Individual-specific determinants of successful adaptation to minimal and maximal running shoes

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Introduction
Minimalist shoes have been touted as a panacea for preventing running-related injuries, although evidence is inconclusive (Ryan et al., 2013). Maximalist shoes, with greater than normal midsole thickness have been introduced in response, but little work has investigated their success in preventing injuries. For both maximal and minimal footwear, it is likely that the wholesale approach to prescription has limited their successful adoption. Prescription of traditional running footwear often relies on the paradigm of pronation, although this is ineffective for preventing injuries (Nielsen et al., 2014). We hypothesize that individual-specific characteristics, other than pronation, such as dynamic foot stiffness, should be considered for prescribing running footwear.

Purpose
To determine the extent to which a simple clinical test can predict successful adoption of minimalist or maximalist running shoes.

Methods
Thirty experienced, rearfoot-striking runners (15 males; 15 females) have been enrolled. Four participants had a complete dataset at time of submission.

Subjects attended four testing sessions:

Session 1 comprised lower extremity isokinetic strength testing and a treadmill VO$_{2,\text{max}}$ test. At Session 2, the subject walked and ran barefoot on an instrumented treadmill while video of the medial foot was recorded (200 Hz). Foot stiffness measures were calculated over the gait cycle (Figure 1; Bencke et al., 2012).

![Foot stiffness measures](image)

Figure 1. (A) Medial longitudinal angle, (B) longitudinal arch angle, and (C) navicular height measured at time-points illustrated in foot force graph (lower right).

At Session 3, subjects ran at 70% VO$_{2,\text{max}}$ speed in four shoe conditions for 10 min each: habitual shoe (HAB), minimal shoe (MIN; New Balance Minimus), traditionally-cushioned shoe (TRD; Altra The One 2.0), and maximal shoe (MAX; Altra Paradigm). MIN, TRD, and MAX were selected for their zero-drop, similar fit, and graded midsole thickness (11, 19, 25 mm). Subjects were instrumented with inertial measurement units (IMUs) on bilateral foot, shank, and thigh, and pelvis and cervical spine. Accelerometers (400 G) were affixed to the top of the shoe, heel, and shank. Continuous IMU (200 Hz), acceleration (1500 Hz), underfoot pressure...
and vertical ground reaction force (VGRF; 200 Hz), and metabolic data were recorded. The subject also provided sensory feedback. At the conclusion of Session 3, participants were randomly assigned MIN or MAX to wear for all at-home runs for four weeks. Session 4 occurred four weeks after and consisted of the same assessments as Session 3.

For each stance, peak VGRF loading rate; peak VGRF; peak midfoot, heel, and shank acceleration and timing; footstrike type; and posture at foot strike were calculated. Footstrike type was determined per stance using the relative timing of the heel and midfoot acceleration peaks (Giandolini et al., 2014).

**Results**
Comparing HAB and 15-s, 10-min and 4-week time-points in the intervention shoe, a shoe- and individual-specific adoption response appears. One subject assigned MAX (MAX 01) demonstrated no change in reported measures, while MAX 02 had an 11-BW/s increase in peak loading rate (Figure 2). Both subjects maintained a rearfoot strike across time points and reported high comfort. The individuals in MIN showed a stronger divergence in outcome variables (Figure 2). Similar to MAX 02, MIN 01 maintained a rearfoot strike across time points and demonstrated a 12-BW/s increase in peak loading rate with minimal change in foot shock. In contrast, MIN 02 changed from rearfoot striking at 15 s to a mixed pattern at 10 min to a forefoot pattern at four weeks. Peak foot shock and loading rate decreased by 10 g and 18 BW/s from HAB to 4-week, respectively.

![Figure 2](image_url)

**Discussion and Conclusion**
Preliminary results (to be augmented with 26 additional subjects) suggest that maximal shoes do not require as large of gait modification as minimal shoes. Minimal and maximal adoptions appear individual-specific. We are currently examining the results of the dynamic foot stiffness as predictor of these strategies.

**References**

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