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ORIGINAL ARTICLE

Targeting Paretic Propulsion to Improve Poststroke Walking Function: A Preliminary Study

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Abstract

Objectives: To determine the feasibility and safety of implementing a 12-week locomotor intervention targeting paretic propulsion deficits during walking through the joining of 2 independent interventions, walking at maximal speed on a treadmill and functional electrical stimulation of the paretic ankle musculature (FastFES); to determine the effects of FastFES training on individual subjects; and to determine the influence of baseline impairment severity on treatment outcomes.

Design: Single group pre-post preliminary study investigating a novel locomotor intervention.

Setting: Research laboratory.

Participants: Individuals (N=13) with locomotor deficits after stroke.

Intervention: FastFES training was provided for 12 weeks at a frequency of 3 sessions per week and 30 minutes per session.

Main Outcome Measures: Measures of gait mechanics, functional balance, short- and long-distance walking function, and self-perceived participation were collected at baseline, posttraining, and 3-month follow-up evaluations. Changes after treatment were assessed using pairwise comparisons and compared with known minimal clinically important differences or minimal detectable changes. Correlation analyses were run to determine the correlation between baseline clinical and biomechanical performance versus improvements in walking speed.

Results: Twelve of the 13 subjects that were recruited completed the training. Improvements in paretic propulsion were accompanied by improvements in functional balance, walking function, and self-perceived participation (each $P<.02$)—all of which were maintained at 3-month follow-up. Eleven of the 12 subjects achieved meaningful functional improvements. Baseline impairment was predictive of absolute, but not relative, functional change after training.

Conclusions: This report demonstrates the safety and feasibility of the FastFES intervention and supports further study of this promising locomotor intervention for persons poststroke.

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Despite an emphasis on walking recovery during poststroke rehabilitation, locomotor deficits[1-7] that contribute to limitations in activity and community participation persist for most patients.[8,9] A recent critical review by Dickstein et al[10] revealed comparable outcomes after current poststroke walking therapies and showed that all failed to improve most subjects' capacity for community ambulation, regardless of treatment mode or sophistication. Clearly, existing rehabilitation paradigms have failed to sufficiently address the factors limiting poststroke walking performance. Until recently, the clinical measures used to evaluate the recovery of walking performance after gait rehabilitation did not have the capacity to differentiate between the restoration of impaired neuromotor processes versus the strengthening of existing compensatory strategies.[11] Without an understanding of the changes underlying intervention-mediated improvements in walking function, the ability to target the specific deficits contributing to the reduced walking performance of individuals poststroke has been limited.[11,12] Recent advances in laboratory instrumentation have allowed a detailed

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quantification of treatment effects, providing a theoretical foundation from which locomotor therapies can be developed.[11] Herein, we report on the development, implementation, and success of a targeted intervention capable of modifying specific impairments known to limit the walking performance of individuals who have sustained a stroke.

For individuals with hemiparesis after stroke, decreased propulsive force generation by the paretic limb during walking has been identified through simulation and cross-sectional studies as a major contributor to walking dysfunction.[1,2,4,13-18] Furthermore, recent studies by Bowden et al[19] show that propulsion symmetry during walking is able to differentiate individuals as limited community versus community ambulators and that individuals who achieve clinically meaningful improvements in walking speed also improve propulsion symmetry.[20] Despite the strong evidence linking paretic propulsive ability to poststroke walking performance, large-scale investigation of interventions specifically designed to improve propulsion during walking are nonexistent.[10,21] Moreover, previous articles that have considered the effects of gait intervention on measures of paretic propulsion have failed to demonstrate significant changes in the paretic limb's capacity to generate propulsive force after intervention,[12,22,23] likely, as posited by Hall et al,[12] because of subjects using a variety of compensatory strategies during training. Therefore, it is currently unknown whether paretic propulsion is modifiable through intervention specifically targeting this impairment and whether such improvements would influence walking performance. In contrast with previous interventions, we developed an intervention specifically designed to improve poststroke walking ability through improvements in paretic propulsion.

An immediate increase in the activation of the paretic plantarflexors during walking is achievable through functional electrical stimulation (FES). However, the translation of increased plantarflexor muscle activation during FES into greater forward propulsion depends largely on the paretic limb's posterior position relative to the individual's center of mass during the double support phase of the paretic gait cycle.[16] Unfortunately, stroke survivors often do not achieve adequate paretic hip extension during walking.[7] However, walking at a faster speed is known to increase paretic hip extension,[24,25] effectively increasing the posterior placement of the paretic limb relative to the individual's center of mass during walking. Based on this framework, we hypothesized that an intervention combining walking at maximal speed on a treadmill and functional electrical stimulation of the paretic ankle musculature (FastFES) would maximize the translation of increased plantarflexor activity into forward propulsion, ultimately resulting in improved walking function. The FastFES intervention was thus conceived.

Contemporary concepts from multiple domains were integrated into the design of the FastFES locomotor program to maximize its effectiveness. The 12-week FastFES program follows principles of motor learning and neuroplasticity through massed stepping practice and task-specific training on both the treadmill and overground.[26] Alternating bouts of walking with and without FES are also included to enhance learning.[27] From a physiological perspective, FastFES incorporates stimulation patterns that better mimic the nervous system's activation of muscle (ie, variable-frequency train patterns), facilitating a more rapid rate of rise in force production[28] and yielding greater changes in walking kinematics[29] compared with traditionally used FES patterns in persons poststroke.

Prior to determining the effectiveness of the FastFES program through a randomized controlled trial, this preliminary investigation was undertaken to investigate whether improvements in paretic limb propulsion could be safely and feasibly achieved through a 12-week gait retraining program that joins walking at maximal speed with the application of FES to the paretic ankle musculature. Moreover, considering the heterogeneity of poststroke locomotor deficits, the clinical characteristics predictive of an appropriate candidate for this intervention are explored. Measurements across all levels of the World Health Organization's *International Classification of Function, Disability and Health*[30] are included in this article.

List of abbreviations:

FES	**functional electrical stimulation**
MWS	**maximal walking speed**
6MWT	**6-minute walk test**
SSWS	**self-selected walking speed**

Methods

Participants

Thirteen subjects (age, 61±8.3y; time since stroke, 3.22±3.05y; 7 men; 8 right hemiparetic) with poststroke hemiparesis participated in this study (table 1). Subject inclusion criteria included at least 6 months poststroke, ability to walk continuously for 5 minutes, and sufficient ankle passive range of motion to allow the paretic ankle joint to reach within 5° of the neutral position with the knee flexed. Exclusion criteria included evidence of moderate to severe chronic white matter disease on magnetic resonance imaging, >1 previous stroke, congestive heart failure, peripheral artery disease with claudication, uncontrolled diabetes, shortness of breath without exertion, unstable angina, resting heart rate outside of the 40 to 100 beats per minute range, resting blood pressure outside of the 90/60 to 170/90mmHg range, an inability to communicate with the investigators, pain in the lower limbs or spine, total knee replacement, cerebellar involvement, neglect (tested via the Star Cancellation Test[31]), and absence of sensation on the skin of the paretic calf or leg. All subjects completed a submaximal cardiac stress test to determine exercise safety prior to participation and signed informed consent forms approved by the University of Delaware Human Subjects Review Board. Results from each subject's cardiac stress test were used to calculate a target heart rate, which served as a maximum during training. The formula used was as follows: target heart rate = ([maximum heart rate − resting heart rate] × 70%) + resting heart rate.

Gait and clinical testing

Subjects completed biomechanical and clinical evaluations at baseline (pre), after 12 weeks of FastFES locomotor retraining (post), and 3 months after the completion of training (follow-up). Previous work has described in detail the methods used during this investigation.[32,33] Briefly, kinetic and kinematic data were collected via an 8-camera motion analysis system[a] as subjects walked at their self-selected speeds on a dual-belt treadmill instrumented with 2 independent 6 degree of freedom force platforms.[b] Data related to the paretic limb's capacity to generate propulsive force—the specific target of the FastFES intervention—were collected and served as the body structure and function variables of interest. These variables included the paretic propulsion integral, peak paretic propulsive force, propulsion

Table 1 Subject baseline characteristics and training information

Subject No.	Sex	Age (y)	Side of Hemiparesis (L/R)	Time Since Stroke (y)	Self-Selected Speed (m/s)	Fugl-Meyer (LE) (score)	No. of Sessions Completed	Average Min Per Session
1	M	67	L	1.83	.70	21	34	26.88
2	M	51	L	9.25	.90	24	33	29.64
9	M	58	R	9.17	.50	15	33	27.82
53	M	71	R	5.83	.50	14	34	24.63
98	M	66	R	1.58	.30	21	41	22.03
108	M	70	L	1.75	.50	13	43	24.70
110	F	65	R	1.25	.70	18	32	27.48
120*	F	52	L	2.75	.80	19	13	NA
128	F	65	R	1.50	.50	18	27	29.15
129	F	54	R	4.58	.50	17	32	29.41
136	F	58	R	1.00	.30	13	32	28.87
137	M	46	R	0.67	.40	15	30	29.53
142	F	70	L	0.75	.30	22	32	30.00
AVG ± SD		61±8.31		3.22±3.05	.53±.19	17.69±3.59	Median: 32 IQR (32–34)	27.51±2.52

Abbreviations: F, female; IQR, interquartile range; L, left; LE, lower extremity; M, male; NA, not applicable; R, right.
* Subject terminated from the study.

symmetry, and peak paretic trailing limb angle. The paretic propulsion integral was measured as the integral of the paretic leg's anterior GRF from the beginning of the anteriorly directed portion of the GRF through the end of the paretic stance phase, normalized to body weight (% body weight.s). Peak paretic propulsive force was measured as the maximum anterior GRF normalized to body weight (% body weight). Propulsion symmetry was calculated as the ratio of the paretic propulsion integral divided by the sum of the paretic propulsion integral and the nonparetic propulsion integral (%). The peak paretic trailing limb angle was the maximum sagittal plane angle (degrees) between the vertical axis of the laboratory and a vector joining the paretic limb's lateral malleolus and greater trochanter.

Clinical evaluations measured performance at the level of activity; that is, the 6m walk test[34] measured each subject's self-selected walking speed (SSWS) and maximal walking speed (MWS) (m/s), the 6-minute walk test (6MWT)[35] measured long-distance walking ability, and the Functional Gait Assessment[36] measured functional balance. Self-perceived participation was measured via the participation domain of the Stroke Impact Scale,[37] which was also completed during the clinical evaluation. Additionally, the lower extremity motor portion of the Fugl-Meyer Scale[38] was completed at baseline to provide information about general sensorimotor impairment. FES was not used during any of the testing.

Training

A licensed physical therapist administered the FastFES intervention for a goal of 12 weeks of training at a frequency of 3 sessions per week. Each training session consisted of both treadmill (27min) and overground walking (3min). After completing four 6-minute treadmill bouts where FES was delivered in an alternating pattern of 1-minute on and 1-minute off to the paretic ankle dorsi- and plantarflexor muscle groups, subjects completed 3 consecutive minutes of treadmill walking with FES. This was immediately followed by 3 consecutive minutes of overground walking without FES. During all periods of walking without FES, subjects were encouraged to reproduce the same walking pattern as practiced with the FES. The training protocol used has previously been described.[32,33]

Functional electrical stimulation

Details regarding the customized FES system[c] and methods used can be found in previous studies put forth by our laboratory.[29,32,33,39,40] FES was delivered to the ankle dorsiflexor and plantarflexor muscles during walking through self-adhesive surface electrical stimulation electrodes.[d,e] Two compression-closing foot switches[f] attached to the sole of the shoe of the paretic limb were used to control the delivery of FES from a Grass S8800 stimulator[g] in combination with a Grass Model SIU8TB stimulus isolation unit. Plantarflexor FES was delivered when the hindfoot switch was turned off (indicating paretic heel off) and ended when the forefoot switch was turned off (indicating paretic toe off). Dorsiflexor FES was delivered when the forefoot switch turned off (paretic toe off) until the hindfoot switch was turned on (paretic heel strike). Footswitch position was modified to accommodate varying foot strike patterns; therefore, the stimulation was consistently delivered during the appropriate time periods.

Data management and statistical analyses

The normality of each variable's distribution was assessed using the D'Agostino-Pearson omnibus test in Microsoft Excel 2007.[h] Statistical analyses were conducted using SPSS version 20.[i] The threshold for statistical significance was set at P>.05. Wilcoxon signed-rank tests or paired *t* tests, pending data normalcy, were used to detect differences between baseline versus each post- and follow-up performance. Spearman rho correlation analyses were used to determine the influence of baseline abilities on treatment outcomes. Absolute and relative improvements in SSWS after the 12-week training period were considered. Relative improvement was calculated as the ratio of the difference between post and baseline performance divided by the baseline performance.

Results

Twelve of the 13 subjects recruited to this study completed the 12-week FastFES locomotor program. The single subject terminated from the study withdrew for reasons unrelated to training. No adverse events were noted during training with the rest periods provided between bouts being sufficient to alleviate the elevations in blood pressure, heart rate, and ratings of perceived exertion that occurred in response to training. Of the planned thirty-six 30-minute training sessions, subjects completed a median of 32 (interquartile range, 32−34) sessions with an average of 27.51±2.52 minutes per session (see table 1). Because of periods of illness throughout the training period, 1 subject (subject 98) was able to complete only between 10 and 19 minutes of training for 6 visits and was therefore asked to complete an additional 5 sessions at the end of the 12 weeks for a total of 41 sessions. Similarly, for 4 visits, another subject (subject 108) was able to complete only about 10 minutes of training; this subject therefore completed additional sessions for a total of 42 visits. The primary reasons subjects missed training days were scheduled physician appointments and traveling for the holidays. The primary reason subjects were unable to complete the full 30 minutes of training per session was the termination of a walking bout when the subject's predetermined maximum heart rate was surpassed.

Complete clinical datasets were available for all 12 subjects; however, because of technical issues during data collection, propulsion data were not available from baseline testing for 2 subjects and from posttesting for 3 subjects. Peak paretic propulsive force data from follow-up were also not available for 1 subject. Therefore, for post- versus baseline statistical testing involving propulsion data, a sample of only 9 subjects was available. For follow-up versus baseline statistical testing involving peak paretic propulsive force data, only 11 subjects were available. Additionally, peak paretic trailing limb angle data were not available from baseline or posttesting for 1 subject, reducing the peak paretic trailing limb angle subject sample to 11 (table 2).

With an average SSWS of 0.5±0.17m/s and lower extremity Fugl-Meyer scores ranging from 13 to 24, subjects presented with a range of functional abilities at baseline (see table 1). All clinical and biomechanical variables improved after training; most of these improvements were maintained through the 3-month follow-up period (see table 2). Only the propulsive integral improvement from pretesting to follow-up ($P = .07$) did not reach statistical significance. The average change in SSWS was .18±.07m/s. Eight of the 12 subjects studied achieved clinically meaningful improvements in SSWS (>.16m/s).[41] Three of the remaining 4 subjects achieved changes in SSWS of .15, .11, and .11m/s, respectively, and demonstrated gains in the 6MWT of 145, 93, and 55m. These gains in the 6MWT were all larger than the minimal detectable change of 54.1m.[42] Two of these same 3 achieved the highest Stroke Impact Scale participation domain gains of 53 and 38 points. The remaining subject (subject 137) presented with only a .03m/s change in SSWS after training and was the lowest performer on all measures (see tables 1 and 2).

Baseline performance on each clinical and biomechanical measure, except for peak paretic trailing limb angle, was predictive of absolute change in SSWS after training (R^2 range, .28−.56, with each $P<.04$), with lower levels of baseline impairment predicting larger gains (fig 1). However, baseline abilities were not predictive of relative improvements in SSWS (each $R^2<.12$ and each $P>.05$) (fig 2), with subjects achieving a median improvement of 39% (interquartile range, 28%−39%) after training.

Discussion

In this preliminary study we demonstrate the feasibility and safety of an intervention joining 2 independent therapies, fast treadmill walking and FES, for the treatment of poststroke walking dysfunction. All subjects tolerated this combined therapy, with all but 1 subject, for reasons unrelated to the training, completing the entire training protocol. Indeed, only periods of illness or scheduling conflicts prevented subjects from completing the prescribed training dosage of 12 weeks (at a frequency of 3 sessions of 36min/wk). Consistent with our hypothesis that improvements in walking function would accompany improvements in paretic propulsion, 11 of the 12 subjects who completed the 12 weeks of gait training achieved meaningful improvements (ie, greater than the known minimal clinically important difference or minimal detectable change values) across the domains of the *International Classification of Function, Disability and Health*.

The FastFES program is the first poststroke therapeutic intervention shown to improve the paretic limb's ability to generate propulsive force while also improving functional performance. To our knowledge, previous intervention studies concerned with paretic propulsion have primarily been limited to the study of propulsion symmetry,[12,21,22,42] with none showing significant group changes post- versus pretreatment. However, when dichotomizing subjects based on their response to treatment, Bowden et al[20] reported a significant improvement in propulsion symmetry for responders versus nonresponders. Although propulsion symmetry is an important measure of lower limb coordination and control during walking, improvements in symmetry are not necessarily indicative of increased propulsive force generation by the paretic limb; rather, improvements in symmetry may reflect changes in the function of the nonparetic limb. In contrast with prior intervention studies examining changes in propulsion symmetry, a recent study by Hase et al[43] reported that a 3-week prosthetic-based gait program had a greater effect on the propulsive force generated by the paretic limb than a 3-week fast treadmill walking program. However, subjects received only 10 to 15 minutes of treadmill training per day for 10 days and achieved only an average of .05m/s improvement in walking speed (prosthesis training subjects improved an average of .06m/s). Similarly, a review of the GRF plots presented revealed that their representative subject achieved approximately a 1% increase in peak paretic propulsive force after training. In contrast, subjects in the present study completed a median of 32 sessions with an average of 27.51 minutes of training per session, ultimately achieving a .18m/s average improvement in walking speed and a median gain in peak paretic propulsive force of 3.28% (interquartile range, 1.23%−3.59%). These findings call for further study of the training dosage necessary to produce an optimal therapeutic response.

The findings of the present study build on recent work demonstrating an association between changes in paretic ankle plantarflexor function and improved poststroke walking speed.[44,45] These studies, consistent with the early work of Olney et al,[6] provide insight into the biomechanical mechanisms that may underlie the improvements in propulsion observed in the present study. Specifically, improvements in the positive power and positive work produced by the paretic plantarflexors during preswing may be major contributors to the improvements in walking speed observed. The present study, by joining treadmill training at a maximal speed and plantarflexor FES, facilitates a second means of improving paretic propulsion (ie, through improving the paretic trailing limb position). Indeed, the FastFES program is designed to improve paretic propulsion through the synergistic effect of increasing the

Table 2 Group (n = 12) pretesting, posttesting, follow-up, and change score values

	Pre	Post	Follow-Up	Change (post–pre)		Change (follow-up–pre)	
Variable	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD (95% CI)	*P*	Mean ± SD (95% CI)	*P*
6MWT (m)	215.00±92.00	303.00±125.00	268.00±122.00	89.00±64.00 (53.00–126.00)	≤.001	53.00±58.00 (20.00 – 86.00)	.005
SSWS (m/s)	0.50±0.17	0.68±0.22	0.62±0.21	0.18±0.07 (0.13–0.22)	≤.001	0.10 (0.08–0.11)[*] (0.06 – 0.15)[†‡]	.001
MWS (m/s)	0.67±0.27	0.85±0.31	0.81±0.31	0.18±0.09 (0.13–0.23)	≤.001	0.14±0.09 (0.09 – 0.19)	≤.001
FGA (score)	9.75±2.73	12.83±4.24	11.67±4.81	3.08±2.68 (1.57–4.60)	.001	1.92±3.53 (−0.08 – 3.91)	.043
SIS-P (score)	67.71±23.81	76.30±21.76	79.17±18.19	8.59±12.23 (0.82–16.36)	.017	6.23 (2.34 – 14.06)[*] (0.00 – 18.75)[†‡]	.020
PropInt (%BW.s)	0.48±.50[#]	1.05±0.94[¶]	0.99±0.82	0.29 (0.10–0.42)[*] (0.10–0.65)[†‡]	.006	0.24 (−0.04 – 0.48)[*] (−0.12 – 0.72)[†‡]	.070
PeakProp (%BW)	2.89±1.83[#]	6.05±2.81[¶]	5.17 (3.62–6.65)[*^]	3.28 (1.23–3.59)[*] (0.80–4.47)[†‖]	.005	2.25 (0.43 – 3.17)[*] (0.34 – 8.00)[†§]	.003
PropSymm (%)	10.57±11.38[#]	16.26±13.24[¶]	21.57±19.75	5.46±4.32 (2.64–8.28)	.003	4.03 (0.44 – 8.82)[*] (0.00 – 14.68)[†§]	.014
PeakTLA (deg)	9.70±6.10[^]	14.38±5.57[^]	13.8±4.9	4.69±5.04 (1.71–7.67)	.006	3.67±4.66 (0.91 – 6.42)	.013

Abbreviations: CI, confidence interval; FGA, Functional Gait Assessment; %BW, percent body weight; %BW.s, percent body weight second; PropInt, paretic propulsion integral; PeakProp, peak paretic propulsive force; PropSymm, propulsion symmetry; PeakTLA, peak paretic trailing limb angle; SIS-P, Stroke Impact Scale participation domain.

[*] If data were not normally distributed, data are presented as median (interquartile range).

[†] If data were not normally distributed data are presented as CI for the median.

[‡] 95% CI for the median actual coverage is 96.1%.

[§] 95% CI for the median actual coverage is 97.9%.

[‖] 95% CI for the median actual coverage is 98.8%.

[¶] Data for only 9 subjects are available.

[#] Data for only 10 subjects are available.

[^] Data for only 11 subjects are available.

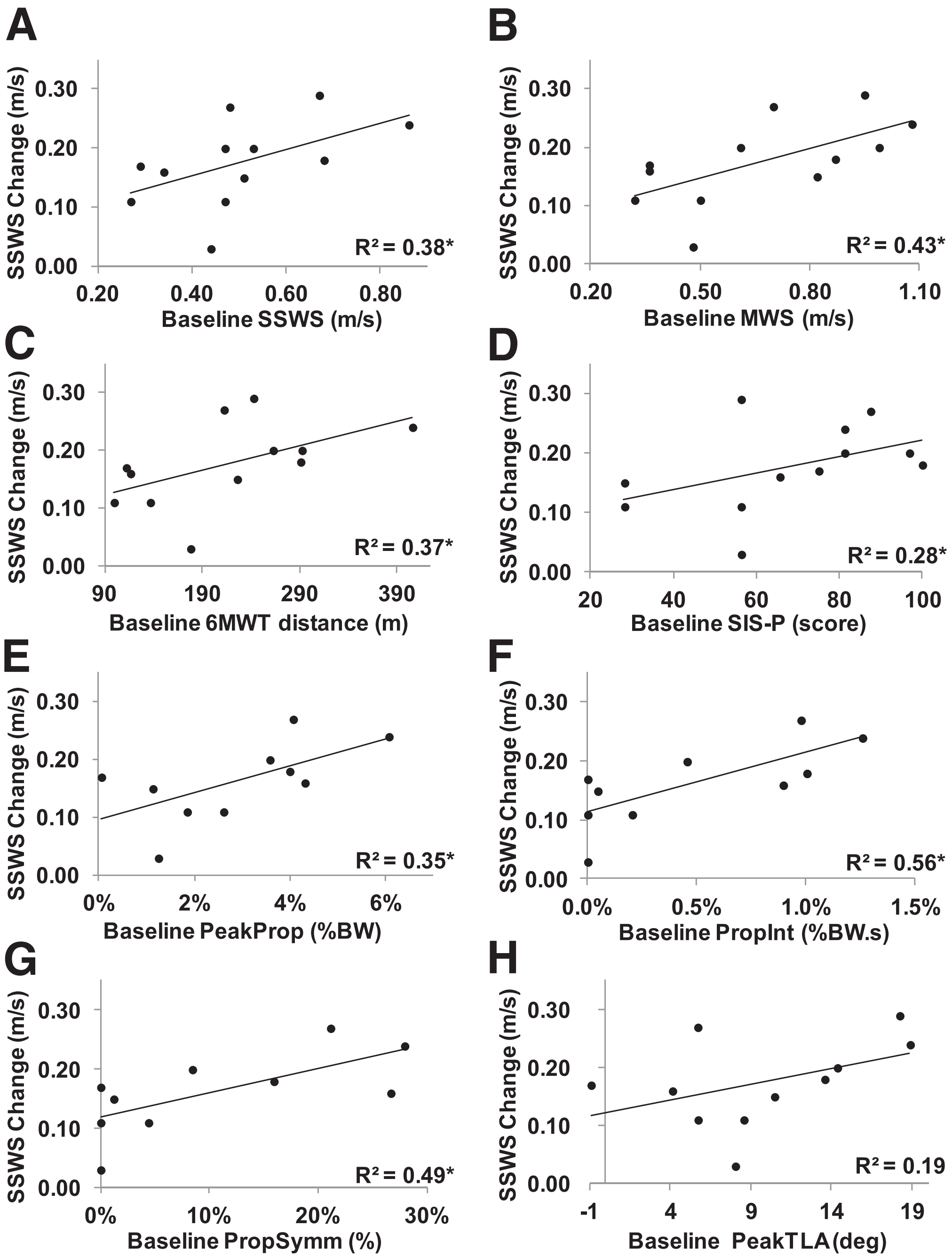

Fig 1 Scatter plots present the relationships between baseline clinical (SSWS, MWS, 6MWT, SIS-P) (A—D) and biomechanical (peak paretic propulsive force [PeakProp], paretic propulsion integral [PropInt], propulsion symmetry [PropSymm], peak paretic trailing limb angle [PeakTLA]) (E—H) performance versus improvements in SSWS after FastFES training. Baseline performance on all measures, except PeakTLA, related to improvements in SSWS. Baseline PropInt and PropSymm performance very strongly related to improvements in SSWS (each Spearman $\rho \geq .70$, $P < .05$). Baseline PeakProp, 6MWT, MWS, SSWS, and SIS-P performance strongly related to improvements in SSWS (each Spearman $\rho \geq .50$, $P < .05$). Baseline PeakTLA was not related to improvements in SSWS. Abbreviations: %BW, percent body weight; %BW.s, percent body weight second; SIS-P, Stroke Impact Scale participation domain.

paretic trailing limb angle via faster walking and increasing the activation of the paretic plantarflexors via FES. However, improvements in one of these components may have a larger effect on propulsion deficits than improvements in the other. For example, although improvements in paretic propulsion may be realized solely through an increased trailing limb angle, changes in plantarflexor activation alone may not be sufficient to increase propulsion without an adequate initial trailing limb position. However, for individuals with an adequate trailing limb position at baseline, improvements in propulsion may only be realized from improvements in plantarflexor force generation. For such individuals, FES-induced increases in plantarflexor muscle activation must carryover to improvements in voluntary muscle activation. Further study of the individual contribution of improvements in each trailing limb

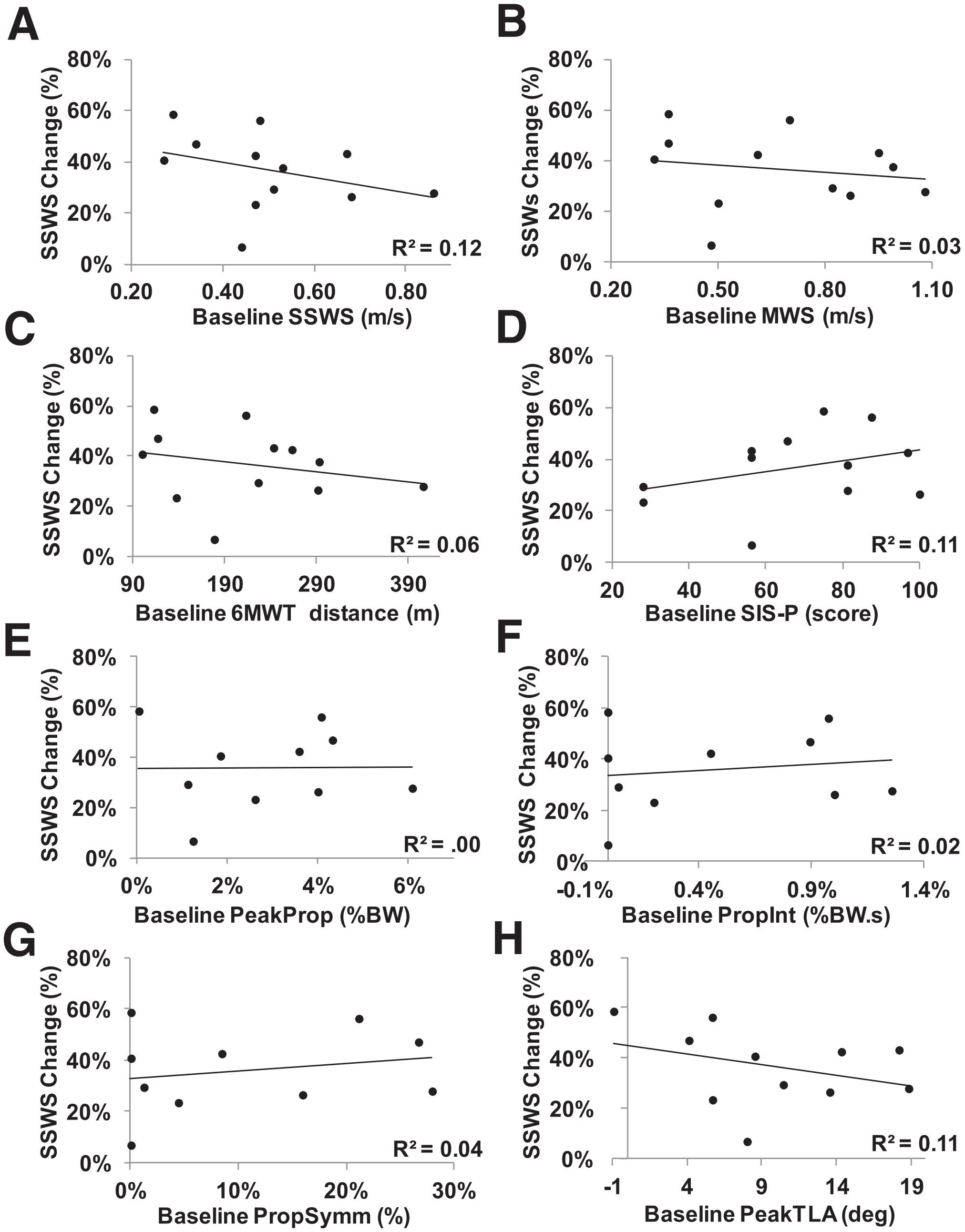

Fig 2 Scatter plots present the relationships between baseline clinical (SSWS, MWS, 6MWT, SIS-P) (A—D) and biomechanical (peak paretic propulsive force [PeakProp], paretic propulsion integral [PropInt], propulsion symmetry [PropSymm], peak paretic trailing limb angle [PeakTLA]) (E—H) performance versus relative improvements in SSWS after FastFES training. Baseline performance was not related to relative improvements in SSWS (all Spearman $\rho \leq .35$, $P > .05$). Abbreviations: %BW, percent body weight; %BW.s, percent body weight second; SIS-P, Stroke Impact Scale participation domain.

angle and plantarflexor force generation to improvements in walking performance is warranted and may influence the selection of treatment parameters. Moreover, considering individuals with chronic stroke have been shown to increase walking speeds preferentially through increased work at the hip versus the ankle,[46] future study of the effect of FastFES on preexisting gait compensations is warranted.

Consistent with the findings of Sullivan,[47] Mulroy,[14] and colleagues, the present study demonstrated that better baseline performance was predictive of larger SSWS gains. In contrast, Barbeau and Visintin[48] demonstrated that in the earlier phases poststroke (~2mo), subjects with greater gait impairments at baseline benefited the most from locomotor training. Taken together, these findings suggest that gait intervention during the earlier phases of stroke recovery may have a larger positive effect on those with greater initial impairments, whereas gait intervention during the later phases of stroke recovery may produce larger gains in higher functioning individuals. However, the present study also demonstrates comparable relative improvements in SSWS, with subjects achieving a median SSWS improvement of 39% (interquartile range, 28%—39%) regardless of baseline level of impairment. To our knowledge, previous investigations have not examined the effect of baseline impairment severity on relative treatment outcomes. As such, whether this finding is unique to the FastFES intervention, or generalizable across interventions, is currently unknown.

Study limitations

As a preliminary study without a control group, this article is unable to determine the effectiveness of the FastFES program. Moreover, the individual contribution of the intervention components—the fast walking speed or the FES—to the gains observed is unknown. However, these 2 components were selected for this intervention based on previously published work that demonstrated that the combination of fast treadmill walking plus FES produced larger immediate gait changes than either alone.[39]

Conclusions

This is the first study, to our knowledge, to demonstrate that individuals who are poststroke can learn to generate greater propulsive force via their paretic leg during walking. Moreover, we show that the combination of walking at maximal speed with FES of the paretic ankle musculature is safe and feasible for persons in the chronic phase of stroke and promising for individuals across different levels of baseline impairment severity. Further study of this intervention will include a randomized controlled trial studying the additive therapeutic effect of FES to fast treadmill training alone.

Suppliers

a. Vicon Motion Systems, 5419 Mcconnell Ave, Los Angeles, CA 90066.
b. AMTI, 176 Waltham St, Watertown, MA 02472.
c. National Instruments, 11500 N Mopac Expy, Austin, TX 78759.
d. TENSproducts Inc, 253 County Rd 41, Granby, CO 80446.
e. ConMed Corp, 525 French Rd, Utica, NY 13502.
f. Motion Lab Systems, 15045 Old Hammond Hwy, Baton Rouge, LA 70816.
g. Grass Technologies, 200 Metro Center Blvd, Unit 8, Warwick, RI 02886.
h. Microsoft Corp, One Microsoft Way, Redmond, WA 98052-7329.
i. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Keywords

Paresis; Rehabilitation; Stroke; Walking

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