) were collected for each device condition. AMTI Biomechanics Platforms (Advanced Mechanical Technology, Inc., Watertown, MA) were embedded in the walkway of the laboratory. Illumination, motion

capture data, and analog to digital conversion of transducer input were synchronized and controlled by the Vicon system, which was in turn controlled by a Pentium based PC. Data were processed using the Vicon Plug-In-Gait biomechanical model in Vicon supplied to generate joint angles, moments, powers, and spatiotemporal parameters of gait. At completion of the single QGA session, study participation was concluded. For purposes of this analysis, specific spatiotemporal, kinematic, and kinetic gait parameters were identified a priori for evaluation (Table 2). Spatiotemporal parameters (walking speed, stride length, cadence, double support time) were chosen based on clinical relevance for gait efficiency and symmetry. Kinematic parameters chosen were 1) peak hip flexion, knee flexion, and dorsiflexion during swing to detect a tPNS-induced flexion withdrawal response, 2) dorsiflexion angle at initial contact as both a tPNS and AFO affect weight-bearing stability via ankle positioning at early stance, and 3) peak knee extension in stance as an AFO can affect knee extension depending on the degree of dorsiflexion incorporated into its design. Kinetic parameters chosen were 1) knee extensor moment due to possible device effect on location of ground reaction force relative to the knee joint, 2) peak hip power due to its contribution to walking speed and forward propulsion, and 3) peak ankle power due to concern that an AFO may inhibit ankle movement and thus ankle power. All QGA sessions were supervised and performed by the same research physical therapist and gait laboratory engineer using standardized procedures.

### Statistical Analysis

Demographic data including age, sex, interval post-stroke, stroke etiology, and involved hemisphere were evaluated for mean, standard deviation and/or frequency. Repeated measures analysis of variance (rmANOVA) testing was performed to compare the means of each parameter by device condition (ND, AFO, and PNS) using motor impairment level as evidenced by dorsiflexion status (presence or absence of active dorsiflexion) as a covariate. Post-hoc pairwise comparisons were performed if a device effect or device×dorsiflexion interaction effect was found. Due to the exploratory nature of this study, post-hoc analyses using least significant differences method were performed if rmANOVA yield a p-value ≤0.10 for device effect or device×dorsiflexion interaction effect. A p-value of ≤ 0.05 was defined as a statistically significant difference for all post-hoc analyses.

## Results

Demographic data are presented in Table 1. Spatiotemporal, kinematic, and kinetic data for the three device conditions, post-hoc pairwise comparisons and subset analyses based on dorsiflexion status are presented in Table 2.

### Spatiotemporal parameters

There was a significant difference in stride length ($F(2,18)=4.812$, $p=0.021$) between device conditions; post-hoc pairwise comparisons found that stride length was significantly improved with both the AFO (1.02 ± 0.25m, p=.035) and the tPNS (1.02 ± 0.22m, p=.029) relative to ND (.96 ± 0.28m). An interaction between device and dorsiflexion status on stride length was found which approached significance ($F(2,18)=2.910$, $p=0.08$), and post-hoc analysis showed a significant device effect in favor of PNS (0.95 ± 0.16m) relative to ND (0.80 ± 0.16m, p=0.034) in subjects with absent dorsiflexion (DA). There was a significant difference in walking velocity between device conditions (($F(2,18)=5.092$, $p=0.018$); however, post-hoc pairwise comparisons failed to detect the differences between conditions. A significant interaction between device and dorsiflexion status on walking velocity was found ($F(2,18)=3.917$, $p=0.039$), and post-hoc analysis showed a significant effect in favor of the tPNS (0.72 ± 0.27m/s) relative to the AFO (0.66 ± 0.28m/s, p=0.015) in DA subjects. The difference in cadence between device conditions ($F(2,18)=2.901$, $p=0.081$) and device

dorsiflexion interaction effect ($F(2,18)=3.389$, $p=0.056$) both approached significance; however, post-hoc pairwise comparisons and subset analysis based on dorsiflexion status were nonsignificant ($p>0.05$). There was no device effect or interaction between device and dorsiflexion status on double support time.

### Kinematic parameters

There was no device effect or interaction between device and dorsiflexion status on peak hip flexion in swing, peak knee flexion in swing, peak dorsiflexion in swing, or peak knee extension in stance. There was no device effect on DFIC; however, there was an interaction between device and dorsiflexion status that approached significance ($F(2,16)=2.946$, $p=0.081$). Post-hoc analysis found a significant device effect on DFIC in favor of the AFO ($5.74 \pm 4.87$ deg) as compared to ND ($-0.87 \pm 6.03$ deg, $p=0.025$) and statistical significance was approached in favor of the AFO over the PNS in subjects with dorsiflexion present ($p=0.075$).

### Kinetic parameters

There was no device effect or interaction between device and dorsiflexion status on peak knee extensor moment in stance or peak hip power. The difference in ankle power at push-off between device conditions approached significance ($F(2,18)=3.217$, $p=0.064$) and post-hoc pairwise comparisons found a difference which approached significance and favored the tPNS ($0.96 \pm 0.66$ W/kg) over the AFO ($0.78 \pm 0.65$ W/kg, $p=0.052$). There was no interaction between device and dorsiflexion status on peak ankle power at push-off.

## Discussion

A primary finding of this analysis is a significant device and dorsiflexion interaction effect on stride length and walking velocity which favored tPNS in subjects with absent dorsiflexion yet an overall equivalent device effect on spatiotemporal parameters when dorsiflexion status was not considered. In this study, eight of the 12 subjects had partial preservation of dorsiflexion and four subjects had absent dorsiflexion on clinical examination at study enrollment. Subjects were presumed to have a higher level of motor impairment if dorsiflexion was absent and a lower level of motor impairment if dorsiflexion was present. For all subjects, the significant increase in stride length noted with both the tPNS and AFO, relative to ND, is consistent with both clinical expectation and a prior temporal spatial analysis of the orthotic effect of an AFO.[5] The lack of a significant difference in walking velocities between device conditions, however, is not consistent with previous studies which have demonstrated increases in hemiparetic walking speed which ranged between 14% to 29%[1–3, 16] for a tPNS and 32% for an AFO[5]. The lack of a robust effect of either device on walking speed for whole group analysis may be due to limitations of the QGA methods. Using QGA, mean walking speeds are determined based on multiple walking trials recorded over a relatively short distance of 10 meters while encumbered with multiple retro-reflective three dimensional markers adhered to key bony prominences from the pelvis to the ankles, and thus maximal comfortable gait speeds, for any given device condition, may not have been achieved. A more accurate measurement of walking velocity may have been obtained if the 10 meter walking velocity had been measured separately and not in the context of the QGA procedure. Regardless of methods of measurement, these findings are generally consistent, however, with the few studies which have attempted to directly compare the effect of a tPNS versus an AFO on walking speeds and found equivalency of effect.[6–9] The lack of difference in double support time suggests that neither device significant affects dynamic balance. The lack of difference in cadence between device conditions, while not consistent with prior gait analyses by Esquenazi et al[5] and Ring

et al[7] who reported improvement in cadence with an AFO and tPNS device, respectively, may similarly be due to the relatively short distances ambulated.

The interaction between device and dorsiflexion status is an intriguing finding in this present study which has not been previously reported. Stride length and walking velocity were significantly enhanced by the tPNS, relative to ND and the AFO, respectively, in the subgroup of subjects with absent dorsiflexion. A possible explanation for this finding is that the tPNS, as compared to an AFO, provides dorsiflexion-assist during swing while not compromising stance phase proprioceptive input (joint position sense, sensation) which may be more important to enhance walking performance in subjects with a higher level of motor impairment (DA subjects). Subjects with a lower level of motor impairment (DP subjects) may have better proximal motor control and strength for compensation and may thus be less reliant on proprioceptive input for gait. As spatiotemporal parameters are influenced by walking velocity, future studies should focus specifically on this subgroup of more severely impaired subjects with the goal to measure device effect while maintaining a constant walking velocity.

In the ND condition, ankle DFIC for the group as a whole and the relative kinematic findings for the DA and DP groups are notable. The goal of both a tPNS and AFO device is to correct for dorsiflexion weakness during the swing phase of gait and maintain the ankle at neutral (90 degrees) at initial contact, at a minimum, so as to stabilize the ankle and facilitate gait progression throughout the weight-bearing (stance) phase of the gait cycle. Thus, ankle DFIC may be the single most important kinematic parameter to examine for effect. In this study, the mean ankle dorsiflexion angle at IC of $-0.75 \pm 5.46$ is greater than might be anticipated in a ND condition for the enrolled subjects. This ND finding may be due to the fact that subjects with varying degrees of dorsiflexion weakness (DF strength range $\leq 4/5$ on MRC) were enrolled. In clinical practice, subjects with mild dorsiflexion weakness may have sufficient strength to achieve DF at IC positioning close to neutral as measured by QGA yet still clinically manifest footdrop during the swing phase of gait. In terms of DA versus DP performance, the two ankle kinematic parameters which might be expected to most dramatically differentiate the DA subjects from the DP subjects are peak ankle DF in swing and DFIC in the no device condition. However, the lack of an interaction between device and dorsiflexion status for peak ankle DF in swing and review of the raw data for both kinematic parameters suggest that these data points were not significantly affected by subject designation as either DA or DP. At entry to the larger RCT, the presence or absence of dorsiflexion was determined with the subject seated, nonweightbearing, and with the lower leg extended. Clinically, this is the most common position from which a clinician measures dorsiflexion strength and range of motion. It is likely that many of the subjects who exhibited 0/5 DF strength when measured statically manifested some degree of dynamic dorsiflexion during gait associated with both tone and proximal knee and hip flexion. Thus dorsflexion strength and active ankle range of motion was likely different dependent on whether the parameters were measured while nonweightbearing in the context of a clinical examination or dynamically during gait as measured by QGA. The larger RCT found that the mean baseline lower extremity Fugl-Meyer scores (a standardized measure of motor impairment) for the DP group was significantly higher than the DA group as a whole. Thus, designation of subjects as either DP or DA based on clinical exam reasonably designated the subject into higher and lower level impairment groups.

A secondary finding is no device effect on the kinematic parameters when dorsiflexion status was not considered yet a significant device and dorsiflexion interaction effect on ankle DFIC which favored an AFO in subjects with dorsiflexion present. A significant improvement in ankle DFIC in the subgroup of subjects with dorsiflexion present, and not the dorsiflexion absent group, is likely due to better ankle positioning for weight-bearing

associated with not simply the rigidity of a plastic AFO but also greater proximal lower extremity strength in this less impaired subgroup. The inability of the tPNS to achieve DFIC of a similar magnitude, irrespective of dorsiflexion status, may theoretically be explained by inadequate positioning of the stimulating electrode over the common peroneal nerve, suboptimal stimulus parameters (frequency, amplitude, pulse width), or lack of precision of the timing of stimulus initiation due to footswitch placement. However, tPNS device set-up is unlikely to be contributory as stimulation parameter settings and electrode placement were optimized by the research therapist prior to commencement of each QGA session. The lack of significant DFIC enhancement in the tPNS device condition may also be due to muscle fatigue of the anterior tibilias associated with device testing order (ND, AFO, tPNS). Muscle fatigue may be an even greater limiting factor in the DP group due to the effect of repetitive volitional muscle contraction. Alternatively, the lack of effect of tPNS on DFIC may reflect limitations in the sensitivity of the QGA software and procedure itself. The DFIC angle is recorded at the moment of the peak vertical ground reaction force whereas the tPNS stimulation turns off at the moment weight-bearing is sensed by the heelswitch. A subtle mismatch of these signals, despite optimal device set-up, could result in the QGA underreporting the actual maximal DFIC in all subjects.

A third finding in this study is the lack of evidence of a tPNS-induced flexion withdrawal response in the kinematic data. A lower extremity flexion withdrawal response is a spinal reflex consisting of a widespread contraction of flexor muscles and simultaneous relaxation of extensor muscles. Prior clinical studies have suggested that clearance of a hemiparetic lower limb during the swing phase of gait may be enhanced by a flexion withdrawal reflex elicited by peroneal nerve stimulation,[13, 17–19] though no previous study has attempted to measure this response to tPNS using QGA. Interestingly, our results are in accord with a recent study by Kottink[12] who found no evidence that an implantable PNS device triggered hip and knee flexion and at odds with a single case report by Van Swigchem[20] who did report an implantable PNS device-induced lower extremity flexion withdrawal response. In the construct of this present study, a tPNS- flexion withdrawal reflex would be evident by an increase in paretic peak hip flexion, peak knee flexion, and peak ankle dorsiflexion angle during swing, relative to the ND and AFO trials. Our data suggests that the neuroprosthetic application of tPNS does not elicit a lower extremity flexion withdrawal response that is either measurable by QGA or of clinical significance. The magnitude of peak hip, knee, and ankle flexion during swing in the ND condition suggests these subjects as a whole, while the appropriate clinical population for the PNS device, may have lesser lower extremity motor impairment deficits than the broader hemiparetic stroke population and thus a lesser margin for enhancement of these parameters. Other possible explanations include inadequate tPNS-induced dorsiflexion torque, loss of range-of-motion at the paretic ankle, knee and hip, or paretic extremity extensor spasticity. An important consideration is that stimulation of the peroneal nerve at the level of the fibular head activates the both the anterior tibialis and peronei musculature, meaning that the PNS device corrects for footdrop by eliciting not simply ankle dorsiflexion during swing but also ankle eversion. DFIC and peak ankle DF in swing, measured in a sagittal plane, were chosen a priori as kinematic parameters, which should theoretically be improved with a PNS, but our study methods may have been insufficient to demonstrate the full neuroprosthetic effect associated with ankle eversion measured in the coronal plane. The lack of significant difference between peak DF in swing tPNS and ND conditions, in the setting of optimal device functioning, suggests the importance of quantifying PNS effect on ankle eversion as well as dorsiflexion to better characterize the neuroprosthetic effect of the device.

Lastly, a trend toward significance in ankle power at push-off between a tPNS and AFO in the group as a whole is notable due to a clinical concern that inhibition of ankle movement by an AFO may enhance weight-bearing stability in hemiparesis but at a cost of loss of

ankle power necessary for optimal walking speeds[21] and forward gait progression. Prior studies of healthy adults have found that an AFO decreases ankle power during both treadmill ambulation[22] and stair locomotion.[23] In our study, the subjects all utilized a hinged AFO which would theoretically diminish ankle power to a lesser degree[23] than a solid AFO. A possible explanation for greater ankle power at push-off of the tPNS relative to the AFO is that repetitive dorsiflexion contraction with the tPNS during ambulation may facilitate reciprocal strengthening or functioning of the gastrocsoleus complex.

Limitations of this study are primarily related to study methods. QGA is ideally performed barefoot with the reflective markers applied directly to the skin overlying prominent anatomical bony landmarks. Neither an AFO nor a tPNS device can be used in the absence of the supporting structure of a shoe, thus for all trials (ND, AFO, and tPNS), QGA was performed with the subject wearing a shoe and the calcaneal and 2$^{nd}$ metatarsal markers adhered directly to the shoe. In approximately half of the subjects, the lateral malleolus was obscured by the AFO which necessitated applying that reflective marker directly on the lateral portion of the AFO over the malleolus. Prior to each of the 3 gait analysis sessions, static trials, which included measurement of ankle joint width, were performed so that the gait analysis software should theoretically have corrected for any between-device discrepancies in marker placement. Secondly, all subjects were evaluated in the same device order (ND, AFO, tPNS) due to a concern that ambulation with the tPNS device may enhance gait performance for subsequent trials due to a “carry-over” effect. The trade-off of this device sequence was that the tPNS gait performance may have been more affected by fatigue as compared to the ND and AFO trials. Of note, any between-subject nonuniformity of the AFOs evaluated in the study, while not ideal, should not have affected results given the within-subject statistical analysis of the three device conditions. Lastly, in this pilot study post-hoc pairwise comparisons were performed with least significant differences in an attempt to avoid a type II error in data analysis and interpretation of the subset analysis was limited due to small group numbers. As a result, any findings regarding relative effects of an AFO and tPNS should be confirmed in a larger RCT.

In conclusion, this study suggests equivalency of effect of a tPNS or an AFO on spatiotemporal, kinematic, and kinetic parameters of chronic hemiparetic gait. The level of motor impairment, however, may influence the relative effects of the tPNS and AFO devices. Future studies are indicated to determine if level of motor impairment status should be considered in the clinical prescription of dorsiflex-assist devices.

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## Table 1

Participant Characteristics including means (standard deviation).

| Participant Characteristics | |
|---|---|
| Subjects | 12 |
| Male: female | 8:4 |
| Age (yrs) | 47.6 (8.9) |
| Interval post-stroke (m) | 41.3 (53.5) |
| Etiology (Ischemic: Hemorrhagic) | 9:3 |
| Hemisphere (R:L) | 7:5 |
| Dorsiflexion absent (DA):present (DP) | 4:8 |

**Table 2**

Mean spatiotemporal, kinematic and kinetic parameters by device group (SD).

| | No Device | AFO | tPNS | p-value Device | p-value Device × DF status Interaction |
|---|---|---|---|---|---|
| *Spatiotemporal parameters* | | | | | |
| Stride length (m) | 0.96 (0.28)*† | 1.02 (0.25)* | 1.02 (0.22)† | .021 | .080 |
| DA | 0.80 (.18)1 | 0.90 (.16) | 0.95 (.16)1 | | |
| DP | 1.02 (.29) | 1.06 (.27) | 1.05 (.24) | | |
| Cadence (steps/m) | 85.83 (12.51) | 84.64 (15.36) | 85.30 (13.87) | .081‡ | .0564 |
| DA | 83.70 (21.16) | 85.74 (23.74) | 88.72 (22.01) | | |
| DP | 86.63 (9.65) | 84.22 (13.23) | 84.02 (11.38) | | |
| Double stance (s) | 0.54 (0.17) | 0.54 (0.21) | 0.52 (0.17) | .144 | .180 |
| Walking velocity (m/s) | 0.70 (0.25) | 0.73 (0.26) | 0.74 (0.24) | .018‡ | .039 |
| DA | 0.58 (.24)3 | 0.66 (.28)2 | 0.72 (.27)23 | | |
| DP | 0.74 (.26) | 0.76 (.26) | 0.75 (.24) | | |
| *Kinematic parameters* | | | | | |
| Peak hip flexion in swing (deg) | 31.93 (8.25) | 33.03 (9.12) | 32.83 (9.38) | .402 | .565 |
| Peak knee flexion in swing (deg) | 42.21 (13.50) | 39.97 (13.10) | 40.82 (14.34) | .768 | .536 |
| Peak ankle DF in swing (deg) | 4.32 (6.50) | 8.63 (5.17) | 4.72 (6.72) | .199 | .103 |
| DF angle at initial contact (deg) | −0.75 (5.46) | 4.62 (5.27) | 1.13 (6.62) | .165 | .081 |
| DA | −0.26 (3.71) | 0.14 (5.83) | 5.99 (1.07) | | |
| DP | −0.87 (6.03)5 | 5.74 (4.87)56 | −0.09 (6.91)6 | | |
| Peak knee extension in stance (deg) | 1.64 (9.35) | 1.96 (11.42) | .78 (10.42) | .677 | .527 |
| *Kinetic parameters* | | | | | |
| Peak knee extensor moment (Nm/kg) | 0.46 (0.23) | 0.54 (0.33) | 0.48 (0.26) | .342 | .361 |
| Peak hip power in swing (W/kg) | 0.86 (0.44) | 0.93 (0.49) | 0.90 (0.49) | .158 | .211 |
| Peak ankle power (W/kg) | 0.84 (0.67) | 0.78 (0.65)§ | 0.96 (0.66)§ | .064 | .189 |

Post-hoc pairwise comparisons when device effect p≤0.10:

*AFO-ND, p=.035;

† PNS-ND, p=.029;

§ PNS-AFO, p=0.052; post-hoc comparisons,

‡ p>0.10. Subset analysis by dorsiflexion status when device DF status interaction p≤0.10:

1 DA PNS-ND, p=0.034;

2 DA PNS-AFO, p=0.015;

3 DA PNS-ND, p=0.09;

4 DA and DP subset analyses, p>0.10;

5 DP AFO-ND, p=0.0025;

6 DP PNS-AFO, p=0.075.

Ankle foot orthosis, AFO; peroneal nerve stimulator, tPNS; dorsiflexion present, DP; dorsiflexion absent, DA; meters, m; seconds, s; degree, deg; Newton, N; Kilogram, kg; Watt, W.