The Immediate Effects of Dorsiflexion Resisted Walking on Ankle Mobility, Muscle Recruitment and Gait Velocity: A Pilot Study

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ABSTRACT

Background: The purpose of this pilot study was to determine the immediate effects of dorsiflexion resisted walking on ankle mobility, muscle recruitment of the ankle dorsiflexors, and gait velocity in healthy adults. *Materials and Methods:* Ten subjects were recruited for the pilot study. Five minutes of dorsiflexion resisted walking using a hook fastener device attached to subject's shoes was performed. Ankle dorsiflexion active range of motion (AROM), muscle recruitment, and gait velocity using goniometric measurements, surface electromyography (sEMG), and GAITRite technology, were measured respectively. *Results:* After 5 minutes of dorsiflexion resisted walking, mean ankle dorsiflexion AROM increased 4.1 degrees immediately post-intervention (p=0.002) and 4.6 degrees at 5 minutes post-intervention (p=0.001). Ankle dorsiflexion sEMG activity increased during the first

and fifth minutes of dorsiflexion resisted walking, 24.8% and 19.5% respectively, compared to pre-intervention walking. Finally, gait velocity increased after dorsiflexion resisted walking (p=0.001). *Conclusions:* The results of this pilot study suggest that dorsiflexion resisted walking may be a useful training strategy for increasing ankle dorsiflexion AROM, muscle recruitment of the tibialis anterior, and gait velocity. Future studies are warranted with larger sample sizes, clinical trials, and patient populations.

BACKGROUND

According to the National Stroke Center,[1] the number of stroke survivors in the United States is about 7 million people and approximately 795,000 strokes occur annually. This is the equivalent of one stroke occurrence every 40 seconds. A major functional limitation impacting the quality of life after stroke is difficulty with walking due to impairments including weakness and decreased active mobility of ankle dorsiflexion. Ankle dorsiflexion is required for normal foot clearance during the swing limb advancement phase of gait, and limitations of this ankle motion contribute to abnormal gait patterns and decreased functional independence. Additionally, falls in general have been attributed to reduced gait speeds.[2] The purpose of this pilot study was to determine the immediate effects of dorsiflexion resisted walking on ankle mobility, muscle recruitment of the ankle dorsiflexors, and gait velocity in healthy adults. This pilot study was conducted in an attempt to validate the anecdotal claims of clinical usefulness of this training strategy on a healthy population prior to conducting clinical trials on patient populations.

MATERIAL AND METHODS

Subjects

Ten subjects [age range=21-26 years; mean 24.4 (1.6)] were recruited for the pilot study from Loma Linda University (LLU). Subjects were healthy adults without any neurological disease who were able to walk independently for 5 consecutive minutes. Subjects read and signed an informed consent document, approved by the Institution Review Board at LLU, prior to participation in the pilot study. Materials used to measure the effects of dorsiflexion resisted walking included goniometry, surface electromyography (sEMG), and GAITRite technology,[2] respectively.

Determination of Ankle Dorsiflexion Active Range of Motion (AROM)

The same investigator took all measurements and pre-experimental intra-tester reliability was established (ICC=.98). The investigator was blinded to the numbers on the standard plastic universal goniometer during all measurements, as described by Youdas et al,[3] to minimize potential examiner bias. Measurements of ankle dorsiflexion AROM were performed as described by Norkin and White.[4]

Subjects sat on a treatment table with their knees flexed over the edge. The goniometer was placed with the center of the fulcrum over the lateral aspect of the lateral malleolus, the proximal arm with the lateral midline of the fibula using the head of the fibula for reference, and the distal arm parallel to the lateral aspect of the fifth metatarsal. Subjects were verbally instructed to lift their foot/ankle upward as far as they could.

Determination of Muscle Recruitment through Surface Electromyography (sEMG)

An sEMG unit was used to determine the timing and intensity of muscle contractions during walking. The quality of the measured sEMG was the result of the ratio between the measured sEMG signal and unwanted noise (artifacts) from the environment. The electrical output from the muscle was amplified with a biopotential amplifier with a gain of 5,000 and frequency response, which was flat from DC to 1000 Hz (Biopac Systems Inc., Goletta CA).[5] The amplified sEMG was digitized with a 16-bit analog to digital converter and sampled at a frequency of 500 samples/sec.[5] The software used to analyze the sEMG was Acknowledge 3.8.3 software on an MP 100 system.[5]

The amplitude of the sEMG was analyzed by integrating the digitized data. The unit had a bioelectric high impedance amplifier with input impedance greater than 10 Ohms. Every time a volt was amplified, there was a rejection of 1,000 volts of noise. The sEMG converted and stored the sEMG signal from analog form to digital form at a rate of 1,000 samples per second with an 8-bit resolution. The electrodes were 35mm pre-gelled, disposable electrodes made by Biopac Systems Inc®.[5] The electrodes were placed on the muscle belly of the target muscle.

Determination of Muscle Activity through Surface Electromyography (sEMG)

An sEMG unit was used to determine muscle activity. Two electrodes recorded sEMG of the target muscle and a ground electrode was placed above the target muscle. The sEMG unit was used to determine the timing and intensity of muscle contraction during an isometric contraction against manual resistance. The amplitude of the sEMG was used to measure the activity of the target muscle by normalizing the sEMG in terms of a maximal effort. Muscle activity was assessed by first measuring the sEMG of the target muscle during a maximal effort and then, during walking, assessing the percent of maximum sEMG to calculate the percent of muscle activity. The target muscle was the tibialis anterior (TA). We measured the amount of TA muscle recruitment when the lower leg was accelerating during the swing limb advancement phase of gait.

Determination of Spatial and Temporal Parameters of Gait

GAITRite technology provided spatial and temporal parameters of gait.[6] The GAITRite is a 61 cm wide and 237 cm long electronic walkway or “electric carpet” that is connected to a Windows® 95/98/ME personal computer, which measured the temporal and spatial parameters of gait. Individual footfalls (steps) were measured with 13,824 sensors embedded in the carpet in a 61 cm X 366 cm grid pattern placed at 1.27 cm centers.[6]

Procedures of the pilot study included taking subjects height and weight measurements followed by performance of a full squat to assure that they had normal leg strength and functional joint range of motion in their lower extremities. A pre-intervention goniometric measurement of ankle doriflexion AROM was then taken. Next, subjects were prepared for electrode placement. Soap, water, a new razor, and shaving cream were used to remove any excess hair prior to electrode placement. Their skin was cleansed and debrided with a 70% USP isopropyl alcohol and 30% purified water solution to reduce skin impedance. The electrode for the TA muscle was placed according to the anatomical landmarks and reference line used by Rainoldi et al.[7] A second electrode, the differential electrode, was placed 30 mm apart in an arrangement parallel to the muscle fiber orientation. A third electrode, the reference electrode, was placed over the muscle belly of the medial head of gastrocnemius. Electrodes were placed using the recommendations of Hermens et al.[8] Subjects then walked across the GAITRite two times at a customary pace without dorsiflexion resistance in order to capture their spatial and temporal parameters of gait and sEMG activity of the TA.

Subjects then donned a dorsiflexion resistance walking device and walked across the GAITRite for a period of 5 minutes. An sEMG recording was taken during the first and fifth minutes. We used a Tib Trainer® to provide dorsiflexion resistance during walking on a carpeted surface. It provided resistance from the ground up through a hook fastener strap, similar to Velcro® (Figure 1).

Subjects then sat on a standard treatment plinth with their legs over the edge and a second goniometric measurement of ankle dorsiflexion AROM was taken. The Tib Trainer® was then removed and subjects rested for 5 minutes. After the 5-minute rest, a final goniometric measurement of ankle dorsiflexion AROM was taken and subjects walked across the GAITRite 2 more times while sEMG and characteristics of walking

Table 1. *Ankle dorsiflexion active range of motion (AROM) measurements (n=10)*

Variable	Pre-Mean Degrees (SD)	Post-Mean 1 Degrees (SD)	Post-Mean 2 Degrees (SD)	P-Value
AROM	13.6 (6.35)	17.7 (7.02)	18.2 (8.0)	*0.002, **0.001

**level of significance between pre-mean and post-mean 1*
***level of significance between pre-mean and post-mean 2*

were taken without wearing the Tib Trainer®.

DATA ANALYSIS

Means and standard deviations were calculated for ankle dorsiflexion AROM. Gait velocity and sEMG were calculated for each time point and compared over time using repeated measures ANOVA with Bonferroni multiple comparison tests to determine which means were significantly different. The level of statistical significance was set at p=0.05.

RESULTS

Mean ankle dorsiflexion AROM improved after dorsiflexion resisted walking with a mean increase of 4.1 degrees immediately post-intervention (p=0.002) and 4.6 degrees at 5 minutes post intervention (p=0.001). Ankle dorsiflexion sEMG activity increased with the dorsiflexion resisted walking during the first and fifth minutes of walking, 24.8% and 19.5% respectively, compared to pre-intervention walking. Gait velocity increased after dorsiflexion resisted walking (p=0.001). See Tables 1 and 2.

DISCUSSION

Subjects in this pilot study improved their active ankle dorsiflexion AROM after dorsiflexion resisted walking with a mean increase of 4.1 degrees immediately post-intervention (p=0.002) and 4.6 degrees at 5 minutes post-intervention (p=0.001). Because of the hook fastener strap, increased TA activity was required to pull the foot off the carpet in order to advance the lower extremity during gait. Although the sEMG results were not statistically significant (p=0.07), there were clinically important increases (>15%, Philadelphia Panel Classification System Grade C+) in sEMG activity for dorsiflexion resisted walking during the first and fifth minutes of walking compared to pre-intervention walking.[10] This was an important finding because increased activity of the TA contributes to increased ankle dorsiflexion and improved ability to clear the foot during swing limb advancement. Perhaps larger sample sizes in future investigations will result in statistically significant increases in sEMG activity to further validate the clinical usefulness of dorsiflexion resisted walking. Lastly, gait velocity increased significantly (p=0.001) after training with dorsiflexion resisted walking. Because gait velocity is an important contributor to fall risk reduction, this was also an important clinical finding.

Limitations of this pilot study include the small sample size and the fact that our

Table 2. *Comparison of gait velocity and surface electromyography (sEMG) over time (n=10)*

Variable	Pre-Mean (SD)	Minute 1 Mean (SD)	Minute 5 Mean (SD)	Post Mean (SD)	P-Value
Velocity	97.4 (8.8)	91.7 (12.6)*	90.7 (12.7)*	100.7 (9.7)	0.001
sEMG	18.2 (6.3)	24.2 (14.0)**	22.6 (10.1)***	17.1 (6.9)	0.07

**Minute 1 and Minute 5 mean velocities are significantly different than post-mean velocity.*
***24.8% increase between pre-mean sEMG and minute 1 sEMG.*
****19.5% increase between pre-mean sEMG and minute 5 sEMG.*

Figure 1. *Dorsiflexion resistance training device*

subjects were healthy young adults. Therefore, the results cannot be generalized to other populations. Future research will include stroke survivors, which represent the largest number of people in the United States living with long-term disability.[1] Also, even though no pre-measurement rest period was provided, a control group is needed to determine whether the dorsiflexion AROM increases were due to walking itself or the resisted dorsiflexion device. Because ankle dorsiflexion is required for normal foot clearance during the swing limb advancement phase of gait, this impairment contributes to compensatory limb advancement strategies such as circumduction, reduced gait speed, and increased energy consumption compared to the normal gait pattern.[9]

CONCLUSION

The results of this pilot study suggest that dorsiflexion resisted walking is a useful training strategy for increasing ankle dorsiflexion AROM, active muscle recruitment of the TA, and gait velocity in healthy adults. Future studies are warranted with larger sample sizes, longer clinical trials, and subject populations including stroke survivors.

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