정형외과 석사 학위논문

무지 외반증의 중증도에 따른 노인 여성의 발 분절의 운동형상학

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김어진의 석사 학위논문을 인준함

2019 년 6 월

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Abstract

Inter-segmental Foot Kinematics during Gait in Elderly Females According to the Severity of Hallux Valgus

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Background: Hallux valgus (HV) is a common condition that may lead to considerable pain and disability. The effect of HV on gait has been previously investigated, and progressive subluxation of the first metatarsophalangeal joint is known to interfere with efficient toe-off. However, the results from previous studies have not been consistent, which might be because of the lack of age- and sex-matched control groups and consideration of the severity of HV deformity. In the last two decades, several multi-segmental foot models (MFMs) have been introduced for the in vivo analysis of dynamic foot kinematics. The objective of this study was to determine the effect of HV deformities on the inter-segmental motion of the foot using an MFM with a 15-marker set (DuPont Foot Model [DuFM]) by comparing with age- and sex-matched healthy adults.

Methods: Fifty-eight symptomatic female patients with HV and 50 asymptomatic older female volunteers were included in this study. According to the radiographic HV angle (HVA), the study population was divided into severe HV (HVA $\geq$ 40°, n=25), moderate HV (20° ≤ HVA < 40°, n=47), and control (n=36) groups. Segmental foot kinematics was evaluated using the DuFM. The temporal gait parameters such as cadence, speed, stride length, step width, step time, and proportion of stance phase were calculated. Inter-segmental angles (ISAs) (hindfoot relative to tibia, forefoot relative to hindfoot, and hallux relative to forefoot) were calculated at each time point (100 time points for the whole gait cycle). The ISAs (position) at specific phases of the gait cycle, change in ISA (motion) between phases, and range of ISAs during the whole gait cycle were calculated and compared among the groups.

Results: Age, height, weight, and BMI were not significantly different between the groups. Among the temporal parameters, gait speed and stride length were diminished depending on the severity of the HV deformity. Sagittal range of motion of the hallux and hindfoot decreased significantly in the severe HV group. Loss of push-off during the pre-swing phase was observed, and forefoot adduction motion during the terminal stance decreased in the severe HV group.

Conclusion: HV deformities affect gait parameters and inter-segmental motion of the foot during gait in proportion to the severity of deformity. However, confounders affecting gait and inter-segmental foot motion should be considered.

keywords : hallux valgus, gait analysis, multi-segment foot model, inter-segmental foot motion

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목차

Introduction

Hallux valgus (HV), which is characterized by the valgus angulation of the first metatarsophalangeal joint, is one of the common conditions encountered in foot and ankle clinics. Although it is assumed that HV may cause considerable pain and disability during gait, it is still not clear how HV effects gait patterns. Several studies have shown that basic spatio-temporal parameters do not differ significantly between those with and without HV [1-4]. However, the previous finding of less stable gait patterns on an irregular surface in older adults with significant HV [3] suggested that there might be a significant differences in inter-segmental motion in the foot and ankle, which cannot be recognized in conventional gait analysis.

In the last three decades, several multi-segmental foot models (MFMs) have been introduced for the in vivo analysis of dynamic foot kinematics [5-10]. To our knowledge, there are few triplanar multisegmental investigations of patients with HV [2; 11-13]. However, previous reports on inter-segmental foot motions of patients with HV have been composed of limited number of subjects with diverse ages and without gender-matched control group. Most of them did not show severity of HV by radiographic evaluation. However, it has been reported that age- & gender-matched control was required for assessment of specific effect on the inter-segmental motion of the foot [14; 15].

The objective of this study were to find the effect of radiographic severity of hallux valgus deformity on inter-segmental motion of the foot by comparison with age and gender controlled healthy adults. We adopted DuPont Foot Model (DuFM, a MFM with 15-marker set) which was validated previously [16-18].

Methods

Study population

This study was approved by the institutional review board, and all subjects submitted informed consents prior to participation. Fifty eight female symptomatic hallux valgus patients (mean age, 64.2) and 50 non-symptomatic older volunteers form local area [15] were tested at the Laboratory of Human Motion Analysis in Seoul National University Hospital. Inclusion criteria for hallux valgus patients were 1) foot discomfort associated with hallux valgus deformity (pain, bunion and/or metatarsalgia); 2) more than 20 degree of hallux valgus angle (HVA); 3) no history of fracture or surgery on the lower extremities; and 4) no history of cardiac, respiratory, neuromuscular, or ocular impairment which can cause gait disturbance. They were divided into severe hallux valgus group (SHV group, HVA ≥ 40°, n=25) , moderate hallux valgus group (MHV group, 20° ≤ HVA < 40°, n=47), and control group (CON group, HVA < 20°, n=36) according to HVA measured using standing anteroposterior radiograph of the foot.

Experimental procedures

For evaluation of inter-segmental foot motion, we used a DuPont foot model (DuFM) using a 15-marker set that was recently proposed by Henley and Miller [10; 19] The placement of the markers, definition of the coordinate systems based on these markers and the method calculating the joint rotation and arch parameters had been described previously [10;16]. Experimental procedures were described thoroughly in previous studies [16;17]. In brief, the participants performed a 5-minute warm-up protocol of comfortable walking. After warming up, each subject had 15 reflective markers placed on each side of foot and lower extremities. And they walked along the 8 meter walkway at a comfortable speed. Gait data was collected using 12 cameras with optical motion capture system (Motion Analysis Co., Santa Rosa. CA) at a sample rate of 120 Hz. Eva Real-Time software (EVaRT, Motion Analysis Co.) was used for real-time motion capture and for post-processing and tracking the marker data. Kinematic data of inter-segmental foot motion was collected and tracked using the Foot 3D Multi-Segment Software (Motion Analysis Co., Santa Rosa. CA). Three representative strides from five separate trials were selected and mean value was used for analysis. For radiographic examinations, hallux valgus angle was measured using standing anteroposterior radiograph of the foot.

Data acquisition, normalization and analysis

The temporal gait parameters such as the cadence, speed, stride length, step width, step time, and proportion of stance phase were calculated. Data of gait speed, stride length and width, foot length and width, arch height, and arch length was normalized with height of the subject to reflect the effect of body size [20; 21].

To assess the inter-segmental position of foot (hindfoot relative to tibia, forefoot to hindfoot, and hallux to forefoot) during the gait cycle, we divided the whole gait cycle into 100 time points with 1% interval and collected inter-segmental angles (ISA) at each time points. Parameters calculated were as follows; (1) hindfoot relative to tibia: dorsiflexion/plantarflexion, pronation/supination, and internal/ external rotation; (2) forefoot relative to hindfoot: dorsiflexion/plantarflexion, pronation/supination, and abduction/adduction; (3) hallux relative to forefoot:

dorsiflexion/plantarflexion and valgus/varus; and (4) arch data: height, arch length, and arch index (arch height/arch length) [16; 17]. Range of inter-segmental angles during the whole cycle of the gait was evaluated by minimum value, maximum value, and gap between minimum and maximum values of inter-segmental angle.

Statistical analysis

ANOVA test followed by multiple comparisons according to Bonferroni correction method were performed to assess differences in range of each inter-segmental motion between groups, with p-values less than 0.05 regarded significant. All statistics were used by SPSS version19 for Windows (SPSS Inc., Chicago, IL).

Results

Of the 58 symptomatic hallux valgus groups, 25 were in the SHV group and 33 were in the MHV group. And of the 50 non-symptomatic older volunteers, 14 were in the MHV group and 36 were in the CON group.

Demographic data is shown in Table 1. One-way ANOVA was used for analysis. Age, height, weight, and BMI in demographic data were not different between groups. And, of course, HVA was different among all groups. The foot width was found to be significantly different between the control group and the HV group.

The temporal gait parameters (cadence, speed, n_speed, stride length, n_stride length, step width, n_step width, step time, stance phase) are presented in Table 2. The speed, stride length, and step width, which are variables that can affect the height, were measured by adjusting the n_speed, n_stride length, and n_step width corrected for height. Temporal gait parameters show significant differences in all items except cadence. As shown in Table 2, there was a substantial tendency of slower gait according to the severity of hallux valgus, which mainly caused by diminished stride length. Proportion of stance phase was significantly increased in proportion to severity of hallux valgus and slower gait speed.

The range of motion (ROM) of each segment of the foot was presented in Table 3. The sagittal ROM of hallux and hindfoot decreased in severe hallux valgus group. The ISAs (position) of the foot segment relative to proximal segment at each phase of whole gait cycle and the change of ISAs (motion) between adjacent gait phases are presented in Figures 1,2, and 3.

In hindfoot kinematics relative to the tibia, plantar flexion motion in the pre-swing phase was significantly lower in HV patients in proportion to the severity of the deformity (Figure 1). In transverse motions, the HV group showed significantly internal rotated position of hindfoot throughout the gait cycle.

In forefoot kinematics relative to the hindfoot, differences in sagittal motions among groups were not substantial (Figure 2). In coronal plane, HV group showed more pronated position throughout the gait cycle. In transverse plane, there was a loss of forefoot adduction motion in late stance phase in HV group.

In hallux kinematics relative to the forefoot, hallux valgus angle was larger in HV patients throughout the whole gait cycle (Figure 3). The plantar flexion motion of the hallux in the load response phase was significantly lower and hallux was in more dorsiflexed position in the HV groups in proportion to the severity of deformity.

In kinetic analysis, ankle power during terminal stance and preswing phase was lower in the hallux valgus in proportion to the severity of deformity (Figure 4).

Discussion

In this study, we presented kinematic characteristics of inter-segmental foot motion during bare foot gait at a comfortable speed in HV patients using a MFM with a 15-marker set (DuPont Foot Model).

This is, to our best knowledge, the first study in which the foot kinematics of hallux valgus patients was assessed based on the radiographic severity of deformity using MFM. Since MFMs had been introduced for the in vivo analysis of dynamic foot kinematics, they are gaining more popularity in clinical gait analysis[22; 23]. Although these models differ in the number of segments within the foot, the position of markers which defines each segment, and the way to interpret segmental motion mathematically, leading to different segmental motion patterns during gait cycle [24], there have been accumulative evidences supporting that MFMs can be applicable to evaluate inter-segmental foot motions. DuPont model also was demonstrated to have reproducibility and correlation with the conventional radiographic indices.[16; 17; 25]

Through MFM analysis, we found that hallux valgus deformity affected the kinematics of the foot and ankle in proportion to the severity of deformity. For temporal parameters, gait speed and stride length was diminished according to severity of hallux valgus deformity. Proportion of stance phase was larger in HV group. Sagittal ROM of hallux and hindfoot decreased significantly in severe HV group. Loss of push off during preswing phase was observed and forefoot adduction motion during terminal stance was decreased in SHV group.

These findings generally concurred with those of previous studies that investigated the effect of hallux valgus on gait and foot biomechanics, while there are some discrepancies. Canseco et al. compared data of 25 healthy adults (13 males, 12 females, average age of 41 years old) with that of 33 symptomatic HV patients (2 males, 31 females, average age of 51.9 years old, severity unknown) [11; 12]. Canseco et al. has used the Milwaukee Foot Model and has shown decreased velocity and stride length. They also has shown prolonged stance. However, there is no radiographic assessment, and the subjects of study had wide range of age (24-72 years). Deschamps et al. compared data of 22 healthy adults (9 males, 13 females, average age of 37.5 years old) with that of 20 patients (4 males, 16 females, and average age of 47.4 years old, unknown severity) [2]. Deschamps et al. has used the Oxford Foot Model and they found no difference in temporal parameters. And subjects of the study also had wide range of age (18-65 years), and there was no information about the HVA of control group. Hwang et al. used the data of 10 healthy adults (unknown age and gender) and 2 persons with HV (grade2 based on the HV angle, gender and age are unknown) [13]. However, this study had some aspects that distinguish it from previous studies. First, this was the first study, to our knowledge, that classified symptomatic HV patients according to the severity of deformity defined by radiographic measurements (HVA), enabling investigation of the effect of severity of deformity on foot kinematics. Second, we studied age- and gender-matched control groups using the DFM. Previously, needs for age- and gender-matched control group were postulated concerning false positive limitation of motion in unmatched control studies.[14; 15]

One of most prominent discrepancies from previous studies was sagittal motion/position of the hallux relative to forefoot. Deschamps et al. presented an increased dorsiflexion motion during terminal stance with relatively decreased dorsiflexion angle throughout the first 30% of the gait cycle.[2] On the contrary, we found a decreased dorsiflexion motion in proportion to hallux valgus deformity with more dorsiflexed position during the early stance phase (Figure 3). We could find result from Canseco et al.[12] was similar with us.

We also showed that plantar flexion motion of the hindfoot in pre-swing phase was significantly lower in HV patients in proportion to the severity of deformity (Figure 1). We think it was related with decreased power generation in late stance phase (Figure 4). However, further evaluation would be necessary for clarifying whether symptomatic discomfort or severe deformity itself is a main cause of loss of effective push off.

The current study has some limitations. First, the number of subjects in each group may not be sufficient to characterize the effect of HV on foot kinematics. However, considering that our study population was confirmed by radiographic examination and compared with age- and gender-matched controls, we believe our results can be considered to reflect HV group reliably. Second, we did not control gait speed in this research. While it is clear that the more severe was hallux valgus deformity, the slower was the gait speed, effect of slower gait on kinematic changes could not be assessed. Further research should be undertaken to evaluate the effect of these potential confounders. However, effect of gait speed would be less profound on coronal and transverse motion of the foot segment, which was characteristic in HV patients. Third, confounders affecting gait and inter-segmental foot motion were not controlled for. Changes such as bunions/osteoarthritis and pain such as metatarsal-proximal phalanx joint pain/metatarsalgia may affect gait or inter-segmental foot motion. However, in this study, we divided the patients into groups according to only the severity of HV, without controlling for these variables. In particular, symptoms such as pain often lead to a change in the movement of the foot to reduce pain during gait. To determine how gait and inter-segmental foot motions change according to the severity of HV, while excluding the effects of gait due to the symptoms, it is necessary to divide the patients in the severe and moderate HV groups into symptomatic and non-symptomatic subgroups. This will allow for a better assessment of the differences in comparison with the control group, which has no symptoms and HV. However, further studies are needed for a better understanding of this .

Conclusion

Hallux valgus deformity affects gait parameters & inter-segmental motion of the foot during gait in proportion to the severity of deformity. However, confounders affecting gait and inter-segmental foot motion should be considered.

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Figure 1. Average kinematics of the hindfoot relative to the tibia during the whole gait cycle according to the severity of hallux valgus. Asterisks and brackets denote phases of gait cycle with significantly different positions (upper) and motions (lower).

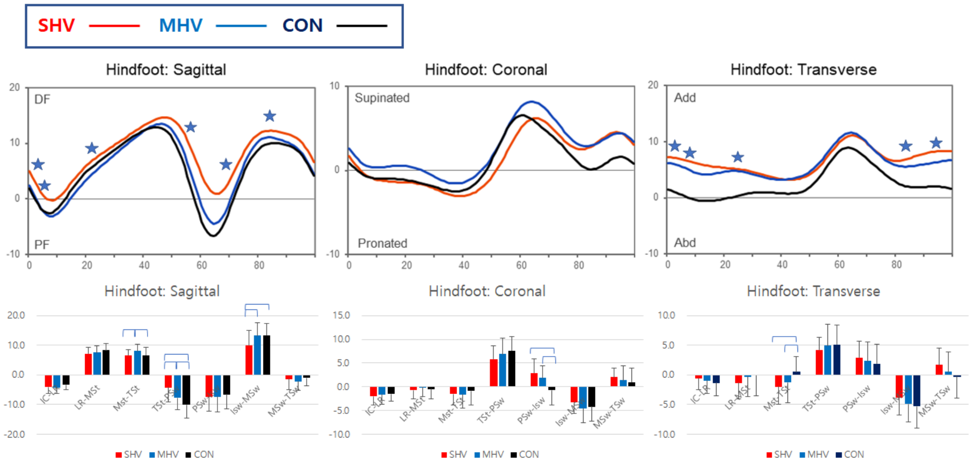

Figure 2. Average kinematics of the forefoot relative to the hindfoot during the whole gait cycle according to the severity of hallux valgus. Asterisks and brackets denote phases of gait cycle with significantly different positions (upper) and motions (lower).

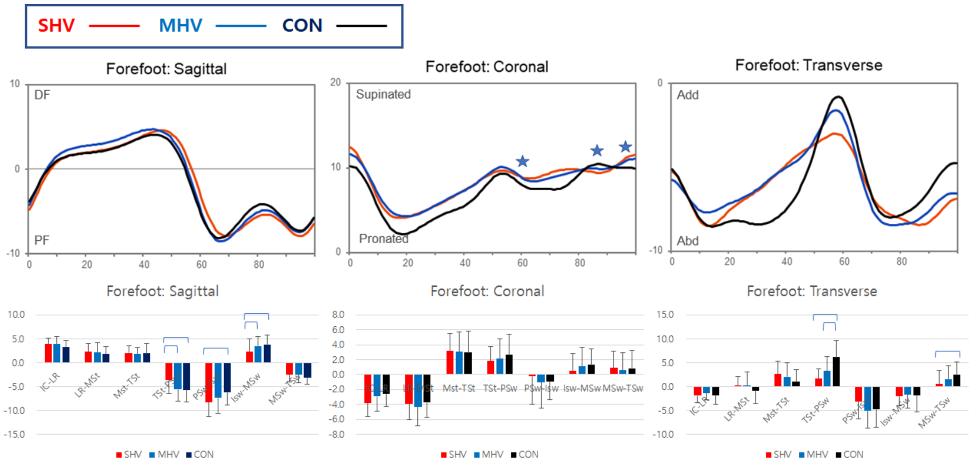

Figure 3. Average kinematics of the hallux relative to the forefoot during the whole gait cycle according to the severity of hallux valgus. Asterisks and brackets denote phases of gait cycle with significantly different positions (upper) and motions (lower).

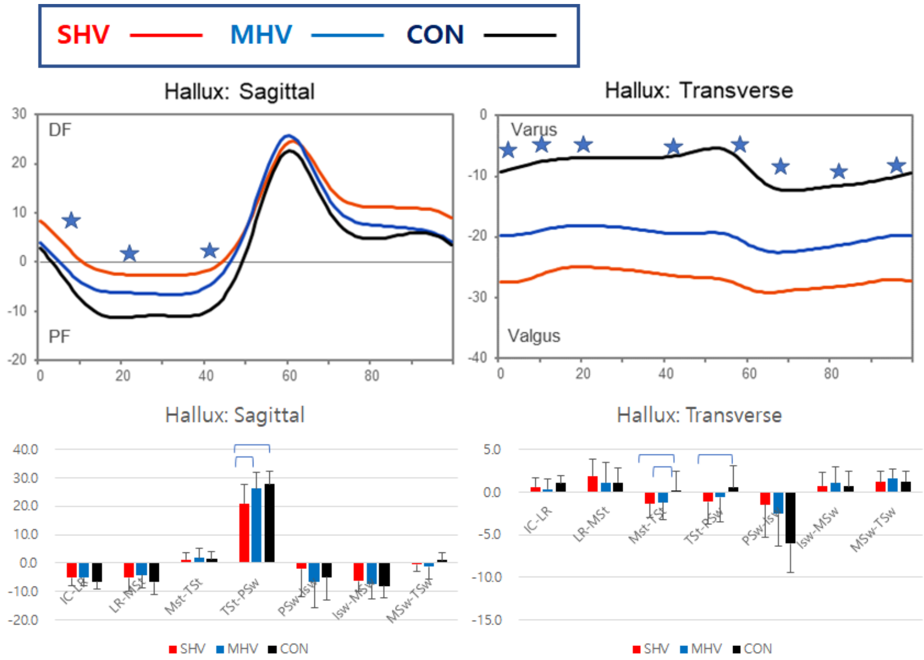

Figure 4. Average kinetics and distribution of the ankle during the whole gait cycle according to the severity of hallux valgus. Asterisks and brackets denote phases of gait cycle with significantly different power.

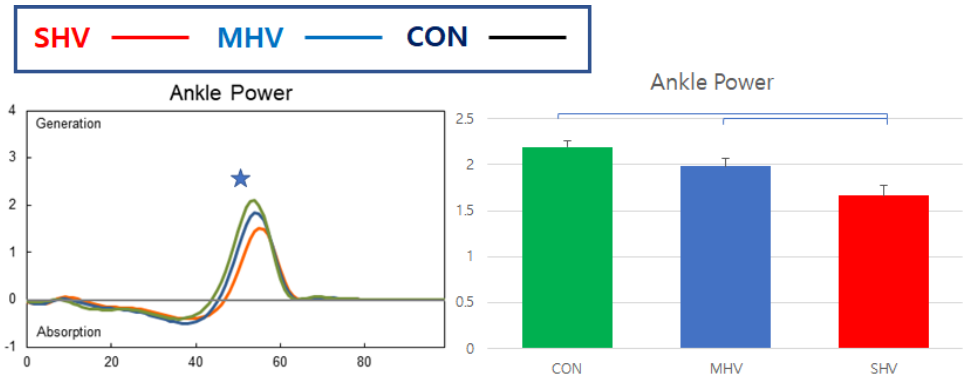

Table 1. Pertinent demographic data of participating subjects. Data are presented as mean value ± standard deviation.

	Study Population							
	SHV (n=25)	MHV (n=47)	CON (n=36)	P value*	F	P**	P***	P****
Demographic measurements								
Age (year)	64.7 ± 6.3	63.0 ± 6.1	63.8 ± 2.9	0.413	0.891			
Height (cm)	154.0 ± 7.0	155.5 ± 5.3	153.6 ± 5.3	0.292	1.245			
Weight (Kg)	59.5 ± 8.9	59.9 ± 8.4	57.5 ± 8.0	0.423	0.868			
Body mass index (Kg/m^2)	25.1 ± 3.7	24.8 ± 3.1	24.4 ± 3.3	0.699	0.359			
Hallux Valgus Angle	47.1 ± 5.3	31.5 ± 5.7	12.7 ± 4.1	<0.001	344.178	<0.001	<0.001	<0.001
Foot parameter								
Foot Width (cm)	10.3 ± 0.8	10.1 ± 0.6	9.4 ± 0.6	<0.001	19.804	0.553	<0.001	<0.001

* : Result of ANOVA

** : Results of multiple comparisons according to Bonferroni correction method between SHV and MHV.

*** : Between SHV and CON.

**** : Between MHV and CON.

Table 2. Temporal gait parameters are presented as mean value ± standard deviation.

	Study Population							
	SHV (n=25)	MHV (n=47)	CON (n=36)	P value**	F	P***	P****	P*****
Cadence (step/min)	114.2 ± 6.8	111.8 ± 8.6	115.7 ± 5.9	0.058	2.924			
Speed (cm/sec)	101.0 ± 13.3	106.1 ± 14.8	111.9 ± 7.5	0.004	5.883	0.311	0.003	0.108
n_Speed*				0.001	7.040	0.483	0.001	0.027
Stride length (cm)	106.3 ± 13.3	113.2 ± 11.1	115.8 ± 7.6	0.003	6.015	0.032	0.003	0.819
n_Stride length*				0.001	7.566	0.043	0.001	0.230
Step width (cm)	10.9 ± 3.3	9.7 ± 2.8	8.6 ± 2.2	0.008	5.075	0.251	0.006	0.235
n_Step width*				0.009	4.944	0.200	0.007	0.324
Step time (sec)	0.53 ± 0.03	0.54 ± 0.04	0.52 ± 0.03	0.040	3.325	0.443	1.000	0.039
Proportion of stance phase (%)	63.3 ± 1.8	61.9 ± 2.1	60.6 ± 1.1	<0.001	17.454	0.006	<0.001	0.003

* Normalized with the subject's height. (Speed, Stride length and width divided by subject's height and multiplied by 100)
** One-way ANOVA
*** : Results of multiple comparisons according to Bonferroni correction method between SHV and MHV.
**** : Between SHV and CON.
***** : Between MHV and CON.

Table 3. Range of motion of foot segment. Data are presented as mean value ± standard deviation.

	Study Population							
	SHV (n=25)	MHV (n=47)	CON (n=36)	P value**	F	P***	P****	P*****
Hallux relative to forefoot								
Max DF	26.04 ± 9.13	26.72 ± 9.40	23.66 ± 7.06	0.268	1.334			
Max PF	3.74 ± 5.60	8.22 ± 6.01	12.20 ± 4.39	<0.001	18.052	0.003	<0.001	0.004
ROM	29.77 ± 8.07	34.94 ± 8.10	35.86 ± 4.36	0.003	6.120	0.012	0.004	1.000
Min Val	23.94 ± 9.98	16.58 ± 7.23	3.74 ± 5.32	<0.001	59.681	<0.001	<0.001	<0.001
Max Val	30.76 ± 10.74	24.06 ± 7.95	12.68 ± 4.96	<0.001	42.115	0.003	<0.001	<0.001
ROM	6.82 ± 2.47	7.48 ± 2.92	8.94 ± 2.86	0.010	4.816	1.000	0.013	0.062
Forefoot relative to hindfoot								
Max DF	5.02 ± 2.75	5.18 ± 3.12	4.57 ± 3.26	0.666	0.408			
Max PF	9.01 ± 3.11	9.20 ± 3.94	8.85 ± 4.00	0.915	0.089			
ROM	14.03 ± 2.91	14.38 ± 3.64	13.42 ± 3.29	0.437	0.834			
Max Sup	13.43 ± 5.40	13.56 ± 6.62	16.05 ± 4.35	0.095	2.408			
Max Pron	-3.44 ± 5.79	-3.46 ± 6.32	-6.15 ± 3.83	0.058	2.919			
ROM	9.99 ± 2.85	10.10 ± 3.34	9.89 ± 3.06	0.957	0.044			
Max Add	-1.59 ± 6.81	-0.45 ± 6.74	0.38 ± 4.69	0.471	0.759			
Max Abd	10.46 ± 6.42	10.78 ± 5.88	10.84 ± 4.64	0.964	0.037			
ROM	8.87 ± 3.36	10.33 ± 3.32	11.22 ± 2.60	0.017	4.217	0.184	0.014	0.593
Hindfoot relative to tibia								
Max DF	16.04 ± 3.86	14.32 ± 3.97	13.81 ± 2.99	0.049	3.101	0.157	0.052	1.000
Max PF	2.28 ± 4.43	6.59 ± 6.86	7.83 ± 4.26	<0.001	9.983	0.002	<0.001	0.779
ROM	18.32 ± 3.33	20.92 ± 5.11	21.64 ± 3.85	0.004	5.715	0.025	0.004	1.000
Max Sup	7.01 ± 6.60	8.75 ± 4.69	7.43 ± 5.07	0.339	1.093			
Max Pron	3.93 ± 7.02	2.87 ± 5.41	3.80 ± 3.77	0.641	0.446			
ROM	10.94 ± 3.84	11.62 ± 4.14	11.23 ± 3.44	0.760	0.275			
Max IR	12.23 ± 6.70	12.39 ± 6.54	9.54 ± 7.32	0.140	2.003			
Max ER	-2.00 ± 6.79	- 0.74 ± 6.01	2.55 ± 5.87	0.011	4.747	1.000	0.016	0.052
ROM	10.24 ± 3.23	11.64 ± 4.57	12.09 ± 3.85	0.202	1.623			

Arch								
Max Height	40.60 ± 6.34	42.73 ± 6.97	46.25 ± 5.08	0.002	6.517	0.516	0.002	0.037
Min Height	28.00 ± 6.34	29.77 ± 7.14	35.44 ± 4.36	<0.001	13.192	0.741	<0.001	<0.001
Range	12.60 ± 3.64	12.96 ± 3.32	10.82 ± 2.75	0.010	4.832	1.000	0.105	0.010
Max Length	182.2 ± 10.24	186.20 ± 7.05	182.96 ± 7.39	0.073	2.689			
Min Length	169.35 ± 9.08	170.50 ± 7.23	165.11 ± 6.95	0.006	5.359	1.000	0.104	0.005
Range	12.85 ± 4.24	15.70 ± 4.09	17.85 ± 2.86	<0.001	12.992	0.009	<0.001	0.034
Arch index*								
Max	0.23 ± 0.04	0.23 ± 0.04	0.26 ± 0.03	0.001	7.595	1.000	0.002	0.006
Min	0.16 ± 0.04	0.17 ± 0.04	0.21 ± 0.02	<0.001	14.624	1.000	<0.001	<0.001
Range	0.06 ± 0.02	0.06 ± 0.02	0.05 ± 0.01	0.003	6.136	1.000	0.027	0.004
Foot progression angle								
Max ER	19.97 ± 6.06	18.08 ± 6.01	22.46 ± 5.94	0.006	5.434	0.622	0.339	0.004
Min ER	6.61 ± 6.44	5.16 ± 5.05	7.62 ± 5.39	0.129	2.087			
Range	13.36 ± 4.00	12.92 ± 4.25	14.84 ± 3.86	0.100	2.354			

* Arch index = Arch height / Arch length
** : Result of ANOVA
*** : Results of multiple comparisons according to Bonferroni correction method between SHV and MHV.
**** : Between SHV and CON.
***** : Between MHV and CON.

초록

무지 외반증의 중증도에 따른 노인 여성의
발 분절의 운동형상학

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배경 : 무지외반증은 상당한 통증과 장애를 일으키는 흔한 질환이다. 무지외반증이 무지의 중족-족지관절의 아탈구로 효율적인 발가락의 움직임을 방해하여 보행에 영향을 미치는 것은 잘 알려져 있다. 하지만 이전 연구들에서는 무지외반증의 중증도와 연령 및 성별이 일치된 대조군을 고려하지 않아 일관성이 없는 결과가 많았다. 지난 20년간 동적 발 운동학의 생체 내 분석을 위하여 여러 가지 발 분절 모델이 도입되었다. 본 연구의 목적은 무지외반증의 중증도에 따른 발 분절의 운동학을 15개의 마커를 사용하는 발 분절모델(DuPont Foot Model, DuFM)을 이용하여 연령과 성별을 통제한 건강한 성인과 비교하는 것이다.

방법 : 본 연구는 증상이 있는 무지외반증 환자 58명과 무증상 여성 자원자 50명을 대상으로 하였다. 무지외반증의 중증도는 방사선 영상 상 무지외반각 40도 이상을 중증, 20도 이상 40도 미만을 중등도, 20도 미만을 대조군으로 하였다. 발 분절의 운동 분석은 DuFM를 이용하였으며 분당걸음수, 보행 속도, 걸음길이, 걸음폭, 걸음시간, 입각기 비율과 같은 시간 보행 요소들을 계산하였다. 전체 걸음을 100으로 나눈 시점마다 발 분절간의 각도를 측정하였다. 그리고 전체 걸음 동안 발의 각 분절의 움직이는 각도를 계산하여 각 그룹끼리 비교하였다.

결과 : 인구통계학적 데이터에서 연령, 신장, 체중, BMI는 그룹간의 차이가 없었다. 시간 보행 요소에서 보행 속도와 걸음길이는

무지외반증의 중증도에 따라 감소하였다. 무지와 후족부의 시상축 운동범위가 중증 무지외반증 집단에서 유의하게 저하되었다. 그리고 중증 무지외반증 집단에서 전유각기 동안에 바닥의 밀어내는 힘의 상실과 입각기 종반에 전족부 내전이 감소되었다.

결론 : 무지외반증은 증증도에 따라서 걸음걸이의 여러 요소들과 발 분절간 움직임에 영향을 미친다. 하지만 걸음걸이와 발 분절간의 움직임에 영향을 줄 수 있는 교란인자에 대한 고려를 반드시 해야한다.

주요어 : 무지외반증, 보행분석, 발분절모델, 분절간 움직임

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