The Relationship between Activity of Abductor Hallucis and Navicular Drop in the One-leg Standing Position

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Abstract. [Purpose] This study examined whether abductor hallucis (AH) activity in the one-leg-standing position can be used to predict the navicular drop (ND) when it is or is not actively supporting the medial longitudinal arch. [Subjects] Forty healthy subjects without foot or ankle problems were recruited. [Methods] For all subjects, the ND was measured as the difference in navicular height between the subtalar joint resting (STJR) and subtalar joint neutral (STJN) positions while standing. AH activity was measured in both positions during one-leg standing. [Results] AH muscle activity in the STJR position was significantly negatively correlated with the ND, while AH muscle activity in the STJN position was not. Using a simple regression model, AH activity predicted the ND based on the STJR position. [Conclusion] The results suggest that AH activity is a good predictor of the ND. Therefore, intervention that activates the AH in the one-leg standing position could be used to correct the ND.

Key words: Abductor hallucis, Navicular drop, Foot pronation

INTRODUCTION

Foot pronation is a complicated but critical triplanar movement that absorbs the shock from ground reaction forces1, 2). However, excessive pronation (pes planus) is a chronic condition caused by insufficient support of the medial longitudinal arch (MLA) of the foot3, 4). An excessively pronated foot is associated with several clinical pathologies of the lower extremity, including plantar fasciitis, tibialis posterior tendinitis, Achilles bursitis or tendinitis, and patellofemoral pain syndrome6, 7). While weight-bearing, the bony structures, ligaments, and extrinsic/intrinsic foot muscles contribute to maintaining the MLA of the foot to control excessive pronation8, 9). Of the midfoot bones, the navicular supports the structures of the MLA10, 11). Consequently, direct measurement of the navicular displacement in a weight-bearing position is one of the simplest methods for providing clinically quantifiable information regarding pronation of the foot12, 13). Clinically, navicular displacement in a weight-bearing position is measured using the navicular drop (ND) test.

The intrinsic foot muscles, including the abductor hallucis (AH), flexor hallucis brevis, and interosseous, contribute to stabilization of the foot arch during locomotion14, 15). Of these, the AH is the medial-most muscle in the first layer of intrinsic muscles at the plantar surface of the foot. Many studies have reported that the AH plays an important role in supporting the MLA and works in conjunction with elevation of the MLA16–20). Moreover, blocking the tibial nerve, which controls the activity of the AH, produces a significant increase in pronation as assessed by the ND test21). Therefore, the literature suggests that strengthening the AH would help to elevate the MLA.

Although previous studies have reported that the AH helps support the MLA22–25), no study has examined the relationship between AH activity and the ND during one-leg standing. Therefore, this study investigated the correlation between the AH and ND and the ability to predict the ND from AH activity, while actively supporting the MLA during static one-leg standing.

SUBJECTS AND METHODS

Forty-nine subjects were recruited and the ND of each was measured. Mueller suggested that an ND > 10 mm in the pronated foot is pathological14, 17). The exclusion criteria were: a history of lower extremity surgery; foot and ankle injury within 6 months of participation; previous or current inflammatory arthritis; diabetes; severe foot deformities such as hallux valgus, hammer toe, and claw toe; rigid foot with an ND < 3 mm; and an inability to actively support the MLA. After excluding nine subjects, the remaining forty participated in this experiment. All subjects provided their written informed consent before participating, and the study was approved by the Institutional Review Board of Yonsei University Wonju Campus.
The height of the navicular tuberosity was measured using Vernier height calipers (Mitutoyo Korea Corporation, Mitutoyo, Japan). The ND was determined as the displacement of the navicular in the sagittal plane between the neutral sitting and resting stance positions\(^\text{14}\). The neutral sitting or subtalar joint neutral (STJN) position was determined by palpating the talar head congruency when the participant was seated in an adjustable-height chair. The subtalar joint resting stance (STJR) position was when the subject relaxed the foot in full-weight bearing\(^\text{17}\). The ND was calculated as the difference in navicular height between the STJN and STJR positions. The reliability and validity of measuring the ND are well established\(^\text{18, 26, 27}\).

The activity of the AH was measured using a surface EMG system (MP100; BIOPAC Systems Inc., Goleta, CA, USA). EMG was performed using a preamplified electrode (BIOPAC Systems Inc.). The skin surface at the electrode site was prepared by sanding and cleansing by rubbing with alcohol. The electrodes were placed over the middle of the AH, parallel to the muscle fibers. A reference electrode was placed on the lateral malleolus. Data were sampled at 1000 Hz and band-pass filtered between 10 and 500 Hz. Root-mean-square (RMS) values were calculated using a moving 50-ms window. The EMG data were converted to a digital signal that was recorded using AcqKnowledge software (BIOPAC Systems Inc.) for processing.

The ND and the EMG activity of AH were measured for all subjects, with the subject seated on a chair with the hips, knees, and ankles at approximately 90°, and the feet placed on the floor with the tibia perpendicular to the floor. In order to measure ND in the STJN position, the examiner palpated the medial and lateral aspects of the talus with the thumb and index finger while the subject slowly inverted and evverted his hindfoot until neither the medial nor the lateral sides of the talar head were protruding or depressed. The examiner repositioned the foot until the talus was located centrally and could be felt equally under each point of palpation. The examiner palpated the navicular tuberosity and marked the site with a washable pen in the STJN position. The calipers were positioned, and the movement arm adjusted so that it was aligned with the navicular tuberosity. The examiner measured the height of the mark on the foot from the floor in the STJN position. Next, the subject was instructed to stand with full weight-bearing, keeping the tibia perpendicular to the floor. The examiner again measured the height of the mark on the foot from the floor and recorded it as the ND in the STJR position. The difference in navicular height between the seated and standing positions was calculated as the ND. The ND was measured three times and the mean was calculated.

For EMG measurement each subject was seated with the foot placed on a foot plate to record the EMG and the belly of the AH on the test foot was located by palpation. The foot was fixed to the foot plate using a strap to prevent movement of the ankle joint. The subject was instructed to make sure that his foot was always in this same position before performing maximal voluntary isometric contractions (MVICs). The subject was instructed to maximally contract the AH by plantar flexion of the first metatarsophalangeal joint and holding the contraction for 5 s. The RMS values of the EMG data were calculated and the maximal EMG signals for normalization were acquired during MVIC. The values of the first and last second were discarded and the mean RMS of the middle 3 s was calculated. The %MVIC was measured three times with a 60-s rest between each trial. After measuring the AH MVIC, the AH EMG data were collected in both the STJR and STJN positions for 5 s in the one-leg standing position with full weight-bearing. To prevent postural sway, the subject lightly held a chair placed to the side of his leg. The initial and last second of the EMG values were discarded, and the remaining 3 s of data were used as the %MVIC.

Demographic data, including sex, age, height, and weight, were analyzed using descriptive statistics. The ND and AH EMG activity were assessed in both the STJR and STJN positions. The correlations between the %MVIC of AH EMG activity and ND in the STJR and STJN positions were determined using Pearson’s correlation coefficient. A simple regression analysis was performed to predict the ND from the measured AH muscle activation, with ND (mm) as the dependent variable and AH EMG activity (%MVIC) as the independent variable. All data analyses were performed using SPSS, ver. 12.0, and are reported as the average ± standard deviation. Values of p < 0.05 were considered statistically significant.

RESULTS

The demographic data of the subjects are summarized in Table 1. AH EMG activity in the STJR position had a significant negative correlation with ND. To better understand the relationship between AH EMG activity and the ND, a linear regression model was constructed (Table 2). This was expressed by the equation \( y = -0.290x + 15.951 \) (\( x = \text{ND}, y = \%\text{MVIC of AH EMG activity} \)). For the model, \( R^2 = 0.505 \). AH EMG activity in the STJN position and ND were not correlated.

DISCUSSION

This study investigated the correlation between AH muscle activity in the one-leg standing position and the ND and predicted the ND from the AH EMG activity in the one-leg standing position. AH EMG activity in the STJR position was significantly correlated with the ND. In addition, the ND could be estimated from AH EMG activity using a linear regression model. These results imply that an assessment of AH muscle activity in the STJR position is a good predictor of the ND. AH EMG activity in the STJN position, while actively supporting the MLA, was not significantly correlated with the ND.

ND is defined as the difference between the height of the navicular in the STJN position, while sitting, and in the STJR position, while weight-bearing\(^\text{17, 29}\). Movement of the subtalar joint can be detected by measuring the extent of movement of the navicular. Regarding the ND test, a difference of 10 mm is considered normal, and one > 10 mm abnormal\(^\text{14, 29}\). Many studies have reported that
the ND is correlated with foot pronation, which is linked to the stability of the MLA. Moreover, the intrinsic plantar musculature clearly plays a significant role in supporting this structure. Consequently, the ND is a useful measurement for understanding the biomechanical relationship between the MLA structures and intrinsic foot muscles. In this study, to predict the ND from AH activity using regression analysis, subjects with excessively low (≤ 3.00) or high (≥ 18.00) ND were excluded, as were subjects with an excessively rigid foot (pes cavus), and those who could not actively support the MLA in a short foot exercise.

Our finding of a correlation between AH activity and the ND is in agreement with studies showing increased contractive effort of the AH in maintaining a well-supported MLA, which induces excessive pronation while sitting or in a one-leg standing position. In other words, if the ND increases significantly, AH activity decreases significantly. Many studies have revealed that decreased AH activity contributes to flattening of the MLA, which induces excessive pronation and isokinetic strength of the ankle musculature. Clinical Orthopaedics Relat Res, 1995, 165–172. [Medline] [CrossRef]

Table 1. Characteristics of subjects

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Demographic values</th>
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<tbody>
<tr>
<td>Gender (Male/Female)</td>
<td>16/26</td>
</tr>
<tr>
<td>Age</td>
<td>21.9 ± 2.1</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.4 ± 7.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>59.9 ± 12.1</td>
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<tr>
<td>Mean ± SD</td>
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</table>

Table 2. Linear regression model of AH EMG activity with ND in the STJR position

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND</td>
<td>10.29 ± 3.91</td>
</tr>
<tr>
<td>AH</td>
<td>19.55 ± 9.58</td>
</tr>
<tr>
<td>Simple R</td>
<td>0.710*</td>
</tr>
<tr>
<td>Simple R²</td>
<td>0.505</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.492</td>
</tr>
<tr>
<td>F</td>
<td>38.709*</td>
</tr>
<tr>
<td>Mean ± SD STJR: subtalar joint resting position. ND: navicular drop. AH: abductor hallucis. *p&lt;0.05</td>
<td></td>
</tr>
</tbody>
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REFERENCES

Ankle Surg, 2003, 42: 327–333. [Medline] [CrossRef]


