Effect of Hallux Valgus Deformity on Gait Phases and Lower Extremity Joints Angular Displacement in 50-60 Years Old Female during Gait

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Abstract

Introduction: Hallux valgus is a common lower extremity deformity especially in older women that affects gait kinematics and increases gait instability among them. How this deformity kinematically effects their gait has not thoroughly investigated carefully. Therefore, we wanted to know if there are differences in gait phases and angular displacement between elderly women with hallux valgus and their healthy peers during walking as a factor in independence. **Materials and Methods:** Participants in this study were 12 (54.25±2.76 years old) healthy and 12 older women with hallux valgus (54.5±3.25 years old). To evaluate the gait phases (percent) and angular displacement (degree) we use an IMU-based Motion Capture System to measure kinematics of motion. All modules were defined and fastened about hip, shank and foot. The MATLAB software version 2019 used respectively. For statistical analysis of data the Independent T-Test was used too. **Results:** The results showed that in older women with HV, during a gait cycle ankle joint angular displacement was significantly different ($P \leq 0.05$) in all planes (frontal: 45%, horizontal: 95% sagittal: 40%) (abduction/adduction: 45%, internal/external rotation: 95%, flexion/extension: 40%), whereas angular displacement was significantly different just in flexion/extension of knee joint (44% of gait cycle) and Flexion/extension and abduction/adduction of hip joint (10 & 8% of gait cycle) ($P \leq 0.05$). **Conclusion:** In older women with hallux valgus group ankle adduction was higher than healthy group, as well as toe out angle. Knee flexion was greater in older women with hallux valgus. Hip abduction and extension at the late swing phase were increased in hallux valgus elderly group. These significant differences probably indicate angular displacement of lower extremity is affected by hallux valgus deformity during gait in elder women.

Key Words: Elderly Women; Hallux Valgus; Kinematics; Lower Limb;

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Introduction

Hallux Valgus (HV) is a common and often progressive deformity characterized by a deviation of distal end of the hallux away from midline of body in a 15 degrees or greater (1-3). HV affects predominantly the female population with reported prevalence estimates ranging from 30% to 58% as opposed to 13-25% in men and 74% in elderly adults (1, 4). The risk factors of HV include aging, being female, increase in body weight, and wearing high heel shoes with narrow toe boxes (1, 5-7).

HV has negative effects on foot posture, gait function, balance and other joints of lower extremity and also increase the risk of falling (8-12). It has been reported knee osteoarthritis and foot pain in individuals with HV so that it may decrease their quality of life (13-16).

HV is related to functional joint centration failure in terms of postural ontogenesis. Due to a chain failure, one malfunctioning segment can cause overloading of other segments and change the movement pattern (17) Increase in stance duration and cadence, decrease in walking speed and stride length, has been reported in several studies (1, 18, 19).

Another vise some more previous studies have shown that HV has not had effect on gait phases (11, 20).

Older women with HV display reduced ankle dorsiflexion during terminal stance compared to controls (11). Reduced toe flexor strength (TFS) is an independent predictor of falling in elders (17).

Weight bearing reduction by big toe during gait is associated with more pressure under other toes and causing pain under little toe (21, 22). In other study has reported that in Older women with HV, stance phase was longer in comparison with control group, walking speed and step length (on regular/irregular surface) was less in individuals with HV however there was a more agreement on walking speed reduction (both young and old individuals) and speed reduction in young people (11, 23). Klugar *et al*. (17) reported that hip flexion is grater in hallux valgus group during a gait cycle compare to control group, they also reported the following results in HV group: less flexion of Knee and higher plantar flexion of ankle in initial stance phase, less dorsiflexion during stance phase, greater plantar flexion during loading respond of stance phase, and during swing phase valgus of knee, extension and abduction of hip were less whereas extension of knee and hip flexion were greater (24).

Typically, the lower limb joints are connected and move in a complex manner during walking. However, this is disrupted by HV, a foot disease that is likely to affect the lower extremities. An important step in the management of hallux valgus is the objective analysis of foot mechanics in dynamic conditions (25). Since the change of gait parameters related to HV is less studied, the aim of present study was to evaluate the probable changes of gait kinematics in dominant lower extremity of elder women with and without HV.

Materials and Methods

By Using G-power® in order to attain a power level of 0.80 for an effect size of 0.80 and alpha of 0.05, the sample size achieved 12 for each group. 24 women in two groups (with and without HV) participated in this study. Participants were interviewed and completed a consent form. HV deformity was established first by observation, then by using foot print. The entry condition to HV group included: deformity severity more than 20 degrees (26), no other deformity in lower extremity or sensible deformity in upper extremity such as scoliosis, right limb dominance, deformity symmetric (moderate HV with less than 5 degrees difference) in healthy groups: no deformity in lower extremities, no deformity in upper extremity (moderate to severe).

Ethics Committee of Sport Sciences Research Institute approved this research with Ethical code: IR.SSRI.REC.1401.1505.

IMU-based Motion Capture System (BSN lab, Iran, Gilan) was used to measure kinematics of motion (27). It includes some sensors (module) and traps with a packet to put the sensor in. Traps have 3 sizes (long, moderate and short) to fasten about limbs, near the joints. All modules were calibrated in advance then defined and fastened about right tight, shank and foot. Modules y-axis should be in a same direction with distal head of limbs. Their placements were on sagittal plane of tight, shank and horizontal plane of foot (27).

Modules position were transmitted to central processor in a 3- axis coordinate system (x, y, z) wirelessly. By using this system, joints kinematics, linear and angular velocity/acceleration and gait cycle were measurable and computable. While Participants were walking at self-selected speed, Gait biomechanical variables were assessed,

Each subject accomplished 2 trials to check the capturing then did the major trial with 5 gait cycles (without shoes). Middle steps (second or third) were used for analyzing and displaying angular displacement. Sampling rate frequencies was 333 Hz (3 m second intervals). Gait events (heel contact and toe off) were recognized by an algorithm in the IMU software. Angles (about sagittal, frontal and vertical axis) were extracted directly from output data. Data were normalized based on gait cycle percentage (101 points) by using Cubic Spline method in the MATLAB software (28).

Statistical analysis

Data analysis was done using MATLAB version 2019. Independent T-Test was used to statistically analyses of data.

Results

The significant level in this study was set as $P \leq 0.05$. Table1 shows the demographic findings and stance phase of the participants. We found no significant differences in variables: age, body bass, BMI and stance phase of subjects ($P>0.05$).

Figure 1 shows ankle angular displacement about frontal, vertical and sagittal planes during a gait cycle in both groups (with and without HV). Figure 1A indicates that abduction/adduction was significantly different during 36-70% and 88-97% of gait cycle. Figure 1B shows that ankle external/internal rotation angles were significantly different during 0-51% and 57-100% of gait cycle. Figure 1C shows that flexion/extension angular displacement was significantly different during 7-29%, 44-49 and 90-100% of gait cycle.

Table 1. Mean (SD) of participants age (year), weight (newton), height (centimeter), BMI (kg*m-2) and gait phases (percent)

Variables	older women with hallux valgus						
	Without HV			**With HV**			**P-value ≤0.05**
	Min	**Max**	**Mean (SD)**	**Min**	**Max**	**Mean (SD)**	
Height (cm)	155	164	160.12 (3.31)	154	166	159.25 (5.7)	0.71
Mass (Kilogram)	60	81	67.88 (7.07)	57	80	67.75 (8.73)	0.98
Age (year)	51	59	54.25 (2.76)	51	60	54.5 (3.25)	0.87
BMI (kg*m-2)	24.60	30.45	26.58 (6.98)	23.45	33.75	26.33 (10.14)	0.84
Stance Phase (percent)	55	62	59.62 (1.77)	53	62	58.62 (2.72)	0.4

Table 2. Illustrates joints angular displacement range of significant differences points during a gait cycle between healthy and hallux valgus groups in all planes. *Total points: sum of the significantly different points throughout a gait cycle

	Points of Significant differences during a gait cycle					
Movement Joints	**Abduction/ Adduction**		**External/Internal rotation**		**Flexion/ Extension**	
	Range	***Total Points**	**Range**	**Total Points**	**Range**	**Total Points**
Ankle	36-70 88-97	45%	0-51 57-100	96%	7-29 44-49 90-100	41%
Knee	none	0%	none	0%	0-33 91-100	44%
Hip	92-100	9%	none	0%	89-96	8%

Figure 2 shows knee angular displacement on frontal, vertical and sagittal planes. Figure 2A indicates that abduction/ adduction angular displacement is not significantly different between two groups as well as external/ internal rotation angular displacement in Figure 2B. But in Figure 2C, there are significant different points during 0-33% and 91-100% of gait cycle and sagittal planes during a gait cycle in two groups.

Figure 3 shows hip angular displacement about frontal, vertical and sagittal planes during a gait cycle in two groups. Figure 3A indicates that abduction/adduction angular displacements are significantly different during 91-100% of the gait cycle. We can see no significant different point between healthy and HV groups in Figure 3B which shows hip external/internal rotation angular displacement during a gait cycle. Figure 3C shows that flexion/extension angular displacements are significantly difference during 89-96% gait cycle.All Figures summarizations are observable in Table 2. It shows that during a gait cycle how many percent different points of angular displacement exist in the specific plane of a joint between healthy and older women with hallux valgus.

Discussion

We know that foot problems may compromise function, leading to mechanical instability (1, 13, 29). We aimed to evaluate the effect of hallux valgus deformity on gait phases and angular displacement of dominant lower extremity in elders' women.

Our results confirmed that ankle joint inversion of elders with HV (Figure 1) during 35-70% & 88-98% of the gait cycle was greater than healthy group. elders women with HV thorough the gait cycle especially during the terminal stance, pre-swing and initial swing phases (35-70% of the gait cycle) and also terminal swing phase (88-98% of the gait cycle) never set to eversion position That is different from Kozaková *et al.* (17) study and was similar to others studies (21, 22). Participants were screened in advanced for other foot deformities, so we prevent participant with pronated foot to take apart in to study, a point that has not been mentioned in previous studies and further researches are required.

Our results confirmed that thorough the gait cycle toe out angle of older women with HV was higher than women without HV and they walked in toe out position. When this characteristic is associated with increase in hip abduction angle during terminal swing (significant), initial contact and loading respond phases (not significant) and also ankle inversion, supports this idea that older women with HV try to enhance step width and base of support. That is in contrast with Hofmann *et al.* study (22), which investigated unilateral HV, and Shih *et al.* (4) with younger participants. Whereas Kim *et al.* (30) reported that there was a direct relationship between severity of HV and step width. Also, was similar to several researches which were about bilateral HV (11, 30, 31).

The results confirmed that plantar flexion during loading respond, mid-stance, a part of terminal stance and also terminal swing phases was greater in older women with HV compared to controls. Similarly, another study reported higher plantar flexion

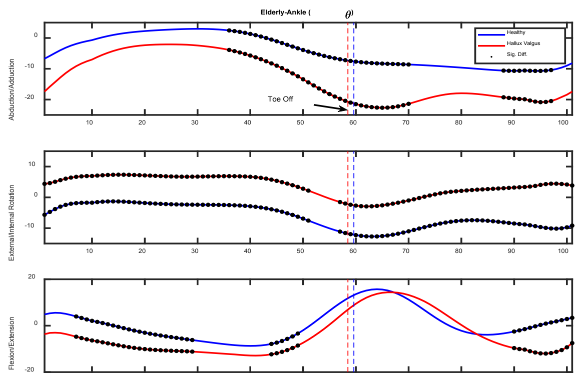

Figure 1. Shows ankle joint angular displacement in two groups (with and without HV); *A*) abduction/adduction angular displacement was significantly different during 36-70 and 88-97% of the gait cycle); *B*) External/ internal rotation angular displacement was significantly different during 0-51 and 57-100% of the gait cycle; *C*) Flexion/Extension angular displacement was significantly different during 7- 29, 44-49 and 50- 100% of the gait cycle. ($P \leq 0.05$)

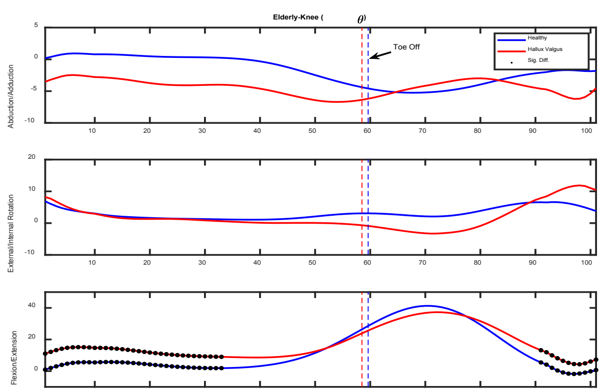

Figure 2. Compare knee angular displacement between groups (with and without HV) ; *A*) No significant difference was seen; *B*) No significant difference was seen; *C*) Flexion/Extension angular displacement was significantly different in 0-33 and 91-100% gait cycle. ($P \leq 0.05$)

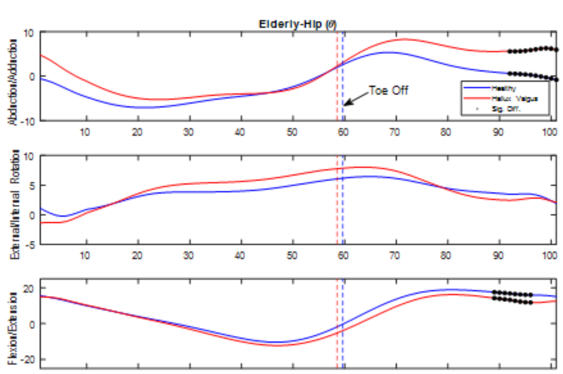

Figure 3. Compare hip angular displacement between groups (with and without HV; *A*) Abduction/Adduction angular displacement was significantly different during 92-100% gait cycle; *B*) No significant difference was seen; *C*) During 89-96% gait cycle, flexion/ extension was significantly different ($P \leq 0.05$)

during loading respond (17). According to our findings during pre-swing and toe off dorsiflexion angle increases. In Sagittal plane knee is more affected than hip. Table 2 exhibited that hip was just affected by HV during terminal swing phase whereas knee of HV older women flexed more than controls during initial contact, loading respond and mid-stance and also terminal swing phases. In fact, Knee of HV older women did not extend completely thorough the gait cycle. Studies have shown that people with HV suffer from secondary diseases such as knee osteoarthritis (13, 16).

Finally, our results confirmed, no changes were seen about duration of gait phases in older women with HV. According to previous studies HV is not associated with stance or swing phase of gait (11, 20).

Conclusion

Angular displacement of ankle joint was affected by Hallux Valgus in all planes. In sagittal plane knee was most affected. In horizontal plane no changes were seen in both knee and hip angular displacement of older women with HV compared to those without HV. Hip angular displacement had been decreased in frontal plane but HV deformity had no effect on gait phases.

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Ethical considerations

Ethics Committee of Sport Sciences Research Institute approved this research with Ethical code: IR.SSRI.REC.1401.1505.

Practical application of the study

These findings, alongside similar research, provide a collection of characteristics that can be used as a tool to trace the effectiveness of corrective exercises or balance-based programs, or even as a diagnostic tool to ensure the practical impact of this deformity in the hallux valgus population

Conflict of interest

None.

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Authors' contributions

All authors made substantial contributions to the conception, design, analysis, and interpretation of data.

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