Does wearing high heels put the ankle at risk? Three-dimensional distance mapping assessment of the syndesmotic space in non-frequent high heel wearers

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INTRODUCTION: High heels have been a prevalent shoe choice across the globe for decades, both in professional and social scenarios. However, medical experts have frequently claimed that wearing HH can have negative repercussions for the forefoot, potentially leading to the development of hallux valgus deformity. In addition to forefoot concerns, the specific impact of HH on the ankle joint remains an understudied area. In recent times, the utilization of weightbearing computed topography (WBCT) has shown great promise in examining the talar and distal tibiofibular syndesmosis (DTFS) regions. WBCT enables analysis of instability under physiological load, shedding light on typical patterns of syndesmotic injury. Nevertheless, it is important to note that the detection of subtle syndesmotic instability in a static weightbearing (WB) position has proven to be challenging. This detection requires application of external torque or controlled dorsiflexion/plantar flexion. Given that HH wearing inherently involves dorsiflexion, it may lead to ankle instability. Furthermore, prior research has established a correlation between varus hindfoot alignment and the narrowing of the DTFS. As wearing HH leads to increased hindfoot varus, a relative reduction in DTFS width might be anticipated.
The primary objective was to study HH wearing at various HH heights through the utilization of an advanced three-dimensional distance mapping algorithm. We hypothesize that as HH increases, DTFS widening will decrease due to both increased hindfoot varus and increased dorsiflexion.

METHODS: In this study, 20 healthy volunteers received a total of 4 bilateral WBCT scans: (1) control/no heel, (2) 3cm high heel, (3) 6 cm heel, (4) 9cm heel. Scans were semi-automatically segmented to create three-dimensional bone mesh models using a commercially available software package. Segmentations were cleaned and confirmed by an expert in the field. Manual selection of the medial gutter, lateral gutter, and talar dome was performed by two readers. To decrease measurement variability, both the segmented bone models and articulating selections were transformed to each consecutive HH height. As scan quality decreased with increased HH height (field of view decreased), this transform allowed for complete assessment of the DTFS space regardless of HH height. Distance mapping was used to evaluate DTFS widening in the first 1cm, 3cm, and 5cm from the joint after injury (Figure 1). Syndesmotic distances were defined as the average normal direction from the tibial subchondral surface to the surface of the distal fibula. DTFS narrowing was found by finding the difference in DTFS widening at each HH height compared to the control. Differences were assessed statistically using paired t-test and ANOVA tests to assess differences between groups. P values < 0.05 were considered significant.

RESULTS: When assessing the entire DTFS space, DTFS widening was significantly decreased for the 3cm HH, but was significantly increased for the 6cm and 9cm HH ($p < 0.001$. Additionally, when assessing specific distances above the ankle joint (1cm, 3cm, and 5cm), significant decreases in DTFS width was found at 1cm and 3cm from the ankle joint at all HH height ($p < 0.01$). 5cm from the ankle joint, a significant decrease was found for the 3cm and 6cm HH. No significant narrowing was present in the anterior and posterior regions of the DTFS space, in their entirety. However, when looking at specific anterior/posterior regions, significant decreases in anterior DTFS width was found at a level 3cm proximal to the ankle joint in the 6cm HH ($p = 0.02385$) and at 1cm and 3cm levels for the 9cm HH ($p = 0.0239$ and $p = 0.01133$, respectively). Results are summarized in Figure 1.

DISCUSSION: In this study, DTFS widening was assessed for non-frequent HH wearers to understand the possible impact HH wearing has on the hindfoot. As previous claims have primarily been in regard to the forefoot, it was of great interest to understand the possible negative implications that HH wearing has on the hindfoot. Our results demonstrate significant narrowing across the DTFS space for all HH heights. This conclusion is likely due to the hindfoot entering increased varus while wearing HH, but future research is needed to correlate hindfoot alignment to DTFS narrowing in HH wearers. While narrowing may not be inherently bad for the ankle, previous studies have demonstrated higher likelihood of subtle injury for decreased DTFS/hindfoot varus. This narrowing could also be caused by increased dorsiflexion. However, as the amount of dorsiflexion varied person-to-person due to possible differences in foot size, more research is also needed to find the relationship between DTFS narrowing and dorsiflexion. Additionally, our results found that narrowing was focused anteriorly. In conclusion, our results demonstrate the HH wearing puts significant stress on the ankle, regardless of high heel height. Precautions should be taken by those with a history of chronic ankle instability prior to wearing HH. Future research on frequent HH wearers may demonstrate the effects of frequent ankle instability.

SIGNIFICANCE/CLINICAL RELEVANCE: This study aims to understand the possible negative impact on ankle joint stability when wearing high heels. This study may provide guidance for physicians when explaining the possible risks of HH wearing, as no study has provided an objective analysis to support previous claims.

Whole DTFS

Heel Height Comparison	Measurement Height	p-value (Welch Two Sample t-test)
0cm vs 3cm	overall mean	0.0006057
	1cm	2.76E-14
	3cm	<2.2e-16
	5cm	1.29E-08
0cm vs 6cm	overall mean	0.8157
	1cm	<2.2e-16
	3cm	<2.2e-16
	5cm	1.09E-10
0cm vs 9cm	overall mean	0.001817
	1cm	<2.2e-16
	3cm	<2.2e-16
	5cm	1.38E-08

Anterior

Heel Height Comparison	Measurement Height	p-value (Welch Two Sample t-test)
0cm vs 3cm	overall volume	0.5939
	1cm	0.1553
	3cm	0.07686
	5cm	0.1736
0cm vs 6cm	overall volume	0.9892
	1cm	0.09814
	3cm	0.02385
	5cm	0.1424
0cm vs 9cm	overall volume	0.5843
	1cm	0.0239
	3cm	0.01133
	5cm	0.1667

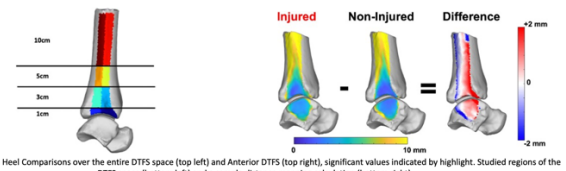

Figure 1: High Heel Comparisons over the entire DTFS space (top left) and Anterior DTFS (top right), significant values indicated by highlight. Studied regions of the DTFS space (bottom left) and a sample distance mapping calculation (bottom right)