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The Immediate Effects of Hallux Valgus Orthoses: A Comparison of Orthosis Designs

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Abstract

Background: Hallux valgus orthoses are available in a wide range of designs and materials, but the effects of their design on functional performance have not been fully investigated.

Research question: This present study aims to comprehensively analyze the immediate effects of soft and semi-rigid hallux valgus orthoses on balance, plantar pressure, hallux valgus angle, and subjective sensations.

Methods: Sixteen female subjects have participated in the study, including 10 subjects with healthy feet and 6 with hallux valgus. Three conditions are tested, including in the barefoot and using two types of commercially available hallux valgus orthoses. The subjects participate in static and dynamic (walking) tests with the use of the Novel Pedar® system. The peak pressure values in the hallux, lateral toes, first metatarsophalangeal joint, 2-4th metatarsal heads, 5th metatarsal head, medial midfoot, lateral midfoot and rearfoot in the various foot conditions are examined and compared. The hallux valgus angle of each subject is measured based on their footprint. Their subjective feelings towards the orthoses are also evaluated. A repeated-measures analysis of variance, and independent-sample t test are performed.

Results: The correction of the hallux valgus angle is statistically significant when the subjects with hallux valgus use the orthoses. In comparing the two types of orthoses, the use of the orthosis made of soft materials results in correction in the hallux valgus angle and higher wear comfort, and lower plantar pressure in hallux area.

Significance: The results provide insights into the design of hallux valgus orthoses, thus offering practical reference for the selection of hallux valgus orthosis with compromise between functional performance and wear comfort.

Keywords

Toes, Foot diseases, Plantar pressure, Angle correction

1. Introduction

Hallux valgus (HV) is a common progressive foot deformity that affects approximately 23% of adults and 35.7% of the elderly [1]. Females are more prone than males, with a ratio of 8:1 [2]. The severity of HV is related to the presence of subluxation of the first metatarsophalangeal (MTP) joint and osteoarthritis [3]. A hallux valgus angle (HVA) ≥15° is a formal diagnosis of HV, the HVA was categorized as normal (< 15°), mild (15–20°), moderate (21–39°), and severe (≥ 40°) [4]. HV is commonly associated with foot pain [5], which inhibits mobility and level of physical activity [6]. Gu et al. [7] compared the plantar pressure distribution of healthy females and patients with mild HV during walking. The latter show a significantly higher peak pressure in the hallux area when walking barefoot. Bryant et al. [8] found that the peak pressure in the lesser toes (MTP1-3) of HV participants increases significantly. The increase in plantar loading might be a cause of foot pain, and therefore deteriorates quality of life and activity level. Extreme cases require surgical intervention, but recurrence rate is high. Surgery can also limit the subsequent mobility of the hallux [6, 9]. Non-operative treatments such as using foot orthoses have been an important treatment modality to prevent progression of foot deformities and relieve foot pain [10]. Charrette [11] suggested that HV orthoses are a form of biomechanical support that reduces the pressure at the MTP to prevent further degeneration of mobility. Moulodi et al. [12] reported that foot orthoses correct the HV angle, reduce plantar pressure and pain.

Clinical choice of HV orthoses is subjective and usually a compromise between comfort and functional performance. Current HV braces are available in a wide range of design features and materials. They can be divided into with toe separators and without toe separators and made of different materials. They are generally made of rigid, soft, or combination of rigid and soft materials (i.e., semi-rigid). Materials such as polyamide, polyurethane gel, elastic bands, and neoprene foams are primarily used. Rigid and stiff materials generally align the foot by exerting corrective forces to designated regions, whilst soft and flexible materials provide wear comfort while protecting the soft tissues from stress and relieving pain. Even though orthotic material is essential for effective treatment, the effects and functional performance of the design and fabrication materials of HV orthoses have not been fully reported. Therefore, this study aims to compare the performance of a soft and a semi-rigid orthosis to examine the center of pressure (COP), plantar pressure distribution, HVA reduction, and perceived comfort through a wear trial. We hypothesize that as compared to the semi-rigid orthoses, wearing the soft orthoses can reduce HVA, COP and the peak plantar pressure in the hallux and metatarsal regions for HV participants with better comfort perception.

2. Methodology

2.1 Participants

A total of sixteen female subjects participated in the study, including ten subjects without HV and no significant foot or lower-limb problems during the 12 months that preceded the study, and six subjects with mild HV. The former was used as the benchmark. The selected subjects are 20 and 30 years old, with a shoe size of EU 35 to 39, no history of foot surgery, and have normal foot type (foot type index between 0.3 and 0.4). The inclusion and exclusion criteria were highly rigorous to isolate the effects of HV from other foot conditions. Those with additional forefoot pathology or experienced foot pain in the past month were excluded. Male were excluded because women in general are more prone to HV, and for uniformity of the subject characteristics. The demographic profiles are listed in Table 1. Only the data of the dominant foot were analyzed. Right foot dominance of the subjects without HV is 70%, while that of the HV subjects is 100%. The study was approved by the Human Ethics Committee of the Hong Kong Polytechnic University. The participants all provided written consent.

TABLE 1: Participant demographics

	Subjects without HV (N=10)		**HV subjects (N=6)**	
	Mean	**S.D.**	**Mean**	**S.D.**
Age	24.72	4.46	24.17	3.98
BMI	20.20	1.40	20.28	1.57
Shoe size	37.42	1.23	36.83	1.34
HVA	11.30	3.35	17.83	1.34
Foot length	22.10	0.69	21.42	1.33
Foot width	8.66	0.44	8.70	0.51
Arch width	3.06	0.47	3.15	0.30
Foot type index	0.35	0.04	0.36	0.03
Hallux dorsiflexion	47.30	10.93	52.00	16.31
Hallux plantarflexion	25.10	10.23	34.00	15.94

2.2 Orthosis features and materials

A semi-rigid HV orthosis (Sample A) and a soft day-use HV orthosis (Sample B) were purchased from the market. Sample A is constructed with polyamide Velcro, has a polyurethane gel cushion which offers suitable cushioning and support [13], and a splint with a solid polyamide hinge with reversal slits. The orthosis corrects the angle of the HV by realigning the hallux through the splint, which also allows dorsiflexion and plantarflexion of the hallux. Sample B is a soft orthosis with a powernet toe cover, elastic band and webbing. Powernet is a warp knitted fabric structure commonly used for pressure therapy garments and/or orthoses in clinical applications [14]. This orthosis corrects the angle of the HV by realigning the hallux with elastic webbing. The size was selected to accommodate the participants. Both enclose similar areas of the foot, including the hallux and arch, but use different materials and designs. The experimental conditions and construction of the two orthoses are shown in Figures 1a and 1b. The type of orthosis material is critical as it can affect gait characteristics and plantar pressure distribution [15, 16]. Therefore, comprehensive tests were done on the material properties of the two orthoses. ASTM D737-96 standard was used to determine the air permeability, KES-FB Thermo Labo to test the thermal conductivity, ISO 20932 standard to determine the tensile extension, and the Kawabata evaluation system of fabric to determine the surface properties including friction and roughness [17].

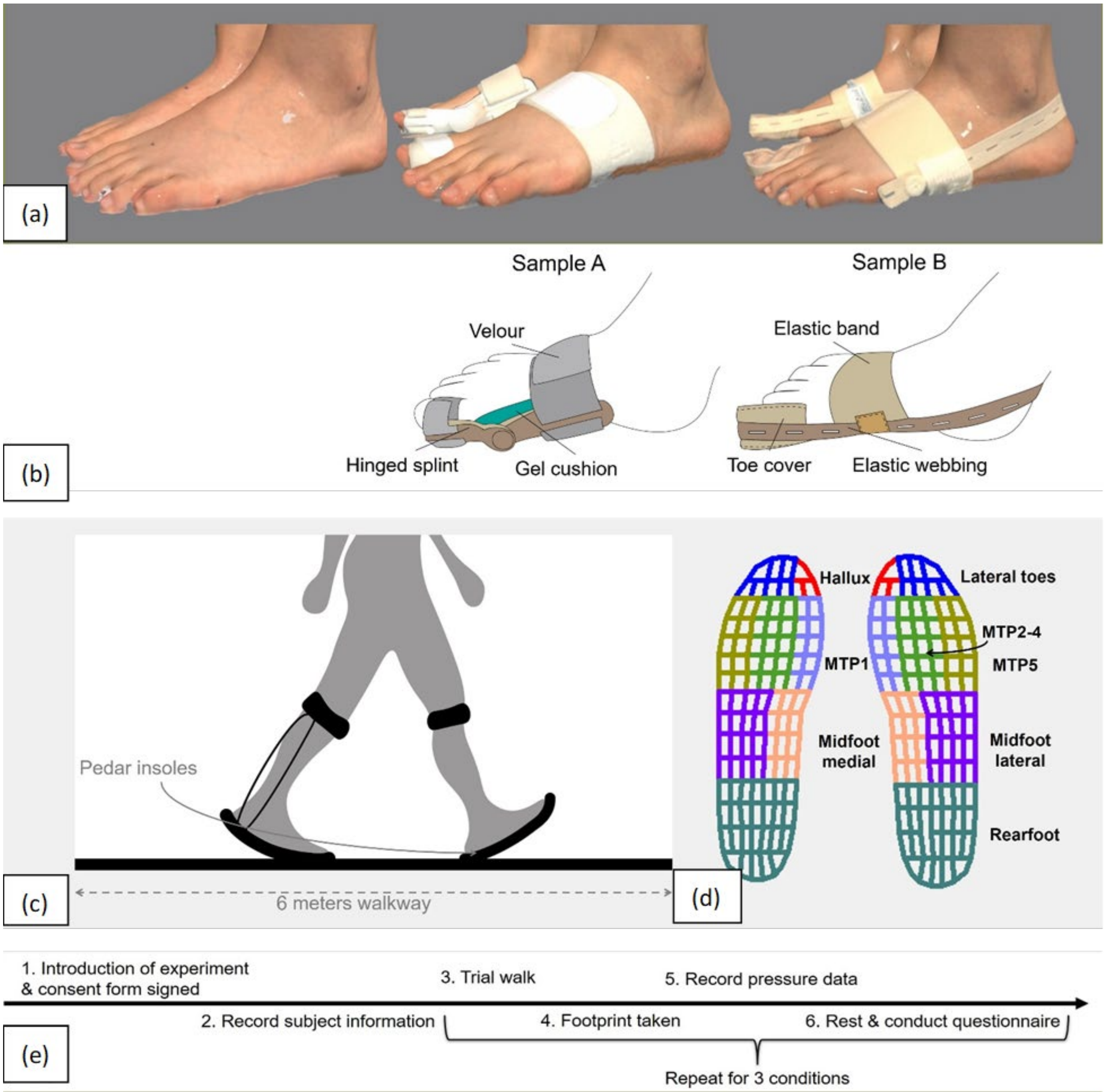

FIGURE 1: (a) Experimental conditions including barefoot, and wearing Samples A and B, (b) design features and materials, (c) schematic of experimental set-up, (d) regions of plantar pressure analysis, and (e) flow of experiment

2.3 Experimental procedure

Each subject conducted a trial walk for each experimental condition for acclimatization purposes (Figure 1e). Then, two-dimensional footprints were collected in a weight-bearing standing posture with a podograph. Foot length, width and angle were measured on subjects' footprint. After that, subjects were asked to stand for 30 seconds and walk on the floor with a flat surface to measure plantar pressure distribution. A straight line of six meters of tape was adhered to the floor as the reference line [18]. Figure 1c shows the schematic of the experimental set-up. Each subject underwent three successful trials to ensure data consistency.

To uniformly and accurately measure the forefoot pressure and COP, the Pedar-X1 analysis program (Novel GmbH, Munich, Germany) and a pair of Pedar® insole sensors (EU size 36/37) were used [19]. The Pedar system can also provide accurate and reliable measurement results as compared with force plate, with advantage that it can be masked to pay specific attention to the forefoot area [20, 21]. The Pedar® insoles were calibrated prior to the experiment by using a standard protocol and adhered to the foot with thin double-sided adhesive tape. Measurements were recorded at a frequency of 50 Hz.

The peak pressure of 8 regions of the foot was examined, including the hallux, lateral toes, MTP1, MTP2-4, MTP5, medial and lateral midfoot and rearfoot (Figure 1d). The location of the COP was recorded as X–Y coordinates [22]. After each test condition, the subjects were given a break to prevent muscle fatigue [23]. During the rest, subjects were asked to complete a survey on the subjective feeling of the orthoses, including the ease of wear, comfort, fit, acceptability, and satisfaction. A simplified 10-point visual analog scale was used with level 1 'Not comfortable at all' to level 10 'Most comfortable imaginable' [24]. The importance of price, durability, function, comfort, and appearance was also ranked. Each experiment took around 90 minutes.

2.4 Data and statistical analysis

Measurements during both walking and standing were taken. The upper and lower outliers were identified and excluded from the result. The plantar side of the foot was examined for the pressure distribution, and the maximum peak pressure was obtained for each of the 8 regions. To eliminate the influence of acceleration and deceleration during the initiation and termination of each walking trial, the first and last two steps were excluded [25]. A statistical analysis was performed with SPSS v.24 (IBM Corp., Armonk, New York). A repeated-measures analysis of variance (rANOVA) was conducted to compare the mean difference between wearing orthoses and barefoot conditions to test the effects of the two orthose. The Bonferroni test adjust the probability for multiple comparisons. Sidak pairwise comparisons were performed to compare the mean difference between (1) barefoot and sample A, and (2) barefoot and sample B. Independent-samples t tests were performed to compare the differences between the subject groups under each condition. The alpha level was set to 0.05.

3. Results

3.1. Material properties

The material test results are presented in Table 2. All the Sample A components are thicker and heavier, so its total weight is twice that of Sample B. The thickness of the side of the MTP1 of Sample B with elastic webbing is only 0.98 mm, while that of Sample A with a gel cushion and hinge splint is 4.99 mm. Sample A requires wearing loose fitting shoes which might cause injury. Sample A is secured with Velcro, and Sample B with an elastic band, which has high air resistance (12.33 kPa·s/m) and therefore poor air permeability. It is tightly woven, and air cannot easily pass through during wear. The powernet toe cover (0.04 W/mk) and the elastic band (0.05 W/mk) have high thermal conductivity, which offers good conductive cooling. On the other hand, the thermal conductivity of the polyamide Velcro (0.02 W/mk) is relatively low, which offers relatively poor thermal comfort. Under a maximum load, the fabric extension of Velcro is low (48.86 mm), therefore, it is less elastic and stretchable. In contrast, the elastic band (99.86 mm) and elastic webbing (100.04 mm) better promote the wear and fit of the orthosis. Lastly, the toe cover and elastic band material of Sample B have higher surface friction and roughness than the Velcro of Sample A in both the warp and weft directions, which contributes to a poor hand feel and rough contact with the skin.

TABLE 2: Experimental Parameters

	Sample A	Sample B
Place of origin	Germany	Hong Kong
Size	EU 36-45	Free size
Components & materials	Polyamide Velcro, Polyurethane gel cushion, Polyamide hinged splint with reversal slits	Powernet toe cover, Elastic band, Button-hole elastic webbing
Design features	Combination of soft-hard materials	Soft material
Mechanism	Align hallux by adjusting the Velcro	Align hallux by adjusting the webbing
Usage	Day Use, Suitable for mild and moderate HV	Day Use, Suitable for mild HV
Thickness (mm)	Velcro: 3.10 Gel cushion: 2.54 Hinged splint: 2.45	Toe cover: 0.41 Elastic band: 2.35 Elastic webbing: 0.98
Weight (g)	31.59	14.17
Air resistance (kPa·s/m) **ASTM D737-18**	Velcro: 3.10	Toe cover: 0.06 Elastic band: 12.33
Thermal conductivity (W/mk) **JIS L 1927**	Velcro: 0.02	Toe cover: 0.04 Elastic band: 0.05
Tensile extension at Maximum Load (mm) **ISO 20932**	Velcro: 48.86	Elastic band: 99.86 Elastic webbing: 100.04
Surface friction (MIU)	Velcro (weft/warp): 0.26/ 0.37	Toe cover (weft/warp): 0.34/ 0.46 Elastic band (weft/warp): 0.37/ 0.34
Surface roughness (SMD)	Velcro (weft/warp): 4.14/ 0.75	Toe cover (weft/warp): 16.35/ 1.03 Elastic band (weft/warp): 9.10/ 8.01

3.2 COP and plantar pressure

The range of the COPx (medial-lateral direction) and COPy (anterior-posterior direction) values were calculated and are shown in Table 3. Compare with the barefoot condition, when walking in sample B ($p = 0.002$), the COPx range of HV subjects increased significantly. The peak plantar pressures of the two groups during walking and standing are shown in Figure 2. The result showed that HV subjects wearing sample B had lower pressure in the hallux area during standing. When they walked wearing sample A and sample B, the pressure was significantly higher in the lateral area of the midfoot (p = 0.013 and p = 0.031, respectively). When subjects without HV walked with sample A, the pressure in the hallux area increased significantly (p = 0.004), and when they stood, the pressure of MTP2-4 decreased significantly (p = 0.005).

TABLE 3: Comparison of COP between subjects without HV and HV subjects

		Static Standing Test		**Dynamic Walking Test**	
		Subjects without HV (N=10)	**HV subject (N=6)**	**Subjects without HV (N=10)**	**HV subject (N=6)**
Range of COPx (mm)	**Barefoot**	2.03	2.25	17.05	15.51
	Sample A	1.66	3.45	15.77	20.72
	Sample B	2.07	3.37	18.48	29.96
Range of COPy (mm)	**Barefoot**	17.73	14.34	103.45	94.88
	Sample A	17.47	20.39	105.97	91.19
	Sample B	16.72	23.87	108.03	129.37

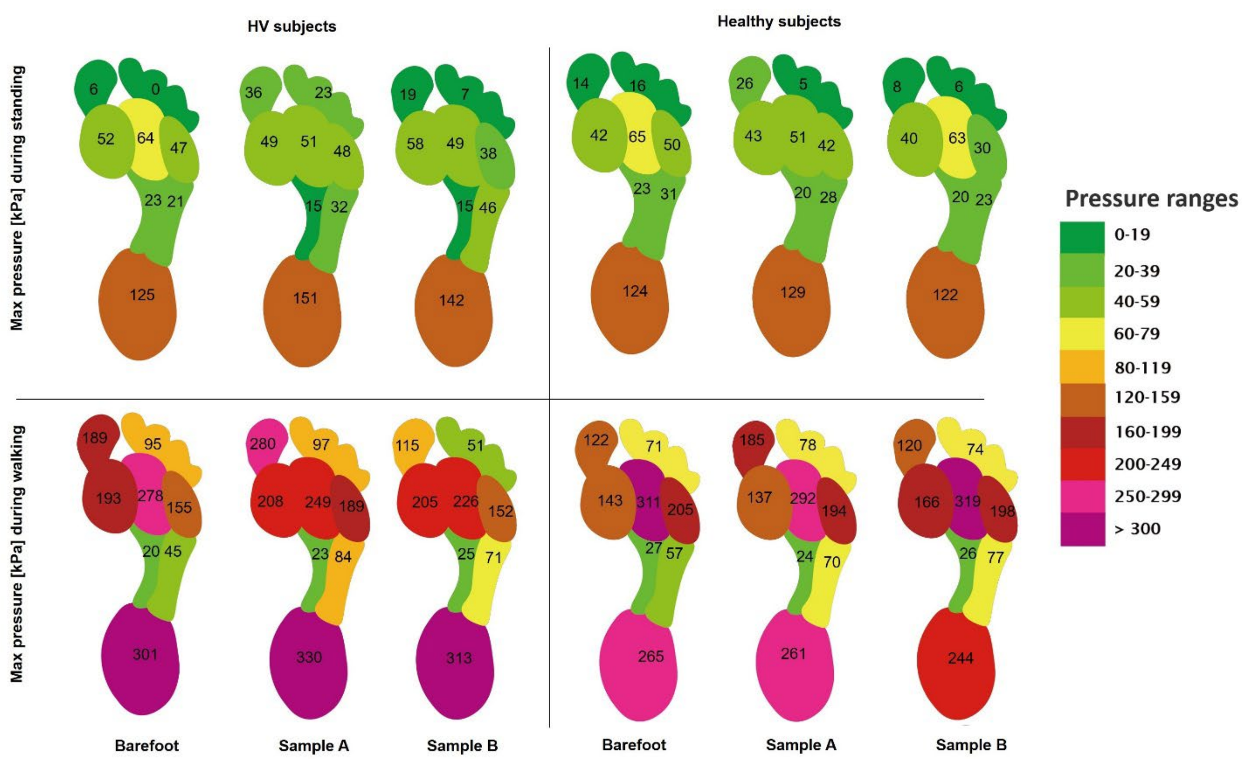

FIGURE 2: Plantar pressure distribution during standing and walking

3.3 Changes in HVA

Compared to the barefoot condition, the HVA of the subjects without HV reduced 1.2 degrees with Sample A and significantly reduced 2.7 degrees with Sample B ($p = 0.005$). The HVA of the HV subjects reduced 2.5 degrees with Sample A and 4 degrees with Sample B. Comparing the HVA of the two subject groups, it was found that the HVA after wearing Sample A and Sample B were significantly different ($p = 0.014$ and $p = 0.005$, respectively).

3.4 Subjective evaluation of orthoses

Among the 16 subjects in the study, the average scores for ease of wear, comfort, fit, acceptability, and satisfaction of the two samples were 6.49 (sample A) and 7.18 (sample B), respectively. Sample B excels Sample A in comfort, which may be attributed to the soft and lightweight materials used. In addition to the rating, participants provided negative feedback on the design and material fabrication of the orthoses, including the poor fit of sample A, inflexible joint design, rough hand feel, and the use of non-breathable materials that adversely affect the overall comfort, acceptability, and satisfaction of the orthoses. It is also noted that the toe cover of sample B increases the friction between the hallux and the second toe, itchiness of the foot arch, and difficulties in donning the contraption. Function, comfort, and price are considered as the most important parameters when a HV orthosis is prescribed.

4. Discussion

4.1 Orthosis designs and materials

Conventionally, rigid orthotic materials enhance support, but also lower tolerance during wear while soft and flexible materials do not correct underlying foot problems. Nevertheless, we show that orthoses made of soft, thin, and light-weight materials reduce the HVA more than semi-rigid materials. The comfort of soft materials was also well recognized by the subjects. Elastic bands also accommodate various foot sizes and shapes. Considering the prolonged use of an orthosis and its intimate contact with the skin, soft and smooth textile materials should be used to minimize the friction between the orthosis and the foot, hence avoiding itching and enhancing wear comfort.

4.2 Physical balance and body loading

Balance control is essential for daily activities with important clinical implications. Machado et al. showed that the risk of falls of the elderly is related to COPx measurements [26]. A large COPy range may also lead to imbalance. Inability to maintain one's center of gravity within base of support results in falls [27]. The range of COPx measurement increased when the orthosis B is worn, adversely affecting the postural balance of the subjects. The increased COPx may associate with the displacement of the orthosis during walking. The foot therefore becomes more unstable and tends to exert greater effort to "correct" the COP back to a neutral position with increased the plantar pressure in the midfoot lateral region.

Plantar pressure is also an indicator of foot function during gait. Previous studies have shown that compared to controls without HV, HV patients show a significantly higher peak pressure in the hallux when walking barefoot [7, 28] caused by the deviation of the first ray angle, which causes foot pain and adaptive changes in gait [28]. Here, the peak pressure relieving performance of both orthoses is poor during walking. Without additional support of the arch region, both orthoses fail to better distribute the body load by increasing the total contact area between the foot and orthosis and relieving the excessive pressure at the forefoot [29]. A full-length insole with an arch support can effectively distribute the plantar pressure [14]. When the subjects used the orthoses, lateral component slip to the plantar side of MTP1 and hallux. Extra plantar pressure may be exerted. This problem is more obvious with Sample A, which has a thicker and cumbersome design. Thinner materials should be therefore used.

4.3 Angle correction and comfort

Orthotic wear reduced the HVA of the HV subjects by more than 2 degrees. The results of Sample A align with Moulodi et al. [12] who found that their orthosis reduces the HVA by 2 to 3 degrees after a month of continuous use. Interestingly, the correction is significantly more obvious with Sample B. Study also suggest that softer materials have less mechanical constraint compared to semi-rigid materials. Kim and Won [30] who compared a conventional ankle-foot orthosis with an elastic band-type orthosis for the range of motion of the ankle and knee joint angles during gait found that the latter can perform just as effectively to realign the foot. The subjective assessment result in this study shows that function and comfort are priorities. Similar results are also found in [30] in which the soft orthosis has a higher wear comfort.

4.4 Limitations and recommendations

The generalizability of the results in this preliminary study may be limited by a relatively small sample size and the difference in the number of participants in each group. Only the maximum peak pressure and COP of the orthosis are examined while neglecting other measurements, such as contact area and force-time integral.

5. Conclusion

This study finds that HV orthoses could cause wear discomfort, and increased COP. However, a soft orthosis provides greater HVA correction, more wear comfort, and reduces the plantar pressure at the hallux. Soft, thin, and smooth flexible materials should be adopted in future orthosis designs. The results can not only be used as a reference for choosing HV orthoses, but also point out the design limitations of current orthosis and provide suggestions on future advanced design.

Highlights

- Soft orthoses offer higher reduction of HVA as compared to semi-rigid orthoses.
- Material properties of HV orthoses might cause wear discomfort.
- Thin and skin-friendly fabrics are recommended to optimize orthosis design.
- An increase in body sway was found when orthoses is used.

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Declaration of Competing Interest

All authors have no conflicts of interest to declare.

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Supplementary material

I. Results of Independent-Samples T Test

	N	p	Mean difference
Sample A- walking pressure- hallux	16	0.110	-95.47
Sample A- walking pressure-lateral toe	16	0.283	-19.90
Sample A- walking pressure- MTP 1	16	0.153	-71.19
Sample A- walking pressure- MTP 2-4	16	0.520	43.41
Sample A- walking pressure- MTP 5	16	0.870	4.45
Sample A- walking pressure- midfoot medial	16	0.848	-0.81
Sample A- walking pressure- midfoot lateral	16	0.875	-14.43
Sample A- walking pressure-rearfoot	16	0.029*	-68.59
Sample B- walking pressure-hallux	16	0.600	5.28
Sample B- walking pressure- lateral toe	16	0.314	23.06
Sample B- walking pressure- MTP 1	16	0.092	-38.97
Sample B- walking pressure- MTP 2-4	16	0.203	92.70
Sample B- walking pressure- MTP 5	16	0.061	46.20
Sample B- walking pressure- midfoot medial	16	0.485	1.63
Sample B- walking pressure- midfoot lateral	16	0.481	6.21
Sample B- walking pressure- rearfoot	16	0.071	-69.23
Barefoot-walking pressure- hallux	16	0.236	-66.87
Barefoot- walking pressure-lateral toe	16	0.471	-23.81
Barefoot- walking pressure- MTP 1	16	0.414	-50.56
Barefoot- walking pressure- MTP 2-4	16	0.465	32.66
Barefoot- walking pressure- MTP 5	16	0.109	50.38
Barefoot- walking pressure- midfoot medial	16	0.222	6.90
Barefoot- walking pressure- midfoot lateral	16	0.224	12.43
Barefoot- walking pressure-rearfoot	16	0.191	-35.52
Sample A- standing pressure-hallux	16	0.516	-10.33
Sample A- standing pressure- lateral toe	16	0.577	-18.25
Sample A- standing pressure- MTP 1	16	0.572	-6.42
Sample A- standing pressure- MTP 2-4	16	0.323	-0.83
Sample A- standing pressure- MTP 5	16	0.079	-6.42
Sample A- standing pressure- midfoot medial	16	0.470	4.58
Sample A- standing pressure- midfoot lateral	16	0.337	-4.08
Sample A- standing pressure- rearfoot	16	0.279	-22.50
Sample B- standing pressure-hallux	16	0.760	-10.75
Sample B- standing pressure-lateral toe	16	0.822	-1.33
Sample B- standing pressure- MTP 1	16	0.196	-17.92
Sample B- standing pressure- MTP 2-4	16	0.303	14.25
Sample B- standing pressure- MTP 5	16	0.419	-7.75
Sample B- standing pressure-midfoot medial	16	0.273	5.17
Sample B- standing pressure-midfoot lateral	16	0.191	-23.25

Sample B- standing pressure-rearfoot	16	0.357	-20.08
Barefoot- standing pressure- hallux	16	0.643	7.83
Barefoot- standing pressure-lateral toe	16	0.620	15.58
Barefoot- standing pressure- MTP 1	16	0.258	-10.58
Barefoot- standing pressure- MTP 2-4	16	0.948	1.25
Barefoot- standing pressure- MTP 5	16	0.706	3.17
Barefoot- standing pressure- midfoot medial	16	0.634	0.75
Barefoot- standing pressure- midfoot lateral	16	0.623	10.25
Barefoot- standing pressure-rearfoot	16	0.455	-1.08
Sample A -standing - COPx	16	0.033	-1.79
Sample B -standing - COPx	16	0.134	-1.30
Barefoot-standing-COPx	16	0.384	-0.22
Sample A -standing - COPy	16	0.289	-2.92
Sample B -standing - COPy	16	0.005**	-7.15
Barefoot-standing-COPy	16	0.565	3.39
Sample A -walking - COPx	16	0.068	-4.95
Sample B -walking - COPx	16	0.027*	-11.48
Barefoot-walking-COPx	16	0.097	1.54
Sample A -walking - COPy	16	0.469	14.79
Sample B -walking - COPy	16	0.186	-21.34
Barefoot-walking-COPy	16	0.666	8.57
Sample A HVA	16	0.014*	-5.23
Sample B HVA	16	0.005**	-5.23

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

II. Results of rANOVA

	HV subjects			Subjects without HV		
	F	**p**	**η_p^2**	**F**	**p**	**η_p^2**
Walking pressure- hallux	6.901	0.013*	0.580	10.490	0.001**	0.538
Walking pressure-lateral toe	2.660	0.119	0.347	0.182	0.721	0.020
Walking pressure- MTP 1	2.988	0.096	0.374	1.130	0.345	0.112
Walking pressure- MTP 2-4	0.907	0.435	0.153	1.328	0.290	0.129
Walking pressure- MTP 5	3.436	0.073	0.407	0.502	0.613	0.053
Walking pressure- midfoot medial	0.178	0.840	0.034	0.976	0.396	0.098
Walking pressure- midfoot lateral	2.301	0.151	0.315	3.874	0.057	0.437
Walking pressure-rearfoot	2.688	0.116	0.350	0.141	0.869	0.015
Standing pressure-hallux	2.158	0.166	0.301	1.843	0.187	0.170
Standing pressure- lateral toe	1.816	0.212	0.266	1.255	0.314	0.201
Standing pressure- MTP 1	1.063	0.381	0.175	0.279	0.759	0.030
Standing pressure- MTP 2-4	1.086	0.374	0.178	6.504	0.007**	0.420
Standing pressure- MTP 5	2.657	0.119	0.347	3.046	0.107	0.253
Standing pressure- midfoot medial	0.798	0.477	0.138	0.253	0.779	0.027
Standing pressure- midfoot lateral	3.195	0.127	0.390	3.074	0.110	0.255
Standing pressure- rearfoot	0.298	0.749	0.056	0.174	0.841	0.019
Standing - COPx	0.888	0.397	0.151	17.045	0.001**	0.773
Standing - COPy	1.289	0.309	0.205	2.335	0.147	0.318
Walking - COPx	12.622	0.002**	0.716	0.783	0.465	0.080
Walking - COPy	1.493	0.271	0.230	0.106	0.853	0.012
HVA	3.621	0.066	0.420	3.270	0.061	0.267

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

III. Results of Pairwise Comparisons

	HV subjects			Subjects without HV		
	N	**p**	**Mean difference**	**N**	**p**	**Mean difference**
Sample A- walking pressure- hallux	6	0.070	91.05	10	0.004**	62.45
Sample A- walking pressure-lateral toe	6	0.910	2.30	10	0.432	7.18
Sample A- walking pressure- MTP 1	6	0.508	14.99	10	0.306	-5.64
Sample A- walking pressure- MTP 2-4	6	0.691	-28.57	10	0.256	-18.82
Sample A- walking pressure- MTP 5	6	0.313	34.38	10	0.351	-11.53
Sample A- walking pressure- midfoot medial	6	0.352	2.97	10	0.183	-2.74
Sample A- walking pressure- midfoot lateral	6	0.013*	39.11	10	0.580	13.50
Sample A- walking pressure-rearfoot	6	0.117	28.52	10	0.746	-3.55
Sample B- walking pressure-hallux	6	0.233	-74.41	10	0.072	-1.73
Sample B- walking pressure- lateral toe	6	0.129	-44.49	10	0.770	3.19
Sample B- walking pressure- MTP 1	6	0.126	12.48	10	0.855	23.07
Sample B- walking pressure- MTP 2-4	6	0.350	-52.13	10	0.641	7.92
Sample B- walking pressure- MTP 5	6	0.352	-2.80	10	0.456	-6.98
Sample B- walking pressure- midfoot medial	6	0.819	4.83	10	0.441	-1.28
Sample B- walking pressure- midfoot lateral	6	0.031*	26.00	10	0.130	19.83
Sample B- walking pressure- rearfoot	6	0.659	12.21	10	0.623	-20.51
Sample A- standing pressure-hallux	6	0.067	30.42	10	0.746	12.25
Sample A- standing pressure- lateral toe	6	0.326	22.83	10	0.822	-11.00
Sample A- standing pressure- MTP 1	6	0.493	-2.92	10	0.585	1.25
Sample A- standing pressure- MTP 2-4	6	0.827	-13.08	10	0.005**	-14.00
Sample A- standing pressure- MTP 5	6	0.104	0.83	10	0.083	-7.75
Sample A- standing pressure- midfoot medial	6	0.248	-8.08	10	0.181	-3.10
Sample A- standing pressure- midfoot lateral	6	0.059	11.25	10	0.799	-2.50
Sample A- standing pressure- rearfoot	6	0.890	26.08	10	0.648	4.50
Sample B- standing pressure-hallux	6	0.787	13.33	10	0.181	-6.25
Sample B- standing pressure-lateral toes	6	1.000	7.00	10	0.623	-10.24
Sample B- standing pressure- MTP 1	6	0.471	5.83	10	0.901	-1.50
Sample B- standing pressure- MTP 2-4	6	0.235	-15.00	10	0.644	-2.00
Sample B- standing pressure- MTP 5	6	0.321	-9.58	10	0.107	-20.00
Sample B- standing pressure-midfoot medial	6	0.371	-7.75	10	0.181	-3.07
Sample B- standing pressure-midfoot lateral	6	0.096	25.00	10	0.641	-7.50
Sample B- standing pressure-rearfoot	6	0.555	17.25	10	0.721	-1.75
Sample A -standing - COPx	6	0.229	1.20	10	0.736	-0.36
Sample B -standing - COPx	6	0.982	1.12	10	0.010*	0.04
Sample A -standing - COPy	6	1.000	6.05	10	1.000	-0.26
Sample B -standing - COPy	6	0.431	9.53	10	0.206	-1.01
Sample A -walking - COPx	6	0.312	5.21	10	1.000	-1.28
Sample B -walking - COPx	6	0.002**	14.46	10	1.000	1.43
Sample A -walking - COPy	6	1.000	-3.69	10	1.000	2.52
Sample B -walking - COPy	6	0.562	34.49	10	1.000	4.57
Sample A HVA	6	0.140	-2.50	10	0.343	-1.20
Sample B HVA	6	0.076	-4.00	10	0.005**	-2.70

Note. * $p < .05$, ** $p < .01$, *** $p < .001$