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Mechanical Hysteresis Performance of Athletics Track Spikes

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Introduction

Evidence suggests that modern track spikes with advanced footwear technology (AFT) produce faster running times [1-3]. These spikes typically feature lightweight, compliant midsole foams and increased longitudinal bending stiffness; there is often substantial variation within a single brand. Recent results on advanced footwear road shoes showed similar polyether block amide (PEBA) foam compliance but with the addition of a carbon plate providing significant increases in flexural stiffness [4] Figure 1. This study reports the results of biomechanical testing of midsole compliance and bending stiffness using cyclic loading to focus on mechanical hysteresis and energy losses in Track spikes.

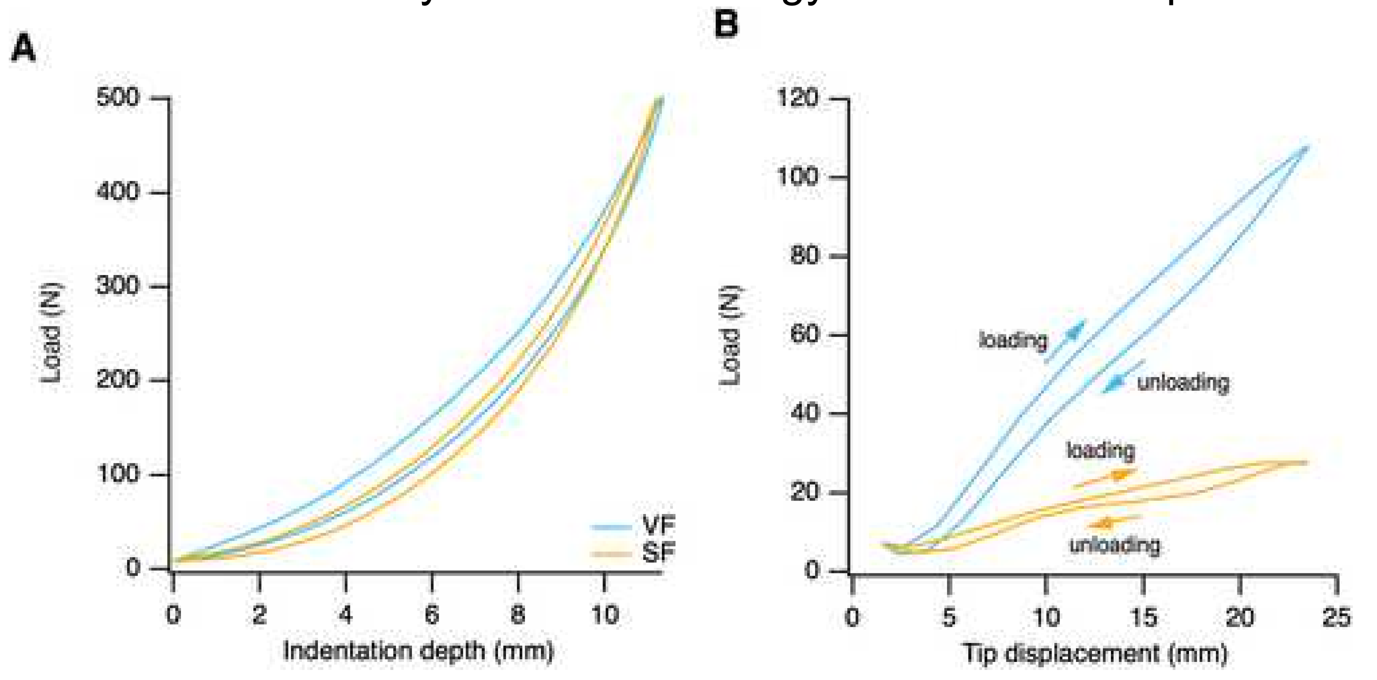


Figure 1. Past results for Road Shoes [4] showing significant variation in indentation (A) and Flexion (B) for Vaporfly (VF) vs Streakfly (SF).

Methods

Five Nike running spikes were compared: All shoes had a single Pebax spike plate outsole, Zoom MambaV6 (2023), ZoomX Dragonfly (2021), ZoomX Dragonfly (after heavy use) and Zoom Mamba V3 after moderate use. The Air ZoomX Victory2 (2024) had an additional carbon insole.

Discussion

In indentation there was a 3-fold variation in midsole compliance across the range of spikes likely linked directly to the thickness of the PEBA foam. Hysteresis was inversely proportional to foam thickness. The multi layered Victory 2 showed reduced hysteresis energy losses in its construction with additional potential for energy storage/return. Older shoes became less compliant with reduced flexural stiffness.

In flexion the stiffness was more related to the number of layers within the sole than the specific layer material. A single layer outsole spike plate shoe is only as stiff as the spike plate, whereas the addition of an internal carbon insole plate increases the moment of inertia proportional to the square of the distance between the plates. The shoes appear to cluster into three broad mechanical designs: traditional spike (e.g. Mamba) combine high cushioning stiffness with low flexural stiffness; hybrid designs (e.g. Dragonfly) combine lower cushioning stiffness with relatively low flexural stiffness; and super-shoe designs (e.g. Victory 2) combining moderate cushioning stiffness with high flexural stiffness. The interaction between plate layering and resilient foam appears central to the mechanical behaviour of AFT shoes [3,4].

The recent smashing of the sub-2 hour marathon times associated with AFT shows the potential benefits of advanced engineering materials. However, the altered mechanical demands of highly compliant yet stiff footwear may require specific musculoskeletal adaptations, potentially increasing injury risk if training conditioning of the athlete is inadequate.

Indentation = Comfort

A 36mm diameter cylindrical indenter was applied centrally across the MCP joint. A 0-500N force was applied sinusoidally at 4Hz replicating a 185ms ground contact time [1] Figure 2.

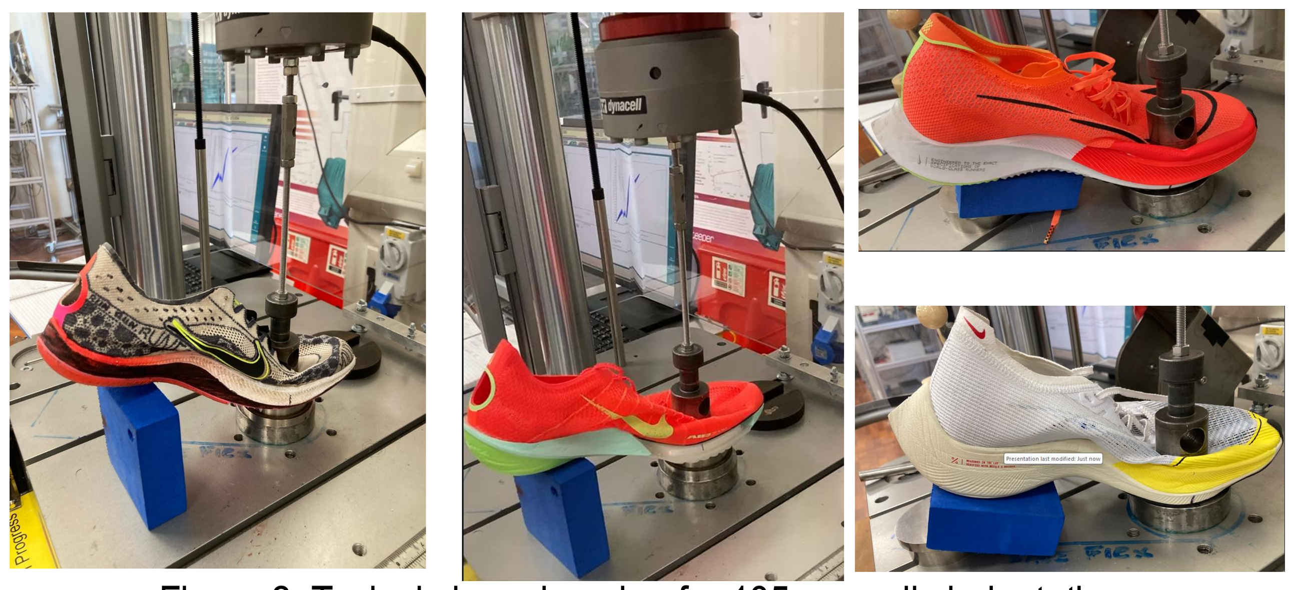


Figure 2. Typical shoe clamping for 185ms cyclic indentation.

The 1000th displacement cycle is shown in Figure 3 and summary results in Table 1.

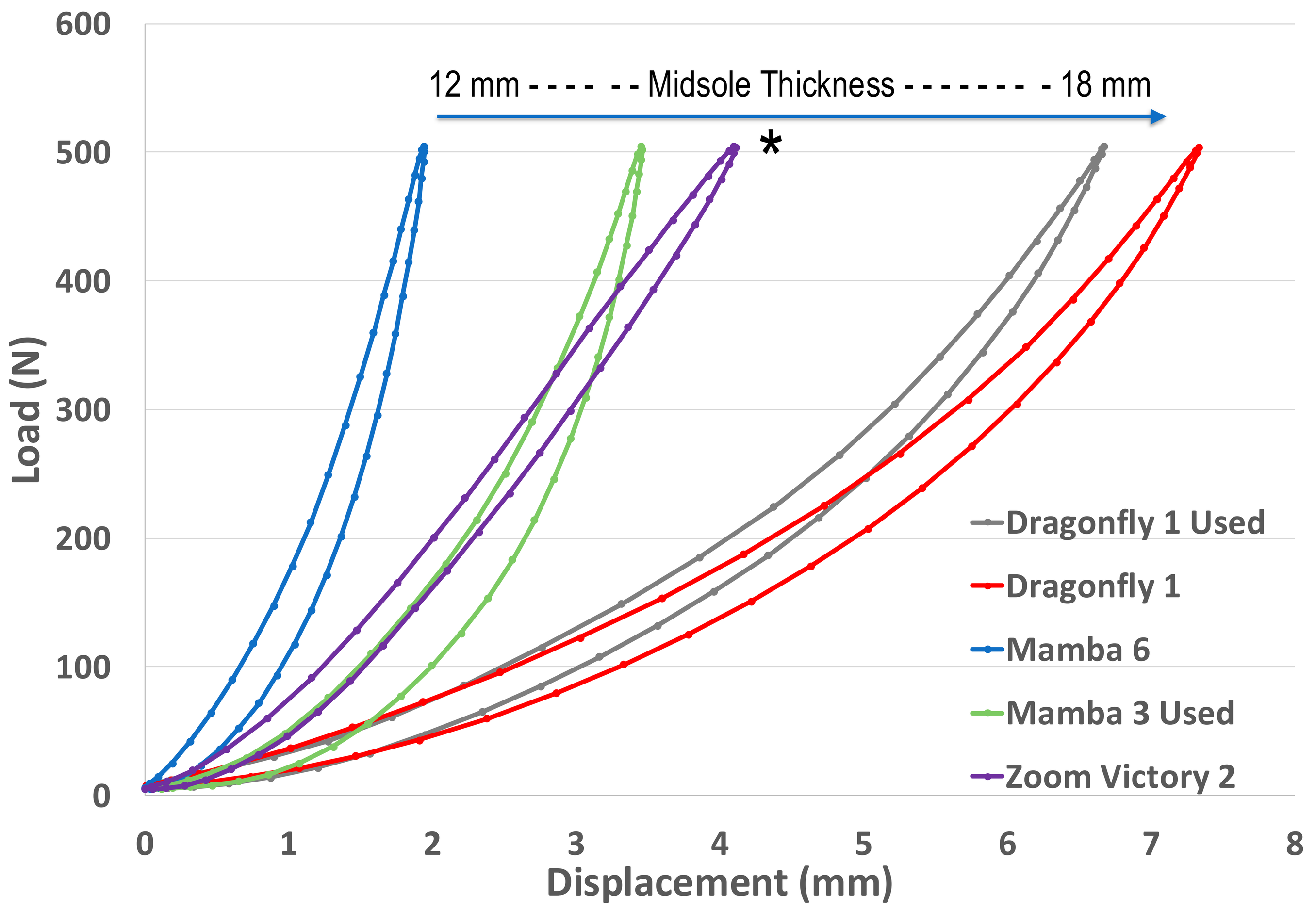


Figure 3. Midsole Indentation load vs. displacement after 1000 cycles.
* Zoom Victory 2 has an additional carbon plate.

Shoe	Max Displacement @500N (mm)	Cushioning Stiffness (N/mm)
Zoom Victory 2	4.1	127
Mamba 6	1.9	257
Mamba 3 used	3.5	143
Dragonfly 1	7.3	66
Dragonfly 1 used	6.7	73
Vaporfly (road shoe)	11.3	42
Streakfly (road shoe)	11.2	42

Table 1. Stiffness of the insole; a measure of comfort.

A large variation in deformation from 1.9 to 7.3mm was observed in the 5 different Nike shoes under a 500N cyclic load. With softer foams deforming more, this demonstrates that a broad range of comfort levels are available from a single manufacturer. The Victory2 produced an uncharacteristically linear loading pattern. This shoe has both a lower pebax spike plate, that all track spikes have, and an additional upper insole carbon plate.

Flexion = Speed

Bending tests applied 16 degrees of flexion at 4Hz across the MCP joint [1] Figure 4. The sole was clamped firmly to prevent chatter.

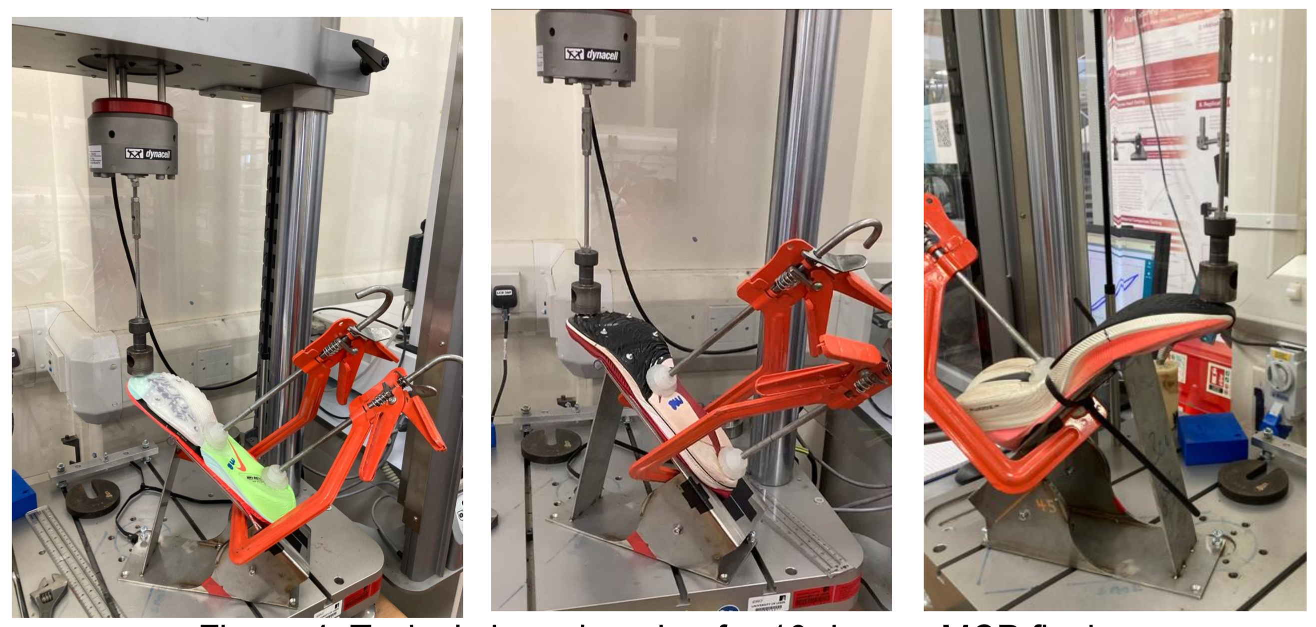


Figure 4. Typical shoe clamping for 16 degree MCP flexion.

The 1000th flexion cycle is shown in Figure 5 and Summary results in Table 2.

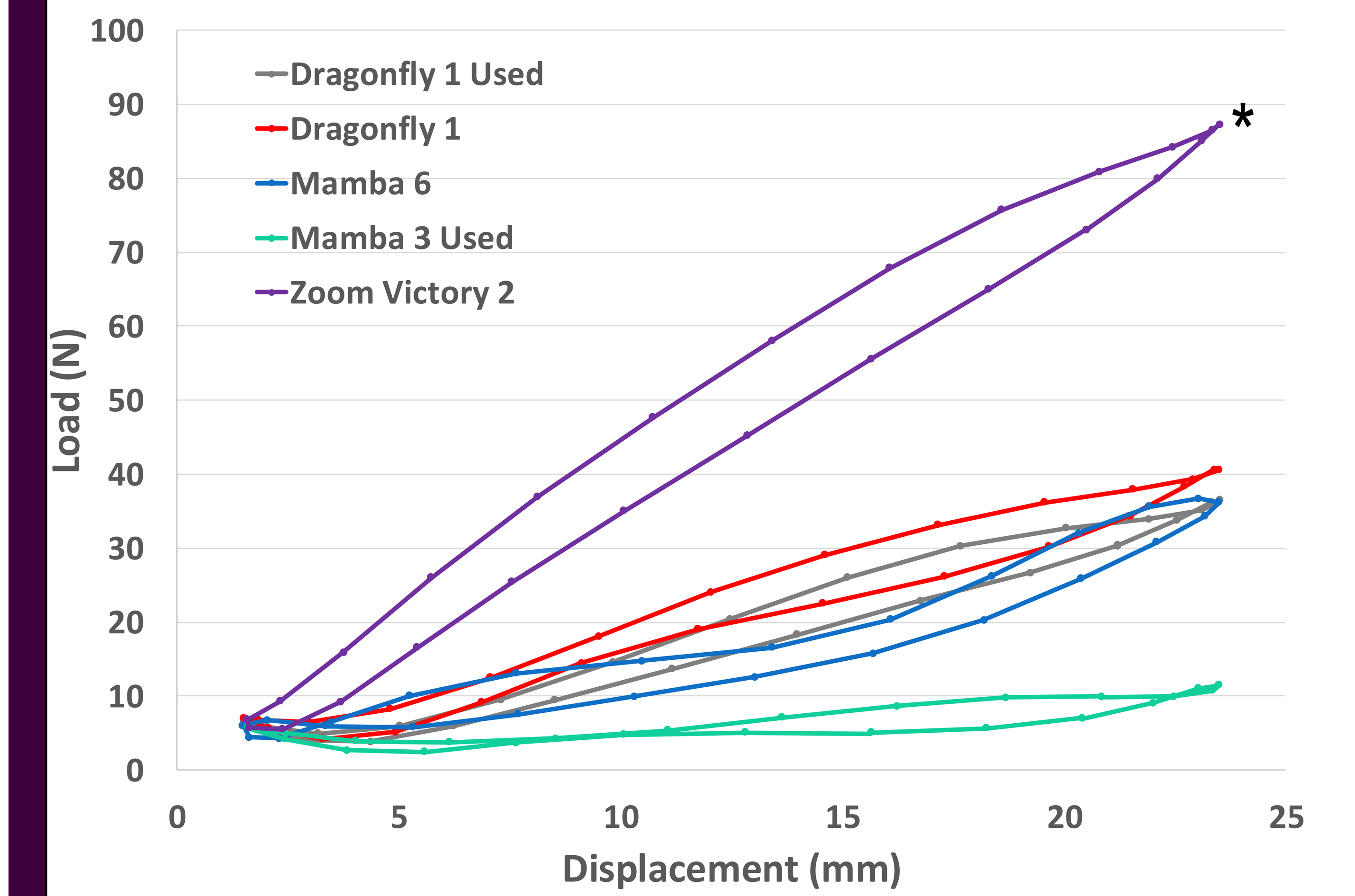
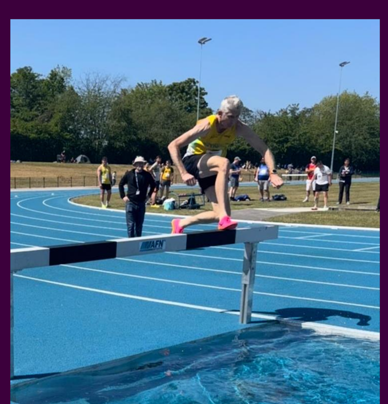


Figure 5. MCP Flexion load vs. displacement after 1000 cycles.
* Zoom Victory 2 has an additional carbon plate.

Shoe	Load @ 23mm Bending (N)	Bending Stiffness (N/mm)
Zoom Victory 2	87	3.7
Mamba 6	36	1.4
Mamba 3 used	12	0.5
Dragonfly 1	41	1.6
Dragonfly 1 used	36	1.5
Vaporfly (road shoe)	108	4.8
Streakfly (road shoe)	27	1.0

Table 2. Flexural Stiffness; a measure of speed?.

Under flexion across the MCP joint most spikes required a force of 30-40N to flex the toe to 16 degrees (stiffness of ~1.6N/mm), except the Victory 2 spike, that required a force of 87N for a stiffness of 3.7N/mm. The construction of this shoe strongly encourages you to run on your forefoot, hence it may not be suited to mid-distance events. Table 2 demonstrates the comparable road shoe's that can have even greater flexural stiffness.



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