Short Foot Exercise Incorporating the Foot Core System Paradigm on Clinical Trials for the Patients with Stroke

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Purpose The purpose of this study was to identify the correlations between activated foot intrinsic muscles through short foot exercise incorporated the foot core system paradigm and muscle tension, gait speeds, and range of motion in affected ankle for the patients with stroke. ***Methods*** Conventional therapeutic exercise group (N=17) was instructed to do conventional therapeutic exercise with physical therapists to increase strengthening of the leg muscles and for proprioceptive training for 6-weeks, 90 minutes/day, 5 day/week. Short foot exercise with conventional therapeutic exercise group (N=17) was assigned to do the same program plus short foot exercise to improve activation of foot intrinsic muscles. The level of muscle tension was measured by electromyography, ankle range of motion was measured by digital goniometer, and gait speed was measured by 10 meter walk test. ***Results*** There were significant differences between conventional therapeutic exercise group and short foot exercise with conventional therapeutic exercise group in muscle tension and fast velocity ($p<0.05$). However, there were no significant differences between conventional therapeutic exercise group and short foot exercise with conventional therapeutic exercise group in affected and non-affected range of motion ($p>0.05$). ***Conclusion*** Short Foot Exercise combined with conventional therapeutic exercise program appeared to show positive effects in muscle tension in stop standing and fast velocity in gait cycle except range of motion in ankle dorsiflexion.

Key words Short foot exercise, Foot core system, Stroke, Gait ability, Muscle tone

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I. Introduction

Foot is the only source of direct contact to the ground while standing and walking, the function of foot is imperative for functional tasks.[1] Up to 50% of chronic stroke patients suffers from foot disorders which decreases functional ability by abnormal walking.[2] Approximately 30% of patients suffer abnormal, asymmetric foot posture while standing. Also, it has been observed almost equal numbers of pronation and supination anomaly. Foot posture abnormalities are strongly associated with walking limitations.[3] Additionally, the stroke group with spasticity bear less weight on the affected limb and exhibited reduced temporal synchrony of center of pressure trajectories .[4]

The human foot is consisting of 26 bones arranged in a mechanically favorable dome shape as well as 3 arch structures. The complex structure of the foot enables functional adaptation to various static and dynamic situations, and the foot arches act as shock absorbers.[5] Concept of core stability may also be extended to the arch of the foot. The arch is controlled with both local stabilizers and global movers of the foot, similar to the lumbopelvic core. The local stabilizers are the four layers of plantar intrinsic muscles that originate and insert on the foot and the global movers are the muscles that originate in the lower leg, cross the ankle and insert on the foot. With each foot step, the four layers of intrinsic muscles act to control the degree and velocity of arch deformation.[6] The six intrinsic muscles of the foot, which are often considered to be crucial elements to arch support, are consisted of the extensor digitorum brevis, the abductor hallucis, the flexor hallucis brevis, the flexor digitorum brevis, the abductor digiti minimi, and the dorsal interosseous muscle between the third and fourth toe. Early intramuscular electromyography (EMG) studies proposed that the plantar intrinsic foot muscles act as a functional unit to stabilize the toes during the push off phase of gait, as well as providing resistance to subtalar joint pronation.[7] When intrinsic muscles are not controlled properly, the basis becomes wobbly and malaligned; and abnormal movement of the foot ensues. This may be noticeable in foot-related problems affects gait abilities.[6] Intrinsic muscle weakness has also been implicated in the development of pescavus in Charcot-Marie-Tooth disease[8] Heel pain[9] Claw toe deformity[10] Hammer toe deformity and Hallux valgus Plantar fasciitis.[11] Also the intrinsic muscle takes a part in support of the medial longitudinal arch in static stance. Disordering the function of these muscles through fatigue resulted in foot pronation as assessed by naviculardrop.[12] Stroke survivors have, overall, a smaller amount of motion in the foot during stance phase and a more pronated foot; the decrease in overall in overall range of motion being due to decreases in range of supination.[1] Foot pronation has been suggested to expedite more proximal lower limb dysfunction and hence contribute to a wide range of lower limb related injuries affecting the lower back, hip, knee, lower leg, ankle and foot.[13] Also decreased passive range of motion (PROM) of joints is a common musculoskeletal problem for individuals with chronic post-stroke hemiparesis.[14] Changes in pronation and supination as well as dorsiflexion and plantarflexion motion in ankle were closely associated with limited walking ability for stroke population.[1]

Strained triceps surae are in sequel of abnormal foot function after stroke, particularly in relation to exaggerated or sustained pronation causing faulty foot kinetic chain force.[15] Stiffness and weakness in muscle are one of features after stroke which are due to alterations in viscoelastic properties. Also connective tissue of spastic, paretic muscle may causes significant passive restraint which leads the limitation torque by the antagonist muscle.[16] Other studies have examined passive muscle tensions in stroke survivors specifically selected for their locomotor ability.[17,18] Also increased passive tension in paretic muscles occurred only in individuals who could not produce adequate active tension. Consequently, the more severely hemiparetic individuals were most likely to exhibit high passive muscle tensions.

Recently, the ‘short foot exercise’ has been described as a means to isolate contraction of the plantar intrinsic muscles.[19] There is an increasing evidence which suggests that training the foot core via short foot exercise progressions can improve foot function. For example, 4 weeks of short foot exercise training in healthy individuals reduced foot arch collapse which was assessed by measuring navicular drop, arch height index, and improve balance ability.[20]

According to previous studies, a short foot exercise was effective technique for facilitating the plantar intrinsic foot muscles which play the essential role in maintaining MLA angles and limiting the foot pronation especially on late stance phase. However, there are a few studies that evaluated the effects of foot intrinsic muscles on the changes over foot extrinsic muscle tensions and functional ability outcomes for stroke population. Also most current short foot exercise related studies are only limited to the healthy participants. Since the short foot exercise can be taught passive modeling by the therapist, it is necessary to study the effectiveness of passive modeling with less active performance short foot exercise for stroke population who have inability to perform an active curb like normal.

II. Materials and Methods

1. Participants

Total of thirty-four subjects were randomly allocated into two groups of equal size by computer software program that generates the random sequence. There were no significant differences of general characteristics between CEG and SFE with CEG <Table 1>. Specific inclusion criteria were as follows. 1) A patient who has been diagnosed with hemiplegia from neu-

Table 1. General characteristics of subjects.

	CEG (N=17)		SFE with CEG (N=17)		F / $\chi 2$
Gender (%)	Male	13(76.4)	Male	8(47)	.170
	Female	4 (23.6)	Female	9(53)	
Age	43.35±7.8		42.64±8.78		.992
Height	168.52±6.49		170.00±5.11		.999
Weight	66.00±7.94		67.58±9.77		.993
MMSE	25.47±1.48		25.47±1.28		.414
Onset	10.41±2.39		10.64±2.47		.846
Hemiplegic side (%)	Left 6 (35.3)		Left4(23.5)		.452
	Right	11(64.7)	Right	13(76.5)	

Note. Values are mean ± standard deviation.
SFE : Short Foot Exercise
CEG : Conventional Therapeutic Exercise Group

rology and rehabilitation medicine specialist. 2) A patient who were not relapsed back within 3-12 months from the onset of stroke. 3) A patient who was able to walk 50-meter or to sit alone. 4) A patient who had MAS grade lesser than 3. 5) A patient who have not had any other neurological disease (eg. Peripheral neuropathy, parkinson's disease, dementia, etc.), surgical disease, or visual impairment.
6) A patient who was able to respond properly from sensory stimuli by the examiner which was ranged score 24 points to 30 points in Korean version of Montreal Cognitive Assessment. 7) A patient who understood the content of study and agree to participate.

2. Study design

This study was a prospective, randomized controlled trial, with 17 participants assigned to an exercise program for conventional therapeutic exercise and 17 participants assigned to the same exercise program plus short foot exercise. However, intensity of both groups were equal as 90 minutes. Participant were assessed at the baseline of pre-intervention and at the end of post-intervention, participated in a 6-week intervention period.

3. Outcome Measures

1) EMG

To acquire EMG signals, surface EMG data were recorded using a Trigo wireless EMG system (Delsys, Inc., Boston, MA, USA). EMG data were collected from the Tibialis anterior muscles and Gastrocnemius muscles on the paretic and non-paretic sides. Electrodes were situated as follows: for the TA, one quarter to one third of the distance between the knee and the ankle, and for the GCM, immediately distal from the knee and 2 cm medial to the midline and 2 cm lateral to the midline.[21] Data analysis was performed using the EMGworks software package (ver. 4.0; Delsys). The sampling rate for the EMG signal was set at 2,000 Hz; the band-pass filter was set between 20-450hz. Raw data from the TA and GCM muscles were transformed into root mean square (RMS) data. The mean RMS values for the reference voluntary contraction (RVC) were calculated from each muscle when subjects were in a static standing.[22] Also, for the dynamic standing, the mean RMS values for the reference voluntary contraction (RVC) were collected during sit to stand in first 2 seconds from height adjustable table. During sit to stand performance, to minimize the deviation of muscle activation, controlling the speed of sit to stand was measured by the time (in seconds) to complete one STS maneuver with metrometer. Individuals were seated on height adjustable table which was adjusted to allow for approximate 90-degree angles at the hip and knee joints. The distance between their feet was placed in accordance with their shoulder width. Subjects performed three independent STS. In order to acquire precise onset point, accelerometer channel consisting triple-axis accelerometer and triple-axis gyroscope were attached to subject's forehead during sit to stand where Ax, Ay, Az is the acceleration in the x-, y-, and z- axes at time before and during the movements. The accelerometer signals were sent to an digital converter at a sampling rate of 2000Hz, and captured with Delsys.[23] Once data were acquired from static standing reference voluntary contractions and dynamic sit to stand reference voluntary contractions, six muscle (two TA, two GCM medialis, two GCM lateralis) %RVC were calculated by equation below.

%RVC = Dynamic sit to stand RVC / Static standing RVC

2) 10M Walk Test

The 10-meter walk test (10MWT) is the most common test for gait speed (Donovan, 2008). Individual walks without assistance 10 meters (32.8 feet) and the time is measured for the intermediate 6 meters (19.7 feet) to allow for acceleration and deceleration. 10M walk test showed excellent reliability ICC=0.998.[24]

3) Digital goniometer

For all the measurements, the same starting position is used. Position the participant on the bed and plinth in long sitting, reclined to about 45 degrees. Small pillow was placed under upper part of the lower legs to prevent hyper-extended knee. The patient was ensured that comfortable during the measurements. Digital goniometer axis was placed approximately 1.5 cm inferior to the lateral malleolus. Stationary arm was placed parallel to the longitudinal axis of the fibula, lining up with the fibula head. Finally, moveable arm was placed parallel to the longitudinal axis of the 5th metatarsal. Only affected ankle dorsiflexion was assessed before and after the CEG and SFE with CEG. The ICCs for intratester reliability range from .74 to .90 for ankle and subtalar joint measurements. With the exception of ankle plantar flexion, these measurements cannot be considered to be reliable between therapists.[25] Goniometric measurements of the subtalar joint position and of PROM of the ankle appear to be moderately reliable if taken by the same therapist over a short period of time. Digital goniometer and universal goniometer showed no statistically significant differences for intra- or inter-rater reliability, with digital yielding higher inter-rater ICC values.[26]

4. Interventions

1) Conventional therapeutic exercise group (CEG)

A study group session involved approximately 5-minute of establishing a physical postural base of support coupled with assessing and facilitating the alignment of the lower limbs. Approximately 10-minute were used to mobilize the foot from 1st-ray of metatarsal joint to 4th-ray of metatarsal joint in an affected foot. Mobilization was performed in supine position on height-adjustable table. Gradual application of the foot oriented movements for 60-minute were being applied after foot mobilization, for example, activating the plantar flexor muscles through plantar flexion prior to activating the foot abductor digiti minimi muscle for facilitating evertor to reeducate the eccentric controls of lower limb muscles. Also the established conventional therapeutic exercise had been applied. Detailed explanations of four conventional therapeutic exercise were examined: (1) quadriceps femoris muscle setting[27], (2) manual lateralization of the patella[28], (3) rhythmic stabilization[29], and (4) the pelvic bridging.[30]

2) Short foot exercise with conventional therapeutic exercise group (SFE + CEG)

Total 75 minutes of conventional therapeutic exercise plus 15 minutes of short foot exercise were applied. Specific short foot exercise protocol was as follows. The subjects were asked to seat on an adjustable-height table with the hip, knee, and ankle joint positioned at an angle of approximately 90 degrees. A cuff (5 lbs.) will attach to surround the surface of medio/lateral malleolus on affected ankle. Also a recent study demonstrated that muscle activity of plantar intrinsic muscles was much greater when the exercise was performed from a weight applied position as measured by EMG. [31] However, subjects in this study were asked to remain seated for the safety purpose while a cuff was strapped. The patient was instructed to raise the toes from the floor while leaving the heads of the metatarsal in contact with the floor and then slowly lowering the toes to the floor while maintain the height of the medial longitudinal arch. The participant's foot was also stabilized by the examiner to prevent lifting of the heel and to prevent movement of the foot during short foot exercise. Then subjects were asked to take the breath in and out. During inhalation, contact the muscles on the bottom of subject affected foot and lower legs to raise the arch of patient's foot without curling toes. Held this isometric muscle contraction for six seconds. During exhalation, the heightened medial longitudinal arch was released to the ground.[32] During SFE, physical therapists was aimed to minimize other substitutional contraction of extrinsic muscles that contribute to surplus the involuntary muscle contraction in an effort to isolate the function of intrinsic musculature. Thereby, two surface EMG were placed on affected medio/lateral gastrocnemius muscles to measure EMG activity of the extrinsic muscles in order to completely rule out the muscle compensations during SFE. Total of 5 repetitions for 15 minutes of isometric contraction for foot intrinsic muscles was applied for study group.

5. Statistical analysis

Descriptive statistic will be used to analyze mean values and standard deviation for the general characteristics of participants. To determine whether data is normal, and therefore, that this assumption is met in data for statistical test, Shapiro-Wilk test will be performed. Paired T-test will be used to calculates the difference within each before-and-after pair of measurements, determines the mean of these changes, and reports whether this mean of the differences is statistically significant. Independent T-test will be used to analyze significant difference between study and control groups. For the statistical analysis, SPSS 18.0 will be used to find significant differences between the groups (p = 0.05).

III. Results

1. Changes in muscle tension

Muscle tension significantly decreased after general lower strengthening of conventional therapeutic exercise, as determined by shift in the average mean values of the EMG signal from non-affected gastrocnemius medialis (pa< 0.01). Subjects exhibited 76.75±60.54% of muscle tension at baseline and 85.64±70.45% at post-intervention for affected gastrocnemius medialis (pa = 0.613). There were no significant differences in affected (pa = 0.388) and non-affected (pa = 0.484) gastrocnemius lateralis which showed 50.98±45.95% and 68.16±60.84% at baseline and 45.21±45.82% and 63.32±67.19% at post-intervention respectively. Also no significant differences were observed in affected (pa = 0.765) and non-affected (pa = 0.287) tibialis anterior muscle showed 198.12±200.65% and 255.96±401.73% at baseline and 207.44±183.75% and 193.16±187.31% at post-intervention respectively <Table 2>. Muscle tension significantly decreased after short foot exercise with general lower strengthening of conventional therapeutic exercise, as determined by shift in the average mean values of the EMG signal from affected gastrocnemius medialis, affected gastrocnemius lateralis, and affected tibialis anterior. Subjects exhibited 55.51±38.40% of muscle tension at baseline and 34.69±33.41% at post-intervention for affected gastrocnemius medialis (pa < 0.01), 87.54±58.11% of muscle tension at baseline and 62.58±36.55% at post-intervention for affected gastrocnemius lateralis (pa < 0.01), and 372.93±516.10% of muscle tension at baseline and 302.93±468.37% at post-intervention for affected tibialis anterior (pa < 0.05). There were no significant differences in all non-affected lower muscles. Non-affected gastrocnemius medialis, non-affected gastrocnemius lateralis and tibialis anterior showed 51.34±41.92%, 55.02±33.54%, and 456.50±737.13% at baseline and 49.32±37.48%, 68.68±81.28%, and 530.14±623.49% at post-intervention respectively (pa > 0.05) <Table 2>.

There were statistically significant differences in non-affected gastrocnemius medialis and affected gas-

Table 2. Comparison of baseline and post-intervention %RVC between conventional therapeutic exercise group and short foot exercise with conventional therapeutic exercise group.

			CEG (N=17)				SFE with CEG (N=17)		
			Baseline	Post-Intervention	t^a	p^a	Baseline	Post-Intervention	t^a
RVC, (%)	GCM(M)	Affected	76.75±60.54	85.64±70.45	-.515	.613	55.51±38.40	34.69±33.41	3.514
		Non-affected	59.34±38.16	43.65+30.61	2.93	.010*	51.34±41.92	49.32±37.48	.595
	GCM (L)	Affected	50.98±45.95	45.21±45.82	.887	.388	87.54±58.11	62.58±36.55	3.201
		Non-affected	68.16±60.84	63.32±67.19	.717	.484	55.02±33.54	68.68±81.28	-.787
	TA	Affected	198.12±200.65	207.44±183.75	-.304	.765	372.93±516.10	302.93±468.37	2.880
		Non- affected	255.96±401.73	193.16±187.31	1.102	.287	456.50±737.13	530.14±623.49	-.640

Note. Values are mean±standard deviation, a within-group comparison, b between-group comparison, *P<0.05, **P<0.001 GCM(M) : Gastrocnemius medialis, GCM(L) : Gastrocnemius lateralis, TA : Tibialis Anterior
SFE : Short Foot Exercise, CEG : Conventional Therapeutic Exercise Group

trocnemius lateralis between conventional therapeutic exercise group and SFE with conventional Therapeutic exercise group. For %RVC muscle tension during the dynamic sit to stand task on the both non-dominant and dominant leg, there were significant main effects in non-affected gastrocnemius medialis (*pb* < 0.05) and affected gastrocnemius lateralis (*pb* < 0.01). Although there were statistical differences between CEG and SFE with CEG, the effect size was small in non-affected gastrocnemius medialis compare to affected gastrocnemius lateralis <Table 2>.

Table 2. Comparison of baseline and post-intervention %RVC between conventional therapeutic exercise group and short foot exercise with conventional therapeutic exercise group.

2. Changes in gait speed

The conventional therapeutic exercise group showed improvements only in self-selected velocity (from 0.44±0.28m/s at baseline to 0.49±0.32m/s at post-intervention; *pa* = 0.34). The short foot exercise with conventional therapeutic exercise group showed significant improvements in both self-selected velocity and fast velocity (from 0.46±0.35m/s, 0.55±0.39m/s at baseline to 0.69±0.47m/s, 0.82±0.55m/s at post-intervention; *pa* = 0.001, *pa* = 0.000 respectively). Also there were significant differences between CEG and SFE with CEG only in fast velocity (*pb* = 0.004) <Table 3>.

3. Changes in range of motion in ankle

The conventional therapeutic exercise group showed no significant improvements in both the affected and the non-affected side regarding range of motion (from 6.33±4.48°, 10.44±3.70° at baseline to 6.55±5.01°, 10.76±4.68° at post-intervention; *pa* = 0.672, *pa* = 0.671 respectively). The short foot exercise with conventional therapeutic exercise group showed significant improvements only in the affected side regarding range of motion (from 4.96±2.96°, 9.75±4.26° at

Table 3. Comparison of baseline and post-intervention 10M Walk Test between conventional therapeutic exercise group and short f therapeutic exercise group.

		CEG (N=17)				SFE with CEG (N=17)				
		Baseline	Post-Intervention	t^a	p^a	Baseline	Post-Intervention	t^a	p^a	t^b
10M Walk Test, (m/s)	SSV	0.44±0.28	0.49±0.32	-2.315	.034*	0.46±0.35	0.69±0.47	-3.903	.001	.43
	FV	0.63±0.44	0.66±0.46	-2.065	.056	0.55±0.39	0.82±0.55	-4.530	.000*	5.7

Note. Values are mean±standard deviation, *P<0.05, **P<0.001 a within-group comparison, b between-group comparison
SSV : Self-Selected Velocity, FV : Fast Velocity
SFE : Short Foot Exercise, CEG : Conventional Therapeutic Exercise Group

Table 4. Comparison of baseline and post-intervention ROM between conventional therapeutic exercise group and short foot exercise with conventional therapeutic exercise group.

		CEG (N=17)				SFE with CEG (N=17)			
		Baseline	Post-Intervention	t^a	p^a	Baseline	Post-Intervention	t^a	p^a
ROM, (°)	Affected	6.33±4.48	6.55±5.01	−.431	.672	4.96±2.96	6.71±3.14	−2.935	.001
	Non-affected	10.44±3.70	10.76±4.68	−.432	.671	9.75±4.26	9.03±4.44	1.106	.000*

Note. Values are mean±standard deviation, *P<0.05, **P<0.001 a within-group comparison, b between-group comparison
SFE : Short Foot Exercise, CEG : Conventional Therapeutic Exercise Group ROM : Range of Motion

baseline to 6.71±3.14°, 9.03±4.44° at post-intervention; *pa* = 0.01, *pa* = 0.285 respectively). However, there were no significant differences between CEG and SFE with CEG in affected and non-affected range of motion (*pb* = 0.064, *pb* = 0.300) <Table 4>.

Ⅳ. Discussion

The main findings of this study were as follows: (1) The results of foot extrinsic tension was affected, (2) the results of gait speed was affected, and (3) in the affected limb, observed a small improvement in range of motion.

SFE with CEG significantly decreased extrinsic muscle tensions regardless of baseline %RVC values in spastic hemiplegic patients. These results reinforce the recent findings that the foot extrinsic muscles function as the global movers of the foot core to generate foot motion. For example, the achilles tendon from the triceps surae controls the tension of the plantar aponeurosis based on their common connection to the calcaneus.[6] The clinician observed for gross changes in navicular height and overactivity of the extrinsic muscles.[33] As triceps surae tension increases, so does the tension on the plantar fascia.[34] And plantar aponeurosis tension significantly dropped during late stance, while activation of foot extrinsic muscle is increasing.[35] On the contrary, the lack of tension in plantar longitudinal arch during late stance suggested that other structures such as intrinsic foot muscles may contribute to arch support during propulsion.[36] Clinically, the "short foot" exercise which emphasizes isometric contraction of metatarsophalangeal joint during seated posture has been advocated as a means of improving neuromuscular control and strength of the foot intrinsic. While the foot is on the ground with a partial weight bearing, the short foot exercise is performed by passive modeling for isometric contraction of intrinsic muscle. During the contraction, Maximal elevation of medial longitudinal arch was encouraged with fore foot and rearfoot on the ground.[19] Surface EMG was well established instrument for evaluating muscle tension for clinicians. However, in the previous studies, surface EMG was not used to assess the relationship between foot extrinsic and intrinsic muscles. In this study, surface EMG was applied to assess the muscle activity of the GCM medialis, GCM lateralis, and TA. Since these three muscles were the most superficial foot extrinsic muscles, the EMG activity of these muscles were considered as a representative of all foot extrinsic muscles. Before and after the conventional therapeutic exercise, subjects exhibited comparable %RVC values only when SFE was applied for 6 weeks, suggesting that the conventional therapeutic exercise had no immediate or prolonged effect on extrinsic muscle tension. Thus, it could be hypothesized that SFE largely contributes for the presumed benefits of foot kinematics. This result also supports the current foot core system paradigm.[6]

Propulsive force has a strong relation to the step length. However, longer steps do not always follow by sufficient propulsive force likely due to compensatory movement and often draw more energy expenditure with undesired outcomes. The proposed that propulsive force and gait speed are not inter-related.[1] Mild hemiplegic patients with higher propulsive force showed slower gait speed than severe hemiplegic patients with lower propulsive force. Other studies have shown that intrinsic muscle tension was increased during poststroke gait. For example, without a concomitant increase in muscle activity, tension was developed in hemiparetic calf muscles during the stance phase.[18] From the previous study, we can have speculated that sufficient propulsive forces are not consistent with gait speed in stroke patient, or rather, step length and step symmetry are more closely related to gait speed in stroke patients. In other words, step length and step symmetry have close relation with gait speed in stroke population. Triceps surae muscle is a powerful supinator at the subtalar joint when the fore part of the foot is fixed on the floor.[7] However, significant decreases in rear foot inversion and adduction in late stance were also seen, resulting in a less supinated foot during the propulsion (late) phase of stance in stroke patients. Supination of the foot during late stance is an important mechanism to produce a stiff lever against which body weight is transferred from one leg to the other in double stance and enables forward propulsion.[37] In stroke population, lacking timing controls and range of plantar flexion bring least propulsion force that would resulted in step asymmetry as well as less ground reaction forces compared to normal. In this study, there were significant increase in self-selected velocity and fast velocity in SFE with CEG. Facilitated foot intrinsic muscles may allow the proper torque in gastrocnemius (powerful supinator), increased plantar flexion and adequate arthrokinematics. Previous study showed not only propulsive force but also insufficient foot supination during toe off and temporal factors might affect the changes of the gait speed. Therefore, the more activations of plantar intrinsic muscles increase the chance to recruit the fibers in triceps surae. This lead to increased rear foot supination, adequate torques in GCM, lesser compensatory movements and symmetric step length from proper foot kinematic chain.

Traditionally, clinical management of foot and ankle problems after stroke focused on impairments of dorsiflexion.[38] Although a finding from this study showed significant difference within a group in SFE with CEG, the recent findings do not support this application that the range of motion at ankle, rearfoot and midfoot dorsiflexion to be normal. The primary abnormality was a decreased range and reduced timing of rearfoot plantar flexion after initial contact and in late stance.[1] Further study are needed to investigate the relation of SFE on dorsiflexion as well as plantarflexion.

All results of current study should be interpreted with caution. Subjects who were able to walk 50-meter alone may regard as independent in activity daily living. It remains, however, to further consider the general characteristics of classification as expected recovering stage or sensory parameters for individuals. Since this study had only validated effects of short foot exercise in limited time, follow-up of short foot exercise screening test is needed. Further research is necessary to address the impact of activated plantar foot intrinsic muscle function on extrinsic spasticity during gait. Lastly, there is a need for bigger sample size of participant to generalize the effect of foot intrinsic muscles on extrinsic tension and their functional outcomes.

V. Conclusion

It is important to understand the influence of foot intrinsic muscles on patient's function to improve quality of life. Many post-stroke patients with weakness in foot musculature remains asymptomatic although they participate in many functional tasks during their admission. If, however both the passive and active systems are insufficient, as may be in the patients with pes planus or poor intrinsic muscle control, the development of abnormal foot kinematic chains may be inevitable.

Foot intrinsic muscles from short foot exercise with the increase of plantar surface loading in sitting position, a powerful invertor that may lead a patient to stand on the rearfoot without pronation in the upright standing posture. Also strengthened foot intrinsic muscles may control a passive tension of magnitude on foot extrinsic muscles. The results of this study may be supporting connections that intrinsic muscles activation may lower the tension on extrinsic muscles. Since foot intrinsic exercise through short foot might also be applied to the post-stroke patients, short foot exercise could be suggested for the one of ways to modulate their hypertonicity

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