Does Short Foot Exercise Combined with Breathing Exercise Increase Muscular Activity in Individuals with Pes Planus?

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Background: Improvements in muscle oxygenation and exercise posture can significantly impact muscle contraction. The aim of this study was to compare the effects of combined breathing and exercise posture (sitting or standing) on the muscle activity of the foot and ankle during short foot exercises (SFE) in individuals with pes planus.

Methods: The study included 15 subjects aged 21.53 ± 1.06 years, diagnosed with pes planus. Short foot exercises were performed with and without breathing exercises (BE) in sitting and standing positions. Surface electromyography was used to measure the activity of the tibialis anterior (TA), peroneus longus (PL), and abductor hallucis longus (ABDH) muscles during four different SFE. Four-way repeated analyses of variance were used to assess the addition of BE to SFE and muscle activities of the foot and ankle.

Results: Muscle activity in the TA, PL, and ABDH was significantly higher in the SFE with BE than without BE in the standing position than in the sitting position. The SFE performed with BE when standing significantly increased the ABDH and ankle muscle activity compared to without BE.

Conclusions: SFE with BE may represent a new strengthening program for ABDH and PL foot muscles in rehabilitation programs for individuals with pes planus. (J Am Podiatr Med Assoc 114(3), 2024; doi:10.7547/22-229)

Pes planus is seen in adults at a rate of 4% to 23%.[1-3] The most important problem associated with pes planus is excessive pronation of the foot when standing and during ambulation.[1] Pes planus is associated with impaired load distribution in gait, excessive stress in the foot and ankle joints, compressive shear forces in the knee joint, and internal rotation in the hip joint.[4-6] As a result, it has been stated that tension develops in the plantar structures of the feet and affects the intrinsic muscles.[5,7]

It has been shown that one of the important structures supporting the medial longitudinal arch (MLA) and medial stability of the foot is the tibialis anterior (TA) muscle.[7] There are studies emphasizing that the peroneus longus (PL) muscle stabilizes the MLA and supports eversion and pronation during gait, thereby providing stability of the lower ankle joint and slowing down the inversion movement of the hindfoot.[4,6,8] The abductor hallucis (ABDH) muscle has been shown to play an anatomical role in the abduction of the big toe, supination of the flexor and first metatarsal, inversion of the calcaneus, and elevation of the MLA.[2] In a previous study, it was reported that ABDH activity was higher during short foot exercises with isometric hip abduction, and TA compensatory activity was lower.[1] Headlee et al[9] emphasized that ABDH fatigue increased the lowering of the MLA. Jung et al[2] showed that that there was less ABDH

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activity in patients with flatfoot and ABDH activity was higher during short foot exercises (SFE) than in toe curl exercise in supporting the MLA and controlling pronation during gait.

It has been stated that short foot exercise is one of the exercise groups that are frequently used in individuals with pes planus and is especially preferred for intrinsic foot muscle strengthening.[4,10] It has been shown in literature that foot-shortening exercises have positive effects on navicular height, foot pronation, foot pain, and plantar strength.[4] There is known to be oxygen consumption from the body during muscle contraction. Therefore, it has been shown in the literature that muscle oxygenation is better, and the performance of the individual is better in an exercise program where exercises are combined with breathing exercises.[10-12]

Breathing exercises have been reported to provide focus on the activity, decrease stress levels and fatigue,[13] provide the organs with oxygen, and maintain the required pH for the body during low intensity activities.[14] Tomas-Carus et al[13] stated that breathing exercises improve functional capacity and decrease fatigue. To the best of our knowledge, there is no previous study that has determined whether breathing exercises (BE) with SFE can activate the ABDH, TA, and PL muscles and change the height of the MLA.

There is a limited number of studies in the literature that have evaluated the effects of exercises and combined foot exercises on the activation of the muscles around the feet.[1,15-17] Choi et al[1] stated that SFE in sitting and standing positions, both with and without isometric hip abduction, reduced TA and increased ABDH muscle activity. Lee et al[15] found that ABDH muscle activity was lower and the ratio of TA to ABDH activity was higher in a pes planus group during sitting SFE. Kim and Moon[16] recommended focusing on the strengthening exercises of the ABDH muscle because of reduced activation of the ABDH muscle in individuals with pes planus. Therefore, it can be considered important to determine both whether the effectiveness of this exercise increases together with BE, and in which position it is more effective. The aim of this study was to compare the effects of combined BE and exercise posture (sitting or standing) on the muscle activity of the ABDH, TA, and PL during SFE in individuals with pes planus. It was hypothesized that during SFE with BE, the TA, PL, and ABDH muscle activities would be greater than during SFE without BE. It was also hypothesized that there would be a difference in muscle activities depending on the exercise position (sitting or standing) during SFE, with or without BE.

Methods

Study Design

This study was based on repeated analysis under different conditions. The surface electromyography (EMG) activity of ABDH, TA, and PL muscles was measured during SFE performed sitting and standing, with and without BE, in individuals with pes planus.

Study Participants

There were two within-subject factors (factor 1, with and without BE; and factor 2, sitting and standing position) in this study. The effect size from a pilot study of five participants based on the primary variable ABDH was calculated as $f^2 = 3.98$ (Eta squared, 0.89 for interaction).[17] A power analysis was performed using the R package *pwr*,[18] and the minimum sample size was determined as nine participants to achieve a power of 0.80, an effect size of 1.00, and an alpha level of 0.05. The study was completed with 15 participants based on literature results obtained from a pilot study of six participants ($P = .369$).[1]

The study included 15 young adults with pes planus who participated voluntarily. To confirm the diagnosis of pes planus, the navicular drop test was used to measure the amount of pronation in the foot. The navicular height measured while standing with the weight on the foot is subtracted from the navicular height measured in the sitting position without placing weight on the foot. Only subjects with a mean navicular drop greater than 10 mm were invited to participate in this study.[19]

The study inclusion criteria were defined as age 18 years or older, voluntary participation in the study, and a diagnosis of pes planus. Exclusion criteria were defined as a history of any lower extremity surgery; any orthopedic, neurologic, or systemic problems that may affect the lower extremity and balance; congenital shortness of the lower extremities; or any visual impairment. Before the study, all the participants were given a thorough explanation of the procedures, and all provided informed consent and completed a personal data form. The study was approved by the Ethics Committee of University of Health Science Turkey (registration number 2021/366) and was conducted in accordance with the Declaration of Helsinki, and was registered in the ClinicalTrials.gov Protocol Registration and Results System website (clinical trial number NCT05128526).

Procedures

In the SFE, the subjects were seated on the floor with their feet in the subtalar neutral position and were then instructed to raise the medial foot and hold it in this position for 5 seconds, trying to bring the heel and toes closer together. The subjects were told to not bend their toes during the exercise to avoid contracting the long flexor muscles of the toes, and they were instructed to perform three repetitions. The SFE was demonstrated by an experienced physiotherapist, with and without the BE, for approximately 30 minutes before the measurements to familiarize the participants with the program. The increase in ABDH muscle activity was monitored during the familiarization session to confirm correct performance of the SFE. After 5 minutes of rest, the subjects repeated the same exercise combined with BE. When the practice was finished, they were told to return to the starting position.

According to the literature, the SFE is performed routinely during sitting and standing postures.[1,2] These positions were chosen because of the similar weightbearing on the foot. The four types of SFE were performed in random order assigned using Microsoft Excel (Microsoft Corp, Redmond, Washington). The SFE protocol was performed in four different ways, SFE without BE in the sitting position (A), SFE with BE in the sitting position (B), SFE without BE in the standing position (C), and SFE with BE in the standing position (D). To ensure randomization of the measurements, the protocol was applied in a different order for each participant: A-B-C-D, C-B-A-D, B-C-A-D, and A-C-B-D.

To evaluate the quality of the SFE, the MLA images were recorded on videotape at 60 Hz, then transferred to a personal computer (model HP 15-dw4008nt; HP, Seoul, Republic of Korea). Noraxon video motion-analysis software (version 3.16; Noraxon Inc, Scottsdale, Arizona) was used to measure the MLA angle on the digital images taken during the SFE and resting state. The researcher set the point based on the three reflective markers of the digital image (the navicular tuberosity, the medial aspect of the first metatarsal head, and the medial side of the calcaneal bone), and the MLA angle was calculated using video motion-analysis software.[1,2,15]

BE

The subjects were instructed to place their hand on their abdomen, and were then taught to expand their abdomen during nasal inhalation and exhalation from the mouth. The participants were seated comfortably on a chair with back support. An explanation was given of the measurement procedures, and the correct performance of the BE and SFE was confirmed.[20] The participants were then instructed to perform both SFE and the BE together in time with metronome beats set by the therapist.

SFE without BE in the Sitting Position. The subjects were seated on a chair with the height adjusted so that the hips and knees were at approximately 90° with the feet placed flat on the floor on a mat. The width between both feet was specified to be equal to the pelvic width by the therapist. Each second toe and patellar bone was aligned to maintain a constant leg position during the SFE. The participant was instructed to sit correctly, keeping the spine upright and the pelvis neutral during the measurements. The participants were shown how to pull the first metatarsal head toward the heel to shorten the foot. The therapist checked that the toes were not bent, and the feet maintained contact with the mat.[1,16]

SFE with BE in the Sitting Position. For the SFE with BE, the same seated starting position was taken. A breathing exercise was taught to the subjects before starting the exercises. To fully expand the lungs, the BE involved slowly exhaling through the mouth and then rapidly inhaling through the nose. The air was then promptly exhaled through the mouth, using the abdominal muscles and diaphragm to the greatest extent feasible. The participants were then instructed to exercise in time with metronome beats given by the therapist.[16,20]

SFE without BE in the Standing Position. The subject was positioned standing with the distance between the feet equal to the width of the pelvis and the second toe aligned with the patella. During the SFE, the participant was instructed to keep the spine straight, the pelvis neutral, and the midline of the body midway between the feet. The therapist provided verbal feedback to help the subject maintain proper body alignment. The participants were instructed to complete the SFE for 10 seconds using a metronome.[1]

SFE with BE in the Standing Position. The starting position of the SFE with BE in the standing position was the same as the starting position of the SFE alone in the standing position, with the addition of a breathing exercise with a metronome applied for 10 seconds.[1,4]

Surface EMG Data Collection

A wireless Noraxon Ultium EMG sensor system (Noraxon) was used to record the EMG activity of the TA, PL, and ABDH muscles during the variations of SFE. The sample rate for data collection was 4,000 Hz. The device had a common mode rejection ratio of less than –100 dB, gain was set at 1,000 (signal-to-noise ratio $<1\ \mu V$ root mean square), and the input impedance was $>100\ m\Omega$. For all the subjects, bipolar silver/silver chloride surface electrodes were placed at an interelectrode distance of 2 cm by the same examiner. The sampling rate for EMG data was 1,000 Hz. Synchronized video capture with a frame rate of 60 frames per second (Webcam C922 Pro stream; Logitech International SA, Lausanne, Switzerland) was used to determine the reach and return phases of the SFE.

The electrode attachment sites were shaved, scrubbed, and cleansed with alcohol. The placement of electrodes for each muscle was made according to the Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles.[21,22] The following is a detailed explanation of the electrode attachment areas. The TA electrodes were placed one-third of the way between the tip of the fibula and the medial malleolus (Fig. 1A). The PL electrodes were positioned at a 25% angle on the line between the fibula head and the lateral malleolus tip (Fig. 1B). The ABDH EMG electrodes were placed 1 to 2 cm posterior to the navicular tuberosity, slightly in front of the vertical line drawn from the anterior border of the medial malleolus (Fig. 1C).

The maximal voluntary isometric contractions (MVIC) of the TA, PL, and ABDH muscles were measured in a randomized order in the first half of the study. The MVIC of each muscle was measured through standard manual muscle testing positions.[23] The researcher used resistance on the medial side of the first metatarsal and the proximal phalanx to create abduction of the metatarsophalangeal joint of the great toe to quantify the MVIC of the ABDH muscle. The subject was instructed to adduct the hallux and forefoot against the imposed resistance.

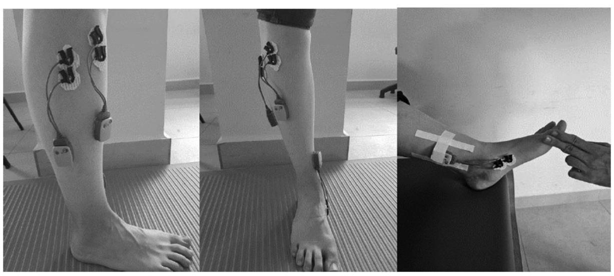

Figure 1. Surface electromyographic electrode placement in the peroneus longus (left image) and tibialis anterior (middle image). Maximal voluntary isometric contractions measurement of the abductor hallucis muscle (right image).

The subject performed maximal ankle dorsiflexion against resistance provided to the dorsomedial side of the foot to assess the MVIC of the TA. The MVIC of the PL was measured by performing ankle eversion and plantar flexion against resistance supplied to the lateral and plantar surfaces of the foot.

The EMG data were recorded for 5 seconds, and three trials were conducted with 30 seconds of rest between contractions, all of which were timed using a metronome (60/min). The EMG data obtained during the exercises was normalized using the average value of the three MVIC trials. In all subjects, the same investigator provided resistance and verbally encouraged the individuals in a consistent manner. The subjects were given a 1-minute break between MVIC measures to reduce the effect of fatigue. Muscle activity was recorded during all exercises for an equal amount of time (10 sec). The collected EMG data of the TA, PL, and ABDH muscle activity during the SFE were described as %MVIC. The average of the trials, expressed as a percentage of MVIC, was used for statistical analysis (Fig. 2).

The data were processed using the Noraxon MyoResearch XP program (version 3.16). The sample rate was set at 1,000 Hz, and the highpass Butterworth filter was set at 20 Hz. Root mean square values were calculated using a moving 100-ms window. Raw EMG signals were rectified, smoothed, and ECG reducted. The study classified muscle activity as absent to minimal at 0% to 15%, low at 16% to 30%, moderate at 31% to 60%, and high at greater than 60%.[24]

Statistical Analysis

The statistical analysis was conducted with R language[25] in R Studio 2022.02.3. The level of statistical significance was accepted as $P < .05$. Quantitative and qualitative variables were summarized as mean $\pm$ standard deviation values, and number and percentage, respectively. The intraclass correlation coefficient (ICC) (two-way mixed effects, the mean of multiple measurements, absolute agreement) and the standard error of measurements (SEM) were used to determine the intrarater reliability of the %MVIC measurements. The SEM was calculated from the square root of the mean square error term in a repeated-measures analysis of variance to determine the amount of variability caused by measurement error. Based on the 95% confidence interval of the ICC estimate, values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 were indicative of poor, moderate, good, and excellent reliability, respectively.[26] The

Figure 2. Medial longitudinal arch angle measurement.

two-way repeated analysis of variance with two within factors was performed to determine the main and interaction effects on TA, PL, and ABDH muscle activity. When the interaction effect was significant, the simple effect was evaluated as a pair-wise comparison with Bonferroni correction. The main effects of within factors were determined when the interaction effect was not significant.

To obtain the intrarater reliability of the muscle activity measurements, the interclass coefficients (ICC and SEM values) and two-way repeated-measures ANOVA results with two within factors, the rel[27] and stats[25] R packages were used, respectively. The graph presentation was constructed with ggplot2[28] and ggpubr R packages.[29]

Results

Evaluation was made of a total of 15 subjects with pes planus, comprising 11 (73.3%) women and four (26.7%) men with an average age of 21.53 ± 1.06 years and body mass index of 20.93 ± 2.11 kg/m^2. The right side was dominant in 46.7% of the patients (n = 7).

The muscle activity of TA, PL, and ABDH was measured during SFE while sitting and standing with and without BE. The measurement of the muscle activity of each muscle showed high intrarater reliability in each position. The ICC values based on the 95% CI are summarized in Table 1.

The mean of the muscle activity measurements of ABDH, TA, and PL was used to compare the results obtained during all types of SFE. There was no significant interaction (position × breathing) in terms of the muscle activity of the TA ($F_{1,14} = 3.98$; $P = .066$; partial $\eta^2 = 0.22$), and PL ($F_{1,14} = 0.22$; $P = .646$; partial $\eta^2 = 0.02$). The muscle activity of the ABDH showed a significant interaction effect ($F_{1,14} = 38.09$; $P < .001$; partial $\eta^2 = 0.73$).

The TA activity was a significant main effect of the exercise position ($F_{1,14} = 59.69$; $P < .001$; partial $\eta^2 = 0.81$) and breathing exercises ($F_{1,14} = 84.88$; $P < .001$; partial $\eta^2 = 0.86$). The muscle activity of TA was significantly increased with BE compared to without BE (mean difference, 7.57) (Fig. 3). Similarly, the muscle activity of TA was greater in

Table 1. Intrarater Reliability and Standard Error of Measurements

	Muscle		
Measurement	TA	PL	ABDH
MVIC			
ICC	0.997	0.998	0.976
95% CI	0.992–0.999	0.995–0.999	0.943–0.991
SEM	1.99	1.41	3.29
% MVIC during			
SFE-S			
ICC	0.993	0.987	0.994
95% CI	0.979–0.997	0.963–0.996	0.982–0.998
SEM	0.65	0.89	0.87
SFE-BES			
ICC	0.972	0.992	0.992
95% CI	0.918–0.991	0.968–0.997	0.969–0.998
SEM	1.47	0.76	0.86
SFE-St			
ICC	0.895	0.98	0.994
95% CI	0.695–0.964	0.933–0.994	0.983–0.998
SEM	1.75	0.84	0.95
SFE-BESt			
ICC	0.984	0.992	0.996
95% CI	0.952–0.995	0.975–0.997	0.988–0.999
SEM	1.15	0.78	0.68

Abbreviations: ABDH, abductor hallucis; CI, confidence interval; $ICC_{3,k}$, intraclass correlation coefficient (two-way mixed effects, the mean of multiple measurements [absolute agreement, >0.90 indicates excellent agreement]); PL, peroneus longus; (%)MVIC, percentage of maximal voluntary isometric contraction; SEM, standard error of measurements; SFE-BES, short foot exercises with breathing exercises in the sitting position; SFE-BESt, short foot exercises with breathing exercises in the standing position; SFE-S, short foot exercises without breathing exercises in the sitting position; SFE-St, short foot exercises without breathing exercises in the standing position; TA, tibialis anterior.

the standing position than in the sitting position (mean difference, 8.29) (Fig. 3B).

The PL activity was a significant main effect of the exercise position ($F_{1,14} = 73.49$; $P < .001$; partial $\eta^2 = 0.84$) and breathing exercises ($F_{1,14} = 71.35$; $P < .001$; partial $\eta^2 = 0.84$). The PL activity was significantly greater with BE than without BE (mean difference, 5.51) (Fig. 4A). The muscle activity of PL was significantly greater in the standing position than in the sitting position (mean difference, 7.55) (Fig. 4B).

For the ABDH muscle activity, the simple effect of the position in each breathing exercise situation is summarized in Figure 5. The ABDH muscle activity was significantly increased in the standing position during the SFE without breathing exercises compared with the sitting position during the SFE without breathing exercises (mean difference, 10.70; effect size d, 1.73; $P < .001$). A significant difference was determined between standing and sitting positions during the SFE with breathing exercises according to ABDH activity values (mean difference, 23.14; effect size d, 2.64; $P < .001$).

For the ABDH muscle activity, the simple effect of the breathing exercise situation in each position is summarized in Figure 6. The muscle activity of ABDH was significantly greater during the SFE with BE in the sitting position than during the SFE without BE in the sitting position (mean difference, 5.86; effect size d, 1.16; $P = .001$). The ABDH activity was significantly increased during the SFE with BE in the standing position compared with during the SFE without breathing exercises in the standing position (mean difference, 18.30; effect size d, 2.75; $P < .001$).

Discussion

Short foot exercise has been described for sport and rehabilitation areas to strengthen the foot intrinsic muscles at different postures in pes planus. Breathing exercises have been used for protection from disease and to improve quality of life, health, and energy balance during the warm-up and cool-down parts of exercise programs.[30] The results of this study showed that the muscle activity of ABDH, TA, and PL is increased in the standing position with BE compared with the sitting position and without BE. This study demonstrates the effects of SFE in different postures on foot and ankle muscle activations. To the best of our knowledge, this is the first study to have shown the effects of SFE on the muscle activities of ABDH, TA, and PL with and without BE.

Short foot exercise has been especially preferred for strengthening intrinsic foot muscles. The effectiveness of SFE in preventing elevation of the MLA has been shown in several studies of individuals

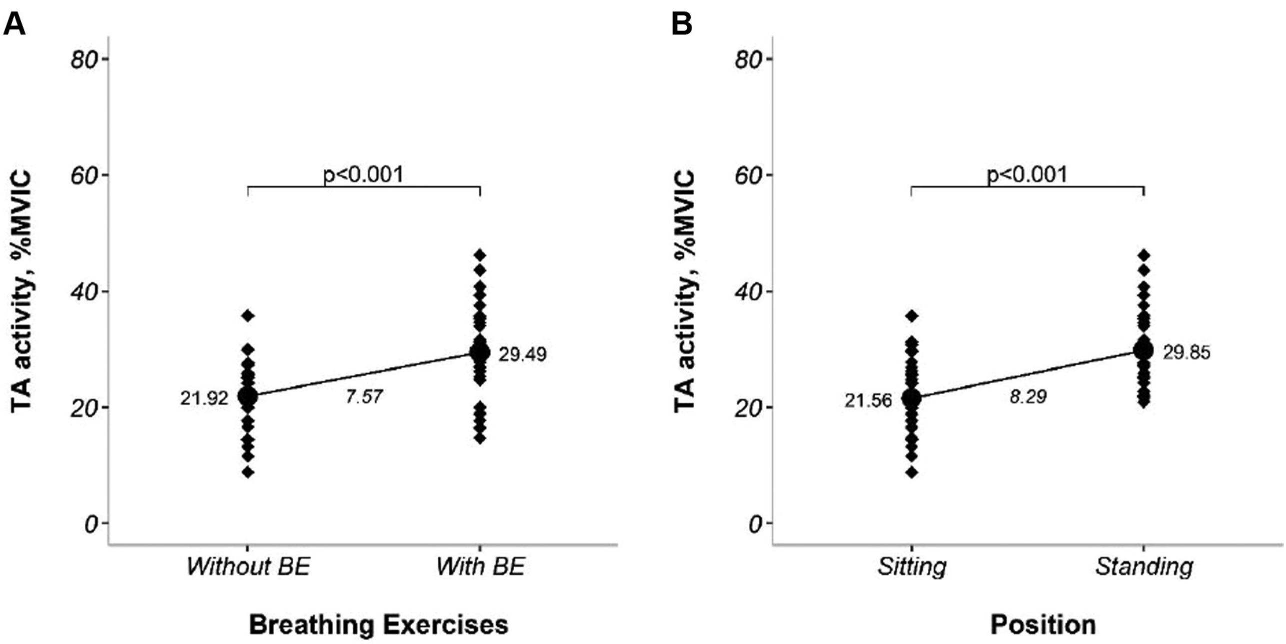

Figure 3. Comparison of the main effect on tibialis anterior muscle activity during the short foot exercises with and without breathing excercises (A) in the sitting and standing positions (B). The mean of the measurements obtained in each and the mean of their differences are presented with the *P* values.

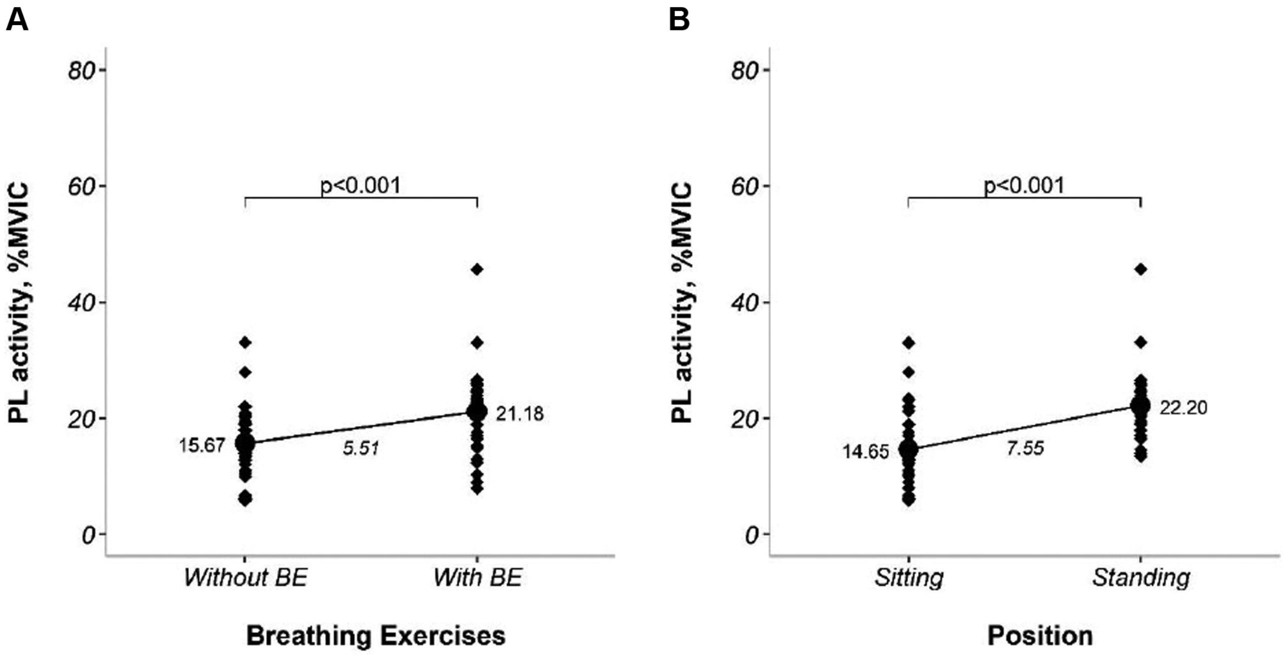

Figure 4. Comparison of the main effect on peroneus longus muscle activity during the short foot exercises with and without breathing excercises (A) in the sitting and standing positions (B). The mean of the measurements obtained in each and the mean of their differences are presented with the *P* values.

with pes planus.[16] Lee et al[15] found that muscle activity of TA is increased during SFE in individuals with pes planus. Yoon et al[31] stated that the muscle activity of TA during SFE is lowest in the ankle plantar flexion position compared with the neutral and dorsiflexion ankle positions. The results of the current study showed that TA muscle activity was higher during SFE with BE than without BE, and in the standing position than in the sitting position.

It is thought that tibialis anterior muscle activation is increased because of the body weight passing through the standing position. The increased activations of the PL can be explained by a windlass mechanism of the foot.[9,15] The TA and PL have prevented excessive pronation of the subtalar joint and prevent collapse of the MLA during weightbearing activities.[9,15] These are also extrinsic muscles of the foot, which stabilize the midtarsal joint during the stance phase and provide dynamic support to the MLA.[15,19] Therefore, it is thought that increased activation is shown by these results of the study. In addition, the reasons for the positive effects of the BE are that breathing stimulates the oxygenation of the muscles, decreases fatigue, and improves performance.[12,13]

In literature, the role of the PL has been stated as affecting the position of the foot and the height of the MLA.[32,33] It is important in individuals with pes planus because of its functions in the talocrural and subtalar joints. The PL has been helped by other plantarflexor muscles, with plantarflexion at the talocrural joint and the eversion of subtalar joints.[9,33] Murley et al[34] showed decreased PL activity in individuals with pes planus; Hunt and Smith[35] also found that PL activities of individuals with pes planus are decreased during the stance phase of gait; and Choi et al[1] stated that PL muscle activity is higher when the foot is in the weight-bearing position. In the current study, PL muscle activity was increased during SFE with BE than without BE and during standing than sitting. Higher loads on the foot in the standing position can result in higher muscle activity.

The ABDH has been one of the important muscles of the foot intrinsic muscle group supporting the MLA and pronation of the foot during the stance phase of gait.[1,2,32] A strong ABDH has been shown as good pronation control of the foot during gait and strong resistance to higher loads in individuals with pes planus. Jung et al[36] emphasized that SFE is a more useful strengthening exercise than toe curl exercise in activating the ABDH muscle. Choi et al[1] reported higher ABDH activity during SFE with isometric hip abduction than without it. In another study, Jung et al[36] showed that ABDH is a dynamic elevator of MLA, and dynamic guidance tubing can be used during SFE exercises to facilitate the activity of an underactive ABDH muscle in individuals

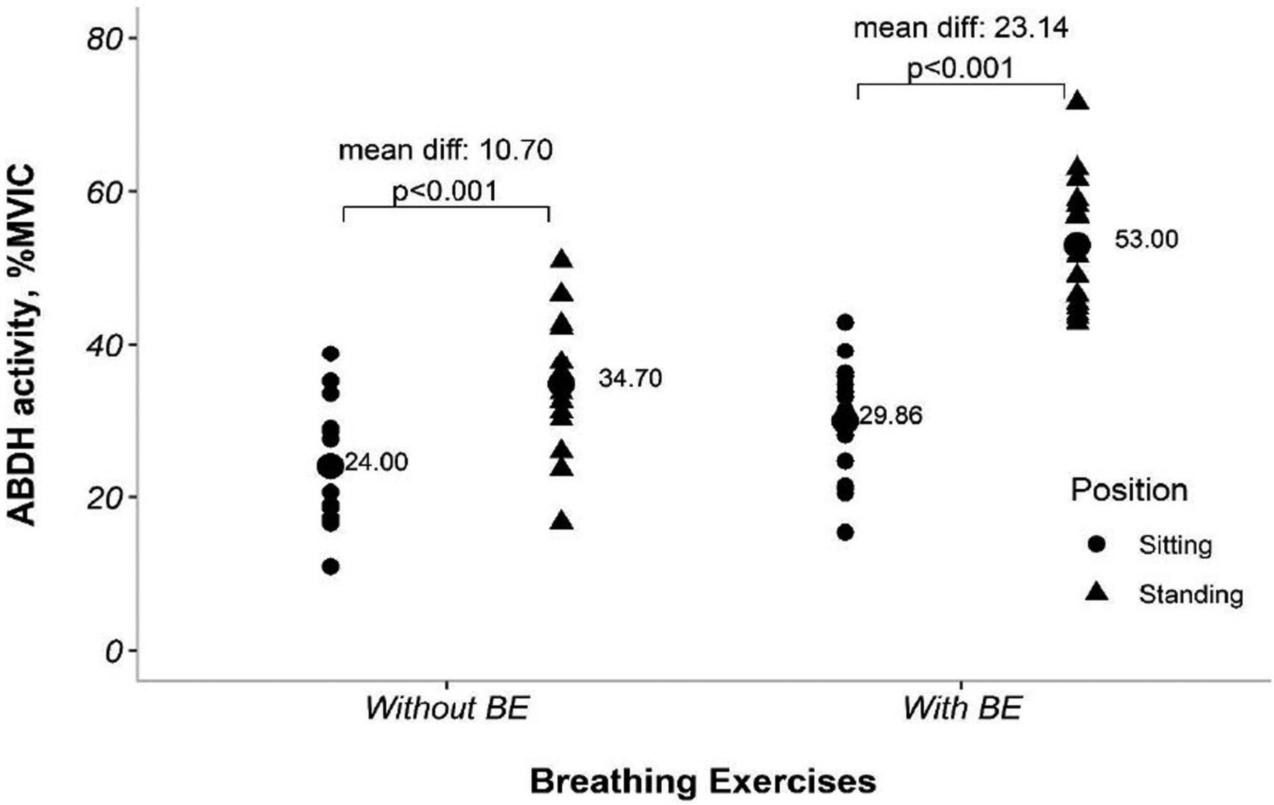

Figure 5. Comparison of the abductor hallucis muscle activity simple effect in the sitting and standing positions during the short foot exercises with and without breathing excercises. The mean of the measurements obtained in each and the mean of their differences are presented with the *P* values.

with pes planus. Kang et al[37] concluded that toe tap exercise as a part of rehabilitation is effective in activating the ABDH and elevating the MLA in individuals with pes planus. The current study results showed that the muscle activation of ABDH is greater during SFE standing with BE than during SFE sitting without BE. All of these studies in the literature and the parallel outcomes of the current study indicate that higher muscle activity of the foot intrinsic muscles is important clinically to strengthen the foot muscles during rehabilitation.

The hypothesis of this study was confirmed, as it was seen that SFE with BE have a positive effect on ABDH muscle activity when standing compared to sitting. Jeon and Kim[38] emphasized that supporting the arch with an insole during exercises increased the muscle activity of ABDH in individuals with pes planus. These results are consistent with previous studies[1,2,37]; therefore, strengthening foot intrinsic muscles with SFE in a standing position with BE can be recommended in the rehabilitation process for individuals with pes planus.

The metatarsophalangeal joint must remain in contact with the ground during the SFE, so the forefoot and midfoot must simultaneously rotate into relative pronation. Subsequently, the MLA may become tense and elevate, and the subtalar joint may supinate. Consequently, the participants performed SFE in the properly aligned foot while elevating the MLA.[1] This study lends credence to this interpretation. In the current study, BEs were seen to considerably increase rather than diminish the shift in the MLA angle in both orientations. This research also revealed that during SFE with breathing, the ABDH muscle activity ranged between 30% and 60% of the MVIC. An MVIC activation level greater than 30% is sufficient for muscle strengthening, according to a recent study.[23] Thus it can be concluded that SFE combined with breathing can be used as an ABDH muscle-strengthening program. However, to complete the SFE and in addition to the breathing exercise, the individual needs to focus carefully. To do this, the use of a metronome will help the patients focus.

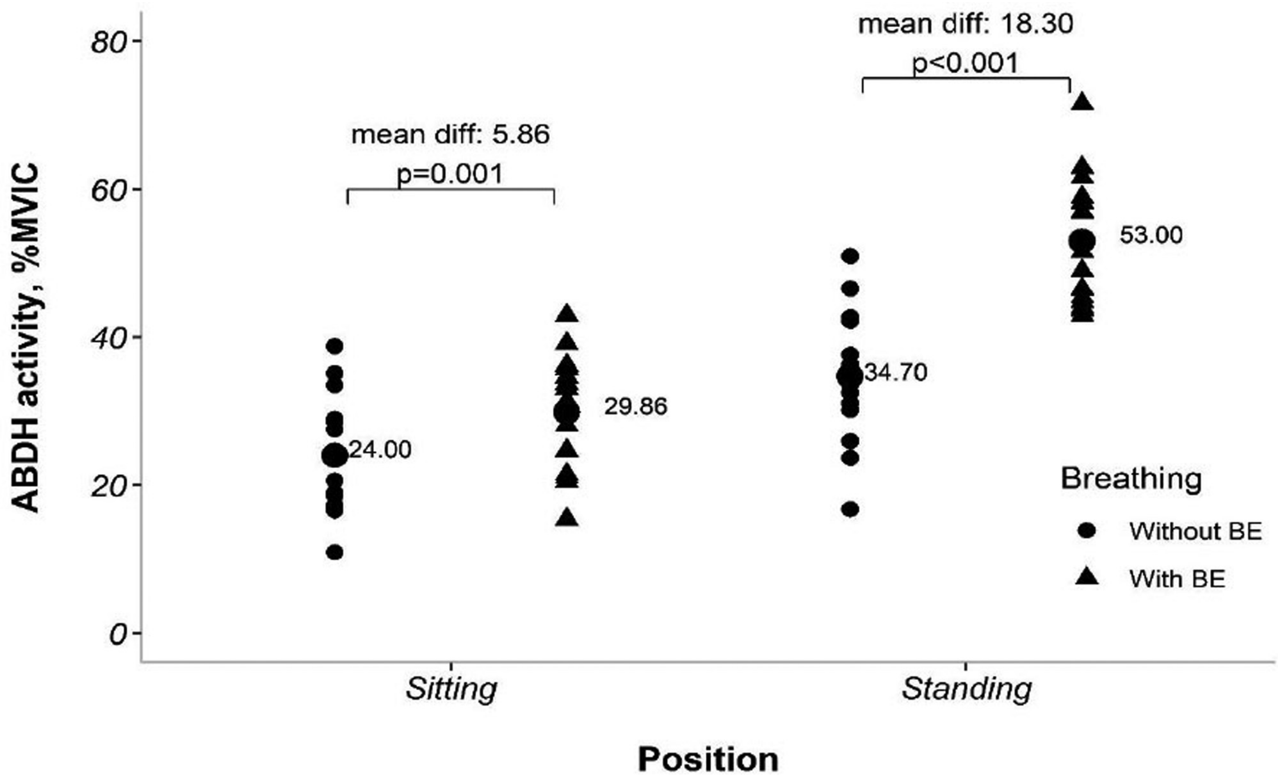

Figure 6. Comparison of the abductor hallucis muscle activity simple effect in the sitting and standing positions during the short foot exercises with and without breathing excercises. The mean of the measurements obtained in each and the mean of their differences are presented with the *P* values.

This study had some limitations. First, the muscle activity of other foot intrinsic muscles was not measured during SFE. Future studies may research the surface muscle activity of foot intrinsic and extrinsic muscles, such as the flexor hallucis longus and tibialis posterior, during SFE with or without BE. Second, this study investigated the effect of SFE with BE only immediately after the muscle contraction. Third, the long-term effects of the four different conditions of SFE on the activity of ABDH and extrinsic foot muscles could not be determined. Finally, the effects were not examined of adding various exercises into the SF, such as lower extremity strengthening exercises.

Conclusions

The results of this study demonstrated that muscle activity in the TA, PL, and ABDH was significantly higher in the SFE with BE than without BE. Furthermore, SFE when standing significantly increased the ABDH and ankle muscle activity in individuals with pes planus. Consequently, SFE with BE may be included in a strengthening program in rehabilitation programs of individuals with pes planus.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

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