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Effects of Homologous instrument assisted mobilization (HIM) on ankle movement, gait-related muscle activation, and plantar pressure distribution in ankle dorsiflexion syndrome: A randomized single control trial

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Abstract.
BACKGROUND: While the limited ankle dorsiflexion syndrome (ADS) is common in neuro-musculoskeletal conditions, the instrument-assisted mobilization focused on the shortened gastro-soleus myofascial structure (IMI) rather than the homologous structure (both gastrosoleus and tibiliais anterior muscles, HIM).
OBJECTIVE: We aimed to compare the immediate therapeutic effects between IMH and IMI treatment groups on the ankle dorsiflexion angle, muscle activation and foot pressure distribution during dynamic gait in ADS.
METHODS: Neuromechanical tests including kinematics (ankle mobility), kinetics (center of pressure distribution), and electromyography were used to determine the immediate therapeutic effects between HIM and IMI treatment groups in 24 participants with ADS.
RESULTS: The ankle joint angle analysis demonstrated a more improved active DF angle in the group who received HIM intervention when compared to the group who received IMI intervention. (11.26% and 3.58%, respectively) EMG analysis showed more decreased mean and peak TA activation amplitudes in the group who received HIM intervention (9.1% and 9%) when compared to the group who received IMI intervention (11.48% and 1.48%). Plantar pressure distribution analysis showed difference that the forefoot/area decreased in the group who received HIM intervention (8.1%), but rather increased in the group who received IMI intervention (14.3%).
CONCLUSIONS: Our neuromechanical results demonstrated promising positive effects on ankle joint mobility, muscle activation and foot pressure distribution during gait in ADS.

Keywords: Limited ankle dorsiflexion syndrome, instrument-assisted mobilization, electromyography

1. Introduction

Limited ankle dorsiflexion syndrome (ADS) is common in both musculoskeletal (e.g., lateral ankle sprain and plantar fasciitis) and neurological conditions (e.g., stroke and spastic diplegia), which alter

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ankle mobility, muscle activation, and foot plantar pressure distribution during dynamic gait. The potential causes of these differential diagnoses and etiologies may involve gastro-soleus muscle shortness or tightness in the musculoskeletal or soft-tissue conditions and spasticity or rigidity in neurological conditions [1]. Among these differential diagnoses, musculoskeletal impairments including gastro-soleus muscle shortness or tightness, plantar fasciitis, and Achilles' tendinopathy are common etiologies [2]. For example, as many as 1 billion female users with high-heeled shoes may experience such gastro-soleus muscle shortness or tightness. Normally, an ankle dorsiflexion (DF) range of motion (ROM) of at least 10° is needed to move the body forward during the stance phase of the gait cycle as the tibia glides forward in a closed chain [3]. However, insufficient ankle DF mobility causes variations in electromyography (EMG) and foot plantar pressure during walking [4]. Shin and his colleagues demonstrated that the peak activity of the tibialis anterior (TA) was higher in individuals with ADS than in normal controls during gait [5]. Kadel and colleagues reported lower gastrocnemius (GCM) activation (20%) in individuals with ADS who wore high-heeled boots during gait [6]. These biomechanical constraints in the ADS affect ankle movement, muscle activation, and foot plantar pressure distribution during dynamic gait in both musculoskeletal and neurological populations, contributing to an increased risk of tripping [7,8].

To address altered ankle mobility, muscle activation, and foot plantar pressure distribution in individuals with ADS, contemporary therapeutic techniques, including active or passive stretching and instrument-assisted mobilization (IMI), have been widely used to increase passive or active ankle DF ROM during static conditions [9,10,11]. However, a review of the current literature failed to produce clinical evidence supporting the therapeutic effects of these techniques during dynamic walking conditions in ADS and reported variable results [12]. Johanson and his colleagues reported that static stretching of the gastrocnemius muscle (GCM) (30 s, 5 times daily for 3 weeks) in individuals with ADS increased the passive ankle DF angle, but there was no difference in GCM activation during walking and no lasting or sustainable effects [10,11,13]. Such inconsistent results may arise from the fact that previous methods or techniques have not addressed the important neuromechanical properties of the *length-tension* relationship, autogenic inhibition, and reciprocal muscle activation [14,15]. Based on this theoretical framework, we developed the HIM technique, which is designed to mitigate muscle *length-tension* relationship by means of applying the deep pressure effulge technique over the shortened GCM-*Achilles'* tendon, while passively or actively moving the ankle into dorsiflexion [11]. Subsequently, restoration of the muscle *length-tension* relationship leads to more normalized muscle activation, which enhances ankle dorsiflexion mobility and plantar pressure distribution [16].

The purpose of this study was to compare the differential effects of HIM and IMI techniques on active ankle DF mobility, EMG ankle muscle activation pattern in the medial GCM, lateral GCM, and TA, and plantar pressure distribution in individuals with ADS. We hypothesized that there would be differences between the HIM and IMI groups in terms of active ankle dorsiflexion and plantar flexion ROM and EMG ankle muscle activation patterns in the medial GCM, lateral GCM, and TA as well as plantar pressure distribution.

2. Method

2.1. Participants

Twenty-four young participants (age 24.77 ± 1.69; male 12, female 11) with ADS were recruited from a local university. All participants provided written informed consent prior to their participation, and the study protocol was approved by the institutional review board of the ethical committee of the

Table 1
Demographic characteristics of the participants ($N = 24$), Mean $\pm$ SD

	HIM group ($n = 12$)	IMI group ($n = 12$)	P value
Age (years)	25.2 $\pm$ 1.95	24.2 $\pm$ 1.44	0.50
Gender (M/F)	6/6	7/5	0.56
Height (cm)	169.7 $\pm$ 11.54	165.5 $\pm$ 10.89	0.12
Weight (kg)	63.0 $\pm$ 15.16	60.9 $\pm$ 12.03	0.37
BMI	22.0 $\pm$ 3.20	20.0 $\pm$ 7.65	0.46

Abbreviations: SD, standard deviation; BMI, body mass index; HIM, homologous (paired tibialis anterior-gastrocnemius), IMI, isolated target gastrocnemius.

university (IRB: 1041849-202305-BM-086-02, 10/07/2023). The inclusion criteria were as follows: (1) aged 21–35 years; (2) $< 10°$ passive ankle dorsiflexion ROM when measured in non–weight bearing with the knee extended; (3) leg length discrepancy of less than 2 cm; (4) no lower extremity injury within 6 months prior to participation in the study; and (5) foot size between 260 and 270 mm or 230 and 240 mm because of the size of the foot insole sensors [4]. Exclusion criteria were as follows: (1) history of ankle trauma or surgery, (2) bone pathology, (3) arthritic or other inflammatory diseases, (4) neurological system dysfunction, or (5) ankle or knee symptoms within 2 weeks prior to participation in the study [17]. The demographic data of the participants are presented in Table 1.

2.2. Research design

A participant-blinded randomized experimental design was used in the present study, in which all participants were randomly assigned to the HIM or IMI group using a random number generator in Microsoft Excel software (Microsoft Excel, Microsoft corporation, USA). To eliminate potential biases resulting from participants' expectations, any experimental information that could influence them was concealed until the completion of the experiment. Both before and after the intervention, the biomechanical measurements including active and passive ankle ROM mobility, muscle activation pattern, and plantar pressure using ImageJ software (National Institutes of Health, Bethesda, MD), EMG, and insole sensor measurements, respectively, which were collected concurrently during self-preferred walking. All assessments and interventions were implemented consistently throughout the experimental procedure. A flowchart of the study is presented in Fig. 1.

2.3. Data collection and procedure

2.3.1. Ankle mobility

Image J was used to determine the *intervention-related* passive and active ankle DF ROM. The participant was positioned lying prone with the knee extended. One of the investigators (S.P.) instructed the participant's ankle DF motion and performed the active DF ROM and the force of passive ankle DF motion was performed by the same investigator. Another investigator (J.Y.) collected camera images of the ankle's lateral side. A camera was positioned 1 m from the sagittal plane of the ankle joint, at the same height and in the same plane as the ankle joint. To reduce distortion, the camera was positioned at a 90° angle on a tripod [18]. The marker was placed at the lateral malleolus, the middle of the lateral side of the fifth metatarsal bone, and the fibular head in the right leg [19]. A mark is consistently made on the same bony landmarks to minimize any potential error associated with the marker placement. The Image J photographic analysis software program was used to analyze the image files. The test was conducted three consecutive times, and the average value of the three readings was recorded as the passive ankle

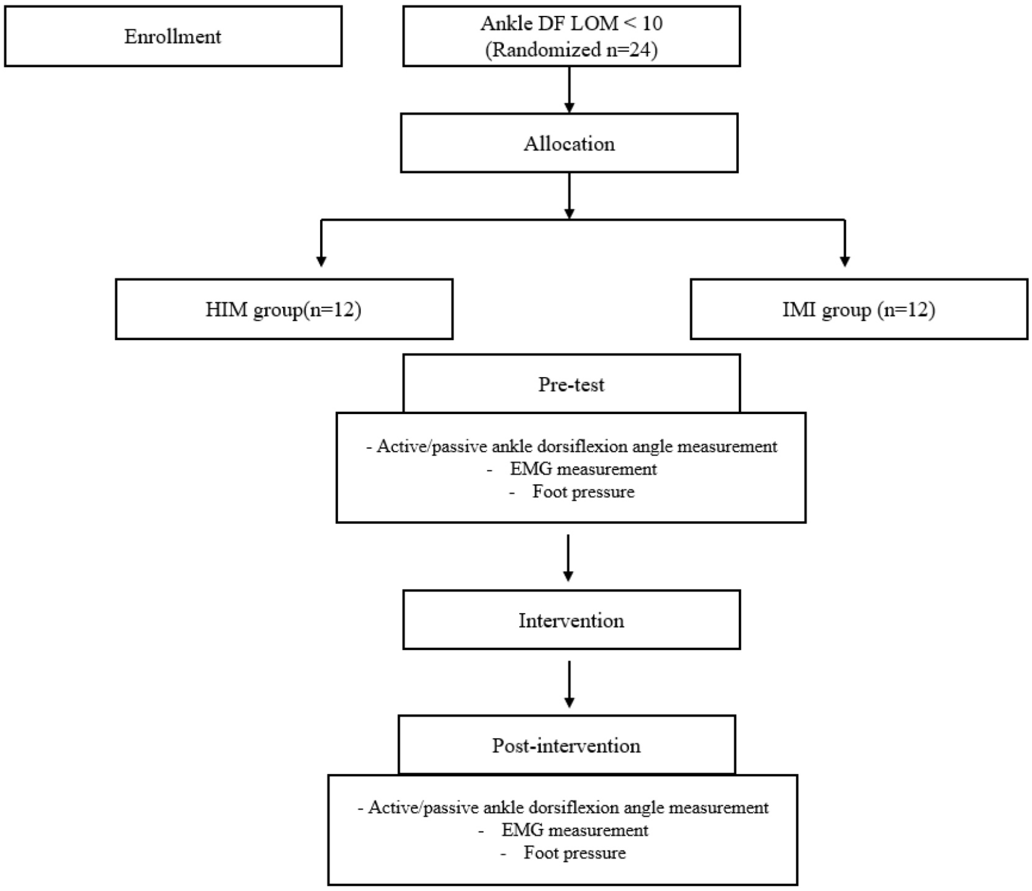

Fig. 1. Flow chart.

dorsiflexion ROM and saved for further statistical analysis [4]. The validity and *test-retest* reliability of the Image J software has been well established elsewhere ($R^2 = 0.976$, $p < 0.01$, Cronbach's alpha = 0.994) [20].

2.3.2. Muscle activation

Surface EMG (MR 3.18, Noraxon USA, Inc., Scottsdale, AZ, USA) was used to determine the muscle activation amplitudes of the medial GCM, lateral GCM, and TA muscles, which were collected simultaneously with the joint angle data during walking trials. The electrodes were attached to the medial GCM, lateral GCM, and TA muscles of the right leg according to the recommendations of SENIAM, and their EMG signals were collected at 2000 Hz using a surface EMG system [21]. The raw EMG signals were *full-wave* rectified, bandpass filtered between 10 and 500 Hz, and smoothed using a *zero-lag* 2nd order Butterworth filter with a cutoff frequency of 6 Hz to obtain a linear envelope of the signals. The processed EMG data for each muscle were normalized to the peak amplitude of the muscle after one minute of walking. The software used in data collection applied a *high-pass* band filter of 10 Hz and a lowpass band filter of 500 Hz as the data were collected. The threshold value of the plantar pressure insole, a device capable of electromyography (EMG) and sinking, was set to 10% for stance phase detection. The stance phase was then extracted and examined. The EMG test was performed three consecutive times,

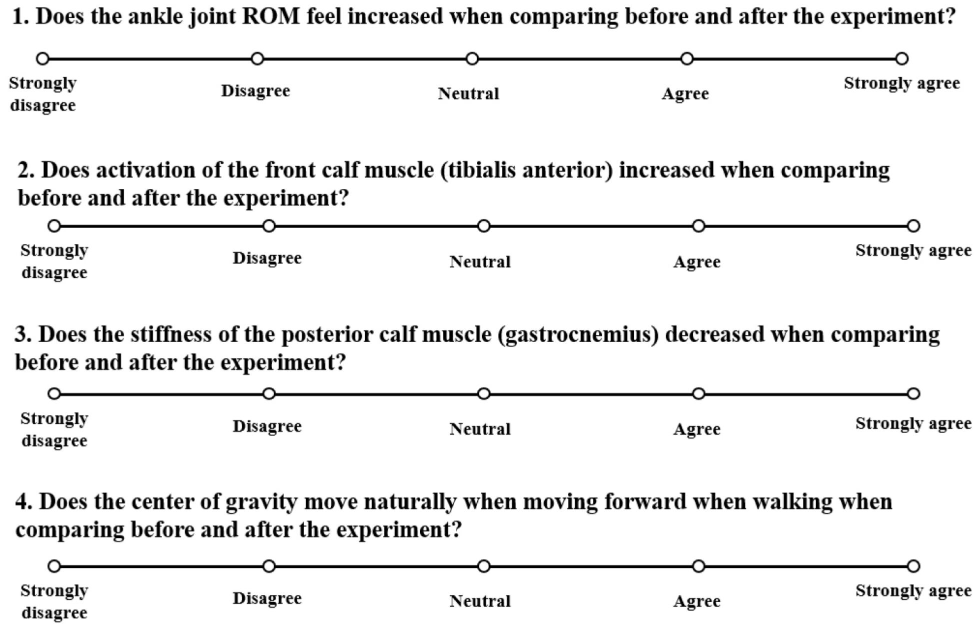

Fig. 2. Post-intervention questionnaire.

and the average value of the three readings was recorded for 10 repeated gait cycles and saved for further statistical analysis.

2.3.3. Plantar pressure distribution

A Noraxon Ultium Insole (SmartLead, Noraxon, Scottsdale, Arizona, USA) was used to determine intervention-related changes in plantar pressure. The participants wore a pair of knitted shoes (Natso Knit Jogging Shoes, Keon Jong, South Korea) equipped with a Noraxon Ultium Insole, and plantar pressure data were collected at a sampling rate of 250/500 Hz Hz. Plantar pressure signals were collected simultaneously with the EMG data during the walking trials. Initially, the Noraxon EMG and Ultium Insole were concurrently calibrated to determine the accurate baseline EMG and plantar pressure distribution before the testing. The acquired plantar pressure distribution was analyzed with the Noraxon EMG and Ultium Insole software. The plantar pressure distribution test was performed three consecutive times, and the average value of the three readings was recorded for 10 repeated gait cycles and saved for further statistical analysis.

2.3.4. Post-intervention questionnaire

The post-intervention questionnaire included four questions related to ankle mobility (Q1), muscle activation (Q2), feeling of stiffness (Q3), and center of pressure (Q4) changes using a Likert scale:1 ('strongly disagree'), 2 ('disagree'), 3 ('neutral'), 4 ('agree'), and 5 ('strongly agree') in Fig. 2.

2.3.5. Intervention

The interventions included (1) HIM and (2) IMI group interventions. All participants were randomly assigned to the HIM or IMI group. Both the experimental and control groups underwent a standardized intervention protocol (30 min/session, one session). In the HIM group, participants were instructed to lie prone on a treatment table with hip and knee extended, and feet in a neutral position at the end of

Fig. 3. Dr. You STM®.

the table. First, the clinician began scanning the GCM muscles using a sweep stroke for 1 min. We then applied the 1–2 Hz low-frequency vibration technique, which is a deep pressure technique for inhibition of the Meissner corpuscle to the medial and lateral GCM. A massage lotion was applied to the target area, whereas the medial and lateral GCM muscles utilized the instrument to apply deep pressure in a proximal-to-distal direction, following the stretching of the muscle from its origin to its insertion (Dr. You STM® in Fig. 3, Seed Tech Cooperation, *Kyong-gi*, Republic of Korea). After the inhibition technique, the TA muscle applies a facilitation technique, which is quick pressure for stimulating the Pacinian corpuscle, from the insertion to the origin (from the proximal to the distal direction of muscular contraction), and participants simultaneously conduct dorsiflexion in Fig. 4. The participants were instructed to provide feedback to the clinician so that they could monitor the treatment intensity and ensure patient comfort. The clinician observed the participant's skin redness and muscle fatigue. If symptoms arose, the intervention was stopped and an ice pack was applied.

For the IMI group intervention, the participants were asked to lie prone on a treatment table with hip extension, knee extension, and feet in a neutral position at the end of the table. A massage lotion was applied to the target myofascial area, whereas the medial and lateral GCM muscles utilized the instrument to apply pressure in a proximal-to-distal direction, following the stretching of the muscle from its origin to its insertion in Fig. 5. The precautions and application methods used during the experiment were the same as those used for the inhibition technique in the HIM group.

2.4. Data analysis

Statistical data were expressed as means and standard deviations. Independent *t-tests* or *chi-square* tests were used to compare baseline clinical characteristics and demographic data between the IMI and HIM groups. A power analysis using G Power software (version 3.1.9.4; Franz Faul, University of Kiel, Germany) was conducted to assess the minimum sample size requirement based on a prior pilot study. Based on a pilot study, the sample size was determined to be 24, and power ($1 - \beta = 0.8$) was based on the effect size from the active angle of ankle DF (eta squared, $\eta 2 = 0.6$). *Two-way* mixed analysis of

Fig. 4. IMI group intervention.

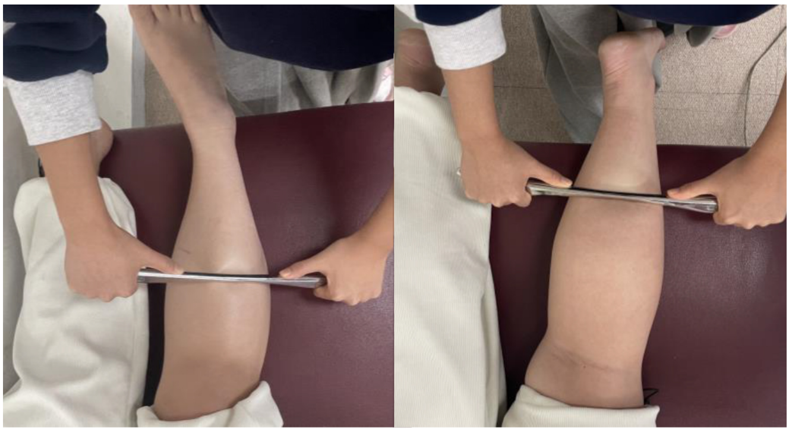

Figure 5-A. HIM group intervention-TA muscle

Figure 5-B. IMI group intervention-GCM muscle

Fig. 5. The lateral and medial GCM muscles were mobilized with the instrument assisted mobilization in the IMI group. The instrument assisted mobilization of the TA muscle was initially performed on the HIM group. And then the GCM muscles, both medial and lateral, are used.

variance (ANOVA) was used to determine any intervention-related significance in ankle mobility (active and passive DF angles), muscle activation (mean TA, peak TA, mean medial GCM, peak medial GCM, mean lateral GCM, and peak lateral GCM), and plantar pressure (pressure per unit area, N/cm^2). Post hoc tests were performed using Tukey's honest significant difference test. *Non-parametric Mann-Whitney* U tests were used to determine satisfaction in the HIM and IMI groups. All continuous variables were analyzed using the Shapiro–Wilk test, assuming forefoot: hindfoot ratio, pressure/area of the forefoot, and hindfoot pressure between groups. For each outcome measure for which sufficient data were supplied, we calculated Cohen's d effect sizes. Cohen's d indicates the effect size, which can be classified as small (0.2), medium (0.5), or large (0.8 and higher). SPSS for Windows (version 26.0, SPSS, Chicago, IL, USA) was used for the statistical analyses. The p-values were set at 0.05.

Table 2
Post-intervention angle and muscle activation outcome analysis, Mean ± SD

	HIM group		IMI group		p-value			
	Pre-test	Post-test	Pre-test	Post-test	Time effect	Betwen groups	Time x group	Time effect
Active DF angle	86.96 ± 10.82	77.16 ± 6.94	80.42 ± 7.16	80.9 ± 5.89	0.048	0.543	0.03*	0.062
Passive DF angle	86.96 ± 8.63	83.87 ± 9.56	87.53 ± 9.53	83.35 ± 6.94	0.002*	0.070	0.105	0.581
Mean TA	34.41 ± 6.2	31.28 ± 6.39	39.81 ± 7.52	35.09 ± 8.44	0.066	0.032*	0.704	0.509
Peak TA	73.84 ± 7.91	66.83 ± 12.59	76.35 ± 5.65	75.22 ± 12.24	0.167	0.067	0.316	0.676
Mean medial GCM	38.24 ± 8.85	38.82 ± 8.21	40.81 ± 6.92	42.99 ± 5.93	0.531	0.130	0.715	0.582
Peak medial GCM	53.75 ± 12.62	54.13 ± 10.07	63.2 ± 10.56	65.41 ± 10.98	0.687	0.002*	0.777	0.108
Mean lateral GCM	27.35 ± 5.16	29.91 ± 6.06	19.53 ± 3.97	21.92 ± 8.78	0.178	0.000**	0.965	1.059
Peak lateral GCM	37.85 ± 7.11	41.81 ± 6.93	29.54 ± 5.86	30.94 ± 8.25	0.198	0.000**	0.533	1.427

Abbreviations: SD, standard deviation; TA, tibialis anterior; GCM, gastrocnemius; HIM, homologous (paired tibialis anterior gastrocnemius); IMI, isolated target gastrocnemius. * $p < 0.05$, ** $p < 0.001$.

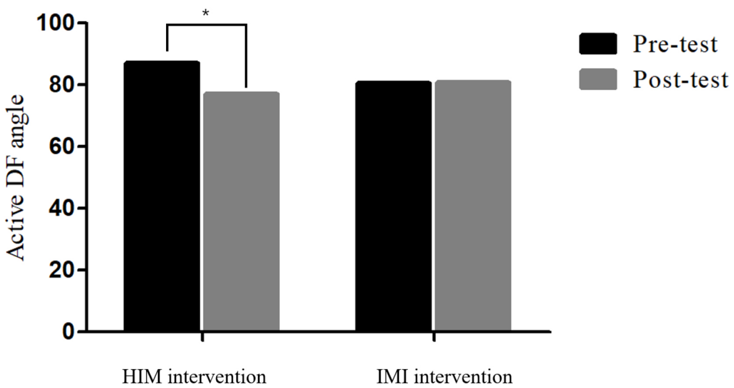

Fig. 6. Active ankle DF mobility data between HIM and IMI groups. Two-way ANOVA was performed at $P < 0.05$. A significant improvement in ankle DF angle was noted in the HIM intervention whereas no significant intervention-related change was observed.

3. Results

Baseline demographic data, including age, gender, height, weight, and BMI did not differ between the groups.

3.1. Ankle joint mobility data

Two-way mixed ANOVA showed a significant time × group interaction ($p = 0.030$) and a time main effect in the active DF angle data. Post hoc analysis confirmed that the relative changes in the active DF angle data were identified *pre- and post-analysis* ($p = 0.0048$) (Table 2). Post hoc analysis revealed that the relative changes in post-passive DF angle data increased in the HIM group. The intervention-related angle data support the potential biomechanical mechanism of the *length-tension* relationship of the *GCM-Achilles* tendon structure; a representative illustration of this mechanism is presented in Fig. 6.

3.2. EMG Muscle activation

Two-way mixed ANOVA showed no significant time × group interaction effect or time main effect, but a group main effect was observed in the mean TA activation data ($p = 0.001$) (Table 2). Post hoc analysis

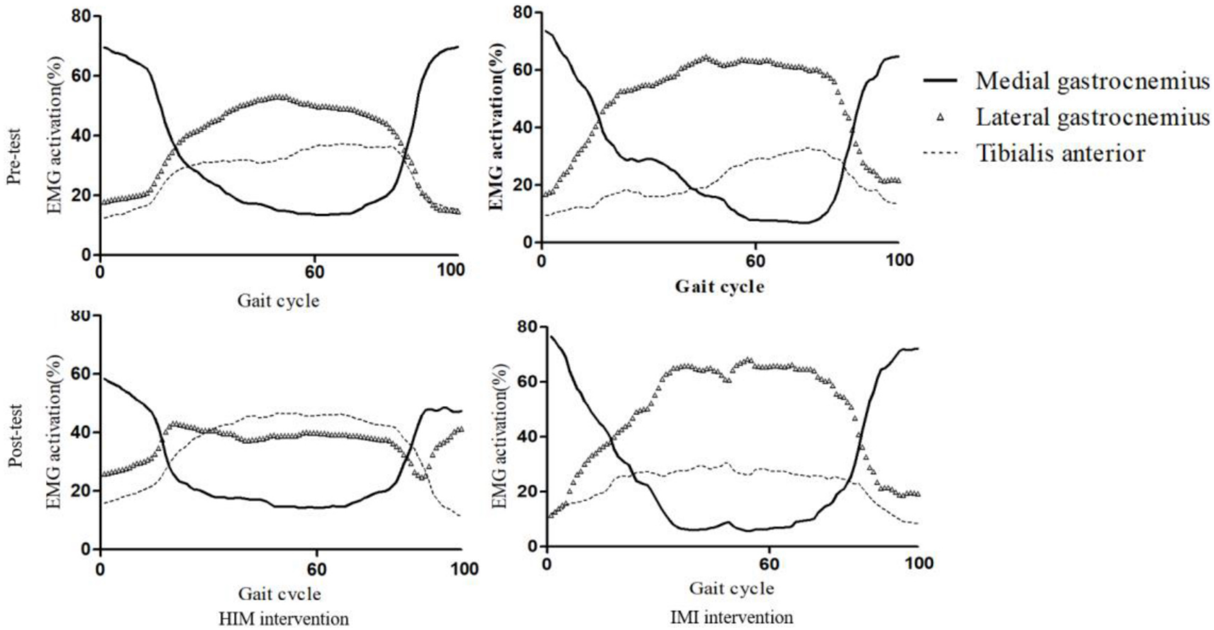

Fig. 7. Pre- and Post-test EMG amplitude data. Two-way ANOVA was performed at $P < 0.05$. A significant improvement in TA, EMG activation was noted in the HIM intervention whereas no significant intervention-related change was observed.

confirmed that mean TA activation was significantly greater in the IMI group than in the HIM group ($p = 0.032$). The peak medial GCM showed significant differences between the groups ($p = 0.002$). Post hoc analysis showed that the peak medial GCM data were significantly lower in the HIM group than in the IMI group. The lateral GCM peak value was significantly different between the groups ($p = 0.000$). Post hoc analysis demonstrated that the mean and peak lateral GCM amplitude data were lower in the IMI than in the HIM group. These EMG data demonstrated autogenic inhibition of the GCM and reciprocal facilitation of the TA mechanism. Its representative neurophysiological mechanisms are illustrated in Fig. 7.

3.3. Plantar pressure

The *two-way* mixed ANOVA showed significant differences in the time × group interaction effect, but a time and group main effect was not observed in the forefoot pressure/area (N/cm^2) or forefoot:hindfoot ratio ($p < 0.048$) (Table 3). Post hoc analysis confirmed that the hindfoot pressure/area (N/cm^2) was significantly greater in the HIM group than in the IMI group ($p = 0.006$).

3.4. Post-intervention questionnaire

Q2, Q3, and Q4 showed significant differences between the groups ($p < 0.039$). In general, the HIM group's satisfaction with the intervention was higher than that of the IMI group in Table 4.

4. Discussion

The present study aimed to highlight the differential effects of IMI and HIM on the ankle DF angle and EMG amplitude of the GCM and TA during gait in individuals with ADS. As anticipated, the HIM

Table 3
Post-intervention foot pressure outcome analysis, Mean ± SD

	HIM group		IMI group		p-value			
	Pre-test	Post-test	Pre-test	Post-test	Time effect	Between groups	Time x group	Effect size
Forefoot:hindfoot ratio	20.43 ± 1.02	18.78 ± 1.07	18.19 ± 1.02	21.91 ± 1.07	0.057	0.752	0.000**	2.925
Hindfoot/area (N/cm^2)	16.67 ± 1.76	16.67 ± 0.64	22.96 ± 1.76	19.97 ± 0.64	0.144	0.006*	0.144	5.156
Forefoot/area(N/cm^2)	1.24 ± 0.34	0.92 ± 0.38	1.18 ± 0.44	1.14 ± 0.31	0.286	0.128	0.048*	0.634

Abbreviations: SD, standard deviation; TA, tibialis anterior; GCM, gastrocnemius; HIM, homologous (paired tibialis anterior gastrocnemius); IMI, isolated target gastrocnemius. * $p < 0.05$, **$p < 0.001$.

Table 4
Post-intervention questionnaire analysis

Q1	Q2	Q3	Q4
0.463	0.00**	0.039*	0.00**

$^{*}p < 0.05$, $^{**}p < 0.000$.

group showed greater improvements in ankle DF mobility and muscle activation amplitudes than the IMI group. Most importantly, ankle DF mobility was more substantially enhanced in the group that received HIM than in the group that received IMI, supporting the important neuromechanisms including the length-tension relationship of the GCM-Achilles tendon structure, the reciprocal facilitation of GCM, and autogenic inhibition of the TA mechanism [22]. It is difficult to compare our present data with previous findings because of the limited evidence in the current literature.

Ankle joint angle analysis demonstrated a more improved active DF angle in the group that received HIM than in the group that received IMI, but the passive ankle DF that remained between the groups was not significant. Our findings are similar to those of earlier studies that examined the effect of IM on ankle DF in ADS. Lee and his colleagues reported an increase of 6.5% in active or passive DF after the application of IMI by Dr. YouSTM [11]. Lee and his colleagues also reported an 18.9% increase in active DF after GCM stretching and TA strengthening exercises; however, passive DF mobility did not differ [9]. The active and passive DF mobilities improved by 11.26% and 3.58%, respectively. Such enhanced passive DF movement may be related to the normalized length-tension relationship via muscle structural remodeling, which would normalize the overextended TA and shortening or tightness of the GCM muscle.

EMG analysis showed decreased mean and peak TA activation amplitudes in the HIM group (9.1% and 9%, respectively) compared with the IMI group (11.48% and 1.48%, respectively). The peak lateral GCM activation amplitudes were higher in the HIM group (8.6%) than in the IMI group (4.5%). The present findings were compatible with previous EMG evidence showing 23.8% increased TA MVIC (%) EMG activation as a result of five trials × 30 s of static stretching and 10 min of TA strengthening exercise in ADS [9]. Such improvements in EMG activation may have contributed to the normalization of connective tissue morphology and associated muscle activation by dissolving or remodeling the underlying adhesion inside the muscular fascicle, thereby resulting in a more successful treatment in individuals with ADS than IMI alone. Another possible neurophysiological mechanism is that the deep firm pressure on the TA (Pacinian corpuscles) and the quick, sweeping cutaneous stimuli via the YOUSTM effulge technique on the GCM (Meissner corpuscles) may have facilitated the Ia fiber and type IIb of the afferent sensory fibers, which subsequently augmented the α-/r-motor neurons of the GCM muscle spindles.

Plantar pressure distribution analysis revealed meaningful changes in the forefoot/area (N/cm^2) in the group that received HIM (−8.1%) but increased in the group that received IMI (+14.3%). The present results are consistent with Yoon and his colleagues' plantar pressure analysis study, which examined the effect of talus posterior glide taping in adults with ADS and observed plantar pressure improvements in the passive ankle DF angle (3.6%), hindfoot pressure by +9.4%, and forefoot pressure by −3.3% [4]. Perhaps IM may have restored the inherent biomechanical constraints, including limited ankle dorsiflexion and compensatory overpressure on the forefoot, thereby redistributing the hindfoot pressure, causing weight bearing in the hindfoot to decrease and relatively increased weight bearing on the forefoot during gait [23]. Repetitive inappropriate pressure balance on the forefoot and hindfoot may cause various pathologies; thus, appropriate distribution of plantar pressure during walking is important in preventing overuse injuries of the lower extremities [8]. Moreover, the current intervention may be beneficial for an altered heel-toe gait pattern typical of idiopathic toe walking (ITW) as characterized by plantar-dorsiflexion angular excursion, diminished or absent heel rocker (23.9% less than normally developing children), and the presence of excessive forefoot rocker (11.9% more than normally developing children) patterns. Nevertheless, further studies are warranted to ascertain the efficacy of this technique for ADS resulting from ITW and PD [23].

Post-intervention questionnaire analysis showed that 46.2% of the participants in the HIM group reported increased ankle mobility compared with those in the IMI group (10%). Participants in the HIM group reported being more satisfied than those in the IMI group, relieving GCM tightness by 10.3%. In addition, the natural movement of the foot (hindfoot to forefoot) query was higher in the HIM group than in the IMI group (37.9%). The positive plantar pressure distribution changes from the forefoot to the hindfoot were perceived by 83% and 33.3% of the participants in the HIM and IMI groups, respectively. Possibly IM may have released GCM tightness and enhanced TA contraction increasing ankle DF mobility contributed to the normalized transfer of plantar pressure from the hindfoot to the forefoot during dynamic gait conditions.

This study had several limitations. One limitation is that our preliminary cross-sectional study could not determine the long-term effects of selective muscle release and facilitation techniques. The second limitation is that while we observed that the data sets didn't differ from normal distribution and effect size was relatively high for angle, EMG activation, and pressure, our results should be interpreted carefully due to sample size. Another limitation is that the present study inclusively examined asymptomatic participants with limited ankle DF; hence, a careful interpretation should be made when applying our empirical evidence to musculoskeletal (e.g., lateral ankle sprain and plantar fasciitis) and neurological conditions (e.g., ITW, PD, stroke, and spastic diplegia). Additional studies are necessary to determine the mechanisms responsible for the decrease in muscular performance following stretching [9].

5. Conclusion

Our study demonstrated that HIM was more effective than IMI in improving ankle mobility, lowering muscle activation, and plantar pressure distribution in individuals with ADS. These results provide evidence-based clinical insights into the utilization of HIM intervention in ADS rehabilitation to maximize the recovery of ankle mobility, muscle activation, and plantar pressure in individuals with ADS.

Acknowledgments

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Conflict of interest

None to report.

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