"SUPER-SHOES" IN DISTANCE RUNNING: IS THERE A POSSIBLE DOWNSIDE IN TRAINED WOMEN?

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Although "super-shoes" provide a metabolic advantage, anecdotal suggest that consistent wear may contribute to development of knee and hip overuse injuries. The purpose of this study was to compare these injury-related running biomechanics variables between "super-shoes" and traditional training shoes in female distance runners. 18 competitive female runners ran for 5min on a treadmill at 3.6 m/s in "super-shoes" (SUPER) and control shoes (CON) while 3D kinematic and ground reaction force data were collected. Peak knee abduction moment and peak hip internal rotation and abduction moment were larger in SUPER compared to CON but no other biomechanical variables were different between shoes. Findings from this study suggest that "super-shoes" may increase knee loading compared to traditional shoes in female distance runners.

KEYWORDS: running, shoes, biomechanics, endurance, women

INTRODUCTION: The world-wide growth in running participation over the last decades has contributed greatly to both consumer and scientific interest in running shoes. Recently, marketing efforts from shoe companies and drastically improving endurance running performances have, arguably, made shoe technology one of the most debated topics in the running world. Advancing technology to improve various shoe characteristics has led to the widely used term, "super-shoes." These shoes are defined as racing or competition shoes designed to improve endurance running performance by reducing the energetic costs or oxygen consumption at a given speed (i.e., running economy; RE). Although "super-shoes" provide a metabolic advantage over traditional footwear, anecdotal reports from elite-level athletes, coaches, and clinicians suggest that consistent wear in training may have contributed to incidences of knee and hip overuse injuries. To date, no studies have been conducted to quantify the magnitude of certain injury-related biomechanical variables between "super-shoes" and traditional training running shoes. For example, higher peak knee (Noehren et al., 2014) and hip adduction (Pohl et al., 2008), peak hip internal rotation (Noehren et al., 2007), peak knee abduction moment, knee abduction impulse (Stefanyshyn et al., 2006), and peak hip abduction moment (Eskofier et al., 2012) have been associated with various running-related injuries. The soft, although resilient, midsole foam of "super-shoes" may increase allow for more frontal and transverse plane motion (e.g., frontal plane rearfoot eversion, hip adduction, knee abduction) of the lower limb to possibly yield greater magnitudes of the aforementioned injury-related knee and hip biomechanical variables. The purpose of this study was to compare these injury-related running biomechanics variables between "super-shoes" and traditional training shoes in female distance runners. We hypothesized that "super-shoes" would produce greater magnitudes for some of these injury-related biomechanical variables compared to traditional training shoes.

METHODS: *Participants*: 18 competitive female runners of various foot strike patterns were recruited for this study. All participants had prior experience in "super-shoes" for competition (i.e., to reduce familiarization effects) and to be included, were required to have completed a half marathon in under 1h44min, a 10km in under 47min, or a 5km in under 22min in the 6 months prior to testing.

Procedures: An 8-camera three-dimensional (3D) motion capture system (240 Hz, Qualysis AB, Goteburg, Sweden) and an instrumented force treadmill (1200 Hz, Bertec, Columbus, OH, USA) were used to simultaneously to collect kinematic and ground reaction force (GRF) data during running trials, respectively. In addition, a metabolic system (TrueOne 2400; ParvoMedics, Murray, Utah, USA) was used to collect expired gases. Participants performed a five-minute warm-up on the experimental treadmill at a self-selected speed in their own running shoes. Participants then completed the experimental testing protocol of 5 minute running bouts at a speed of 3.6 m/s (i.e., 7min30s per mile) on the force instrumented treadmill in two shoe conditions: 1) the “super-shoe” condition (Nike Vaporfly Next% 2TM; SUPER) and 2) the control shoe condition (Nike Pegasus 38TM; CON). The SUPER condition had a mass of 176 g, stack height of 32 mm in the forefoot and 40 mm in heel, and a heel-to-to offset of 8 mm. The CON condition had a mass of 248 g, stack height of 23 mm in the forefoot and 33 mm in heel, and a heel-to-to offset of 10 mm. A randomized and mirrored (e.g., ABBA) testing order was used for experimental trials (Hoogkamer et al., 2018). After reflective markers were placed on the participants, participants were fitted with a rubber facemask (covering the nose and mouth) connected to the metabolic system via a breathing tube. Participants then ran for five minutes (until physiological steady-state is reached [i.e., plateau in VO2 with RER below 1.05]) on the instrumented treadmill at the testing speed in the first shoe condition. Participants received approximately 7-8 minutes of rest before the start of testing in the second shoe condition. Kinematic and GRF data were collected for 15 seconds in the last minute of the first trials in each shoe condition.

Data Analyses: Visual3D software (C-Motion, Germantown, MD, USA) was used to process and analyse kinematic and kinetic variables from the running trials. Kinematic data were interpolated using a least-squares fit of a 3rd order polynomial, with a three data point fitting and a maximum gap of 10 frames. Kinematic and GRF data were filtered using a low-pass Butterworth filter with cut-off frequencies of 8 Hz and 40 Hz, respectively. A right-hand rule with a Cardan rotational sequence (x-y-z) was used for the 3D angular computations where x represents the medial-lateral axis, y represents the anterior-posterior axis, and z represents the longitudinal axis. Newtonian inverse dynamics was used to calculate net internal joint moments normalized to body mass ($Nm \cdot kg^{-1}$) during the stance phase.

Statistical Analyses: Paired sample t-tests (SPSS 24.0, IBM) were used to compare footwear conditions for all dependent variables. Cohen’s *d* effect sizes were calculated to assess the effect magnitudes between footwear conditions (i.e., small: $d \leq 0.2$, moderate: $0.2 < d < 0.8$; large: $d \geq 0.8$). The significance level was set at $p \leq 0.05$.

RESULTS: Peak knee abduction moment (~7.5%), peak hip internal rotation (~23%), and peak hip abduction moment (~6.5%) were moderately larger in SUPER compared to CON (Table 1; Figure 1). Peak knee abduction moment, peak hip internal rotation, and peak hip abduction moment in the SUPER (compared to CON) increased in 61%, 67%, and 60% of runners, respectively.

Table 1. Sagittal plane joint kinematics and kinetics in “super-shoe” (SUPER) and control (CON) conditions (mean ± SD).

Variables	SUPER	CON	p	*d*
Peak Eversion (deg)	18.5 ± 4.6	18.8 ± 5.0	0.38	0.06
Mean Frontal Knee (deg)	-0.5 ± 3.3	-0.3 ± 2.4	0.40	0.06
Mean Transverse Knee (deg)	-0.4 ± 4.6	-1.7 ± 3.6	0.07	0.32
Peak Knee Valgus (deg)	-3.8 ± 3.5	-3.6 ± 2.4	0.42	0.04
Peak Knee Abduction Moment (Nm/kg)	-1.63 ± 0.43	-1.51 ± 0.28	**0.04**	**0.33**
Knee Abduction Impulse (Nm·s/kg)	-0.16 ± 0.03	-0.16 ± 0.03	0.37	0.05
Peak Hip Internal Rotation (deg)	10.9 ± 4.1	8.9 ± 4.6	**0.01**	**0.47**
Peak Hip Adduction (deg)	10.0 ± 3.3	10.0 ± 3.1	0.47	0.01
Peak Hip Abduction Moment (Nm/kg)	-3.3 ± 0.4	-3.1 ± 0.3	**0.02**	**0.53**

Notes: **Bold**: p-value < 0.05. Frontal knee and hip angles: + = adduction; - = abduction. Transverse knee and hip angles: + = internal; - = external. *d* = Cohen's *d* effect size.

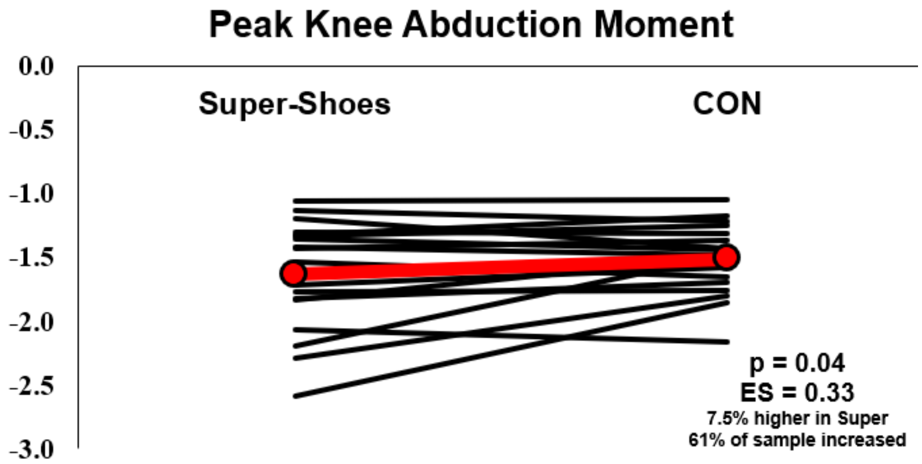

Figure 1. Mean peak knee abduction moment (red) and individual responses for all runners in Super-Shoes and control (CON) shoes.

DISCUSSION: This study aimed to compare injury-related running biomechanics variables between "super-shoes" and traditional shoes in trained female distance runners. In partial agreement with our hypothesis, peak knee abduction moment, peak hip internal rotation, and peak hip abduction moment were moderately larger in the "super-shoes" compared to the control shoe in trained female runners. Although it was speculated that the soft and large stack height of the midsole foam in SUPER may increase lower limb motions (e.g., rearfoot eversion, knee abduction, hip adduction) which could explain larger injury-related knee and hip joint variables, these kinematic variables were similar between shoes (Table 1) and the mechanisms to explain the footwear differences remain unclear. Given the calculations in Newtonian inverse dynamics, the larger stack height of the midsole foam in SUPER may increase the lever arm of the medial-lateral GRF to the ankle joint which could partly explain increases in knee and hip moments. These three variables have been associated with running-related injuries and particularly those of the knee such as anterior knee pain, patellofemoral pain syndrome, and iliotibial band syndrome (3-5). Although the magnitude of these three variables was larger in "super-shoes" compared to control shoes, it is difficult to conclude that the moderately larger magnitude would be responsible to increase risk of injury development in this cohort. Although anecdotal reports from elite-level athletes, coaches, and clinicians suggest that consistent wear in training may have contributed to incidences of knee and hip overuse injuries, there is currently no scientific evidence or available mechanisms for greater knee or hip injury risks from "super-shoes". This new evidence from the current study warrants further control studies on prospective knee injury development from chronic wear of "super-shoes" for training. Further, findings from the current study may help footwear companies alter current "super-shoe" designs to limit the magnitude of these injury-related variables. Finally, given that many factors contribute to running injuries, future studies should consider these additional factors such as training load, runner experience and tissue resilience, and the interaction of these factors with the biomechanical response from "super-shoes" to better understand risks of injury development.

CONCLUSION: Findings from this study suggest that "super-shoes" increase the magnitude of some injury-related biomechanical variables and in particular, those related to knee injuries compared to traditional shoes in female distance runners. The greater magnitudes of these variables may partly explain some anecdotal reports of increased injury incidences, specifically of the knee joint. However, it is impossible to conclude that the moderately larger magnitudes of these variables would be responsible to increase risk of injury development in this cohort. Other factors such as increased training load may contribute to the higher incidences of knee and hip injuries from "super-shoe" wear. Future studies should more systematically study injury development in distance runners from controlled training exposures in different types of shoes including "super-shoes".

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