# LATERAL EDGE FRICTION VARIABILITY IN INDOOR SPORTS SHOES

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It has previously been speculated that the occurrence and severity of lateral ankle sprain injuries is linked to excessive shoe-surface friction. The purpose of this study was to assess the amount of lateral edge friction in indoor sports shoes, and evaluate the variation from the traditional forefoot traction test. Therefore, we modified the ISO:12387:2019 test for slip resistance and positioned the shoe on its lateral edge while simulating a sideways movement. All tests were conducted on an indoor surface. In general, we found that lateral edge friction on average was 22% lower than forefoot friction ($p<0.0001$). However, linear regression showed that the forefoot test could only explain 63% of the variation in edge friction, thereby suggesting that a lateral test is needed to adequately inform on lateral edge friction. Future research is planned to determine whether a noticeable change in friction coefficient is also a ‘valuable change’, hence potentially having clinical implications for injury prevention.

**KEYWORDS:** footwear, traction, shoe-floor interaction, ankle injury, mechanical testing

**INTRODUCTION:** It has been proposed that high shoe-surface friction could be a direct risk factor for non-contact lower extremity injuries, and for lateral ankle sprains in particular (Dragoo & Braun, 2010). It remains plausible that the higher incidence rate of lateral ankle sprain injuries in indoor sports, compared to outdoor/field sports (Doherty et al., 2014), could thus be a direct result of the high viscoelastic friction between shoe and floor.

It is widely acknowledged, that lateral ankle sprain injuries are caused by an excessive supination moment around the subtalar joint (Fong, Chan, Mok, Yung, & Chan, 2009), which in turn is directly affected by the position, magnitude, and orientation of the ground reaction force vector – in respect to the ankle joint center (Wright, Neptune, Van Den Bogert, & Nigg, 2000). Here, the orientation of the ground reaction force vector is dependent on the friction between shoe and surface (Frederick, 1993). In this light, it seems reasonable to speculate that excessive friction, in cases where the foot is placed in a vulnerable position (i.e., inversion and plantar flexion), might have a causal effect on the occurrence and severity of a lateral ankle sprain injury. This speculation is especially fueled by the way in which the application of a low-friction patch on the lateral side of indoor sports shoes effectively reduced both injury incidence rate and severity of lateral ankle sprain injuries in a recent clinical trial (Lysdal et al., 2021). Varying friction properties in different traction areas of a shoe could lead to an unexpected shoe-surface interaction for the athlete and therefore cause involuntary movements in critical match situations. All in all, this suggests that excessive friction on the lateral edge of the shoe sole and its divergence to the flat forefoot scenario could be important external risk factors.

The ability to assess and quantify this mechanical characteristic could therefore have a potentially high clinical relevance for prevention of lateral ankle sprain injuries. However, traditional slip-resistance tests used in the footwear industry do not consider lateral friction, or edge friction for that matter (ISO: 13287:2019).

Consequently, the purpose of this study was to test lateral edge friction of indoor sports shoes, and assess if this varies from the outcome of a traditional forefoot traction test.

**METHODS:** We retrieved information on the most commonly used indoor sports shoes in Denmark (Season 2017-18) from a nation-wide survey among indoor sports athletes. The 12 most popular models were purchased and tested conforming to the *'Personal protective equipment – Test method for slip resistance'* (ISO: 12387:2019).

The mechanical test setup (Figure 1) comprised of a steel frame that was bolted to the floor above a force plate-equipped mechanical hydraulic platform (Serman & Tipsmark, Brønderslev, Denmark). The hydraulic rams were controlled using Mr. Kick software (Mr. Kick version 3.0, Aalborg, Denmark) to provide robust and repeatable vertical and horizontal movements (Doornik & Sinkjaer, 2007), making it possible to mimic different shoe-floor interactions. A constant passive load of 500 N was matched using standard weight plates atop the test shoe through a vertical load distributor. The steel frame allowed for free vertical movement of shoe and passive load but ensured a fixed (horizontal) position. The shoes were tested against the floor surface five times, in each respective test, at a sliding velocity of 0.3 m/s as per ISO: 13287:2019. All tests were conducted against a standard vinyl indoor sports floor (7.5 mm Taraflex – Evolution, Gerflor, Lyon, France). Lateral edge friction was further tested by placing the test-shoe in a 15º pitch and 30º roll angle in relation to the floor surface – and rotated 90° to perform lateral translation.

Ground reaction forces were recorded using an AMTI force plate (AMTI-OPT464508HF-1000, Advanced Mechanical Technology, Watertown MA, USA) operating at a sample frequency of 1000 Hz. The movement of the force plate was captured via a single retro-reflective marker using eight infrared cameras sampling at 500 Hz (Oqus 300+, Qualisys AB, Gothenburg, Sweden). Raw GRFs were imported into MATLAB (R2020a, The MathWorks, Massachusetts, USA) where it was low-pass filtered with a cut-off frequency of 30 Hz, using a 2$^{nd}$ order Butterworth filter. Zero-phase filtering was performed using MATLAB function FiltFilt, filtering both forwards and backwards. All measurements were synchronized using the kinematics of the single retro-reflective marker by calculating cross-covariance and aligning data by circular shift. Ten empty (no contact) force plate movements were also recorded for later subtraction of the inertial contribution from the hydraulics accelerating the force plate.

The friction coefficient (μ) was then calculated via Equation 1, where $F_x$ and $F_y$ are the horizontal reaction forces and $F_z$ the reaction force in the vertical direction (normal force). The dynamic friction coefficient was ultimately calculated as an average over the plateau following the peak in static friction, as per ISO: 13287:2019.

$$\mu = \frac{|F_x| + |F_y|}{|F_z|} \qquad \textbf{Eq. 1}$$

For statistical analysis, we performed a paired-samples t-test between the two orientations to look at the differences between both test conditions. We also conducted a one-way ANOVA using R statistics (www.r-project.org) on both linear forefoot traction and lateral edge traction, separately, to analyze the difference between shoes. The most popular shoe ("Asics 2") was used as reference in the Tukey's HSD post-hoc test. Finally, to see if lateral edge friction can be described by normal forefoot friction, we conducted a linear regression analysis to test for correlation between testing conditions, using Microsoft Excel Analysis ToolPak (Microsoft Corporation, Washington, USA).

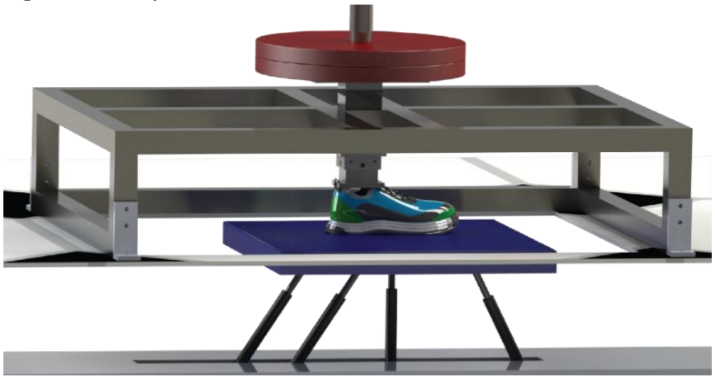

**Figure 1: Test setup consisting of a steel frame bolted to the ground above a hydraulic force platform. Standard weight plates atop the test shoe ensure 500N passive vertical load.**

**RESULTS:** The mean friction coefficient for all shoes in the forefoot test was 1.18 (±0.21). On average, this was 22% lower on the edge (0.91±0.16, $p$<0.0001) (Table 1; Figure 2).

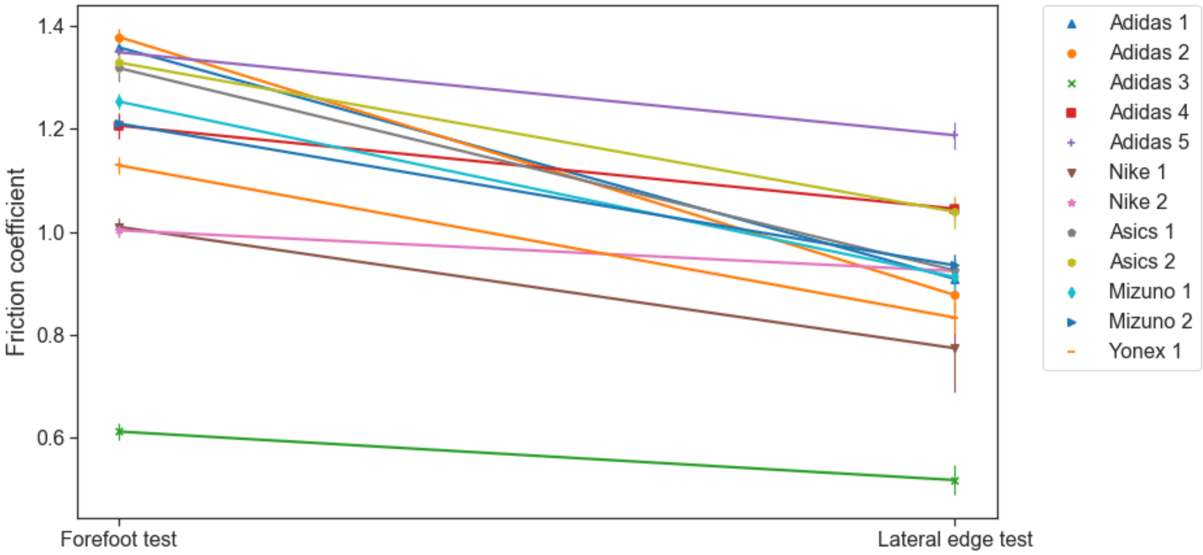


**Figure 2: Mean dynamic coefficient of friction for the forefoot- and lateral edge traction tests.**

The mean friction coefficient of the Asics reference shoe in the forefoot test was 1.33 (±0.019). The Tukey post-hoc test revealed that one shoe (Adidas 2) had a significantly higher friction coefficient, while seven shoes were significantly lower (Table 1). In the lateral edge test, the mean dynamic friction coefficient of the Asics reference shoe was 1.04 (±0.032). One shoe scored significantly higher (Adidas 5), while nine shoes scored significantly lower (Table 1).

**Table 1: Mean dynamic friction coefficient for the two tests; absolute and relative change.**

| | Forefoot friction | Edge friction | | |
|---|---|---|---|---|
| **Shoe ID** | **Mean (SD)** | **Mean (SD)** | **Δ** | **Δ%** |
| Adidas 1 | 1.36 (0.012) | 0.91 (0.033) **** | -0.45 | -33% |
| Adidas 2 | 1.38 (0.017) ** | 0.88 (0.033) **** | -0.50 | -36% |
| Adidas 3 | 0.61 (0.017) **** | 0.52 (0.029) **** | -0.09 | -15% |
| Adidas 4 | 1.21 (0.025) **** | 1.04 (0.020) | -0.16 | -13% |
| Adidas 5 | 1.35 (0.013) | 1.19 (0.027) **** | -0.16 | -12% |
| Nike 1 | 1.01 (0.018) **** | 0.77 (0.086) **** | -0.24 | -23% |
| Nike 2 | 1.00 (0.014) **** | 0.92 (0.024) *** | -0.08 | -8% |
| Asics 1 | 1.32 (0.026) | 0.92 (0.030) *** | -0.39 | -30% |
| Asics 2 (*REF*) | 1.33 (0.019) | 1.04 (0.032) | -0.29 | -22% |
| Misuno 1 | 1.25 (0.015) **** | 0.91 (0.032) **** | -0.34 | -27% |
| Misuno 2 | 1.21 (0.013) **** | 0.93 (0.021) ** | -0.28 | -23% |
| Yonex 1 | 1.13 (0.015) **** | 0.83 (0.032) **** | -0.30 | -26% |
| **Test Mean** | **1.18 (0.211)** | **0.91 (0.156)** | **-0.27****** | **-22%** |

(*) indicates statistically significant difference in COF (*: p<0.05, **: p<0.01, ***: p<0.001, ****: p<0.0001).

The linear regression analysis revealed that the linear forefoot friction coefficient significantly predicted the edge friction coefficient ($y$=0.59$x$+0.21, $p$=0.002), and that 63% of the variation in edge friction coefficient is predicted by linear forefoot friction ($R^2$ = 0.63, $p$=0.002).

**DISCUSSION:** This study was designed to assess lateral edge shoe-floor friction properties of indoor sports shoes, and determine whether this relates to the outcomes of a traditional forefoot test. In general, we found that lateral edge friction on average was 22% lower than forefoot friction. This is in line with existing knowledge on viscoelastic friction, where the effective friction coefficient usually decreases with a decrease in contact area (Persson, Albohr, Tartaglino, Volokitin, & Tosatti, 2005). The regression analysis showed that the linear forefoot friction

coefficient could significantly predict lateral edge friction. However, only with a correlation coefficient ($R^2$) of 0.63. This implies, that if one wishes to accurately assess lateral edge traction, one should perform a lateral edge test.
Surprisingly, the indoor sports shoes varied significantly in-between models in frictional properties. The most popular shoe had a significantly higher friction coefficient than the majority of the 2017-18 models in both slip-resistance tests. The total difference in friction coefficient between the highest and lowest scoring shoe was 0.77 (77%) in the forefoot test, and 0.67 (78%) in the lateral edge test. Contemplating the notion that the friction coefficient might not just be a unitless descriptor but instead directly related to the moment around the ankle joint, and a direct risk factor for the occurrence of a lateral ankle sprain injury, then one would arguably assume that the 'Adidas 5' would carry the highest risk.
Additionally, all shoes, except for one, had forefoot friction characteristics that substantially exceeded the critical traction value of 0.82 (+22-68%), after which performance is no longer enhanced (Luo & Stefanyshyn, 2011). Considering the potentially heightened risk of non-contact lower extremity injury in general (Dragoo & Braun, 2010), more traction is not necessarily better. It is in this context interesting to note that ordinary people are likely able to detect relative changes in coefficient of friction as low as 11% when testing shoe rubbers with their own hands (Gueorguiev, Vezzoli, Mouraux, Lemaire-Semail, & Thonnard, 2017), hence indicating a threshold value of COF ±11% for *"Noticeable Change"*. The variation between shoes, or different regions of one shoe, could in this context be directly noticeable for the consumer. Therefore, the athlete could potentially choose safer footwear based on tactile perception.

**CONCLUSION:** This study showed that there is a significant (and most likely noticeable) difference in friction coefficient between a traditional forefoot test and the modified lateral edge test presented. Future research is planned to determine whether a noticeable change in friction coefficient is also a 'valuable change', hence having clinical implications for injury prevention.

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