Update on Measurements Testing of Slip-Resistance – A Scoping Review

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Summary

This study reviews advancements in slip resistance measurement devices or tribometers and challenges in aligning measurement approaches. Insights from recent tribometer validations are used to recommend approaches leading to aligning certifications with real-world scenarios.

Introduction

Slip resistance is critical for safety, yet existing certification standards arguably fail to reflect realistic slip events [1,3]. A review published in 2001 discussed pros/cons of portable and laboratory-based slip resistance devices [2]. Portable devices were environment-specific but lack the ability to use whole shoes and reflect the biomechanical loading of slipping events, while laboratory setups used whole shoes and provide better precision but lack the ability to simulate real-world contaminants and surfaces. We seek to identify potential progression in the development of shoe/surface tribometers and discuss the current challenges.

Methods

We conducted a scoping review, focusing on design of whole shoe tribometer or slip resistance devices, including validation approaches and discrepancies between state-of-the-art and certification standards. Papers were identified through searches in four databases using three thematic keyword blocks: tribology, slipping, and footwear/floor. Reviews, editorials, expert opinions, and guidelines were excluded. The inclusion criteria were (1) peer-reviewed papers (2001–2024) in English. (2) Studies describing testing devices/tribometers for shoe-surface slip resistance in lab or field using quantitative friction measurements. Two independent reviewers (L.J. and M.M.-H.) conducted the screening of titles, abstracts, and full texts based on inclusion criteria, resolving disagreements with a third reviewer (F.G.L.).

Results and Discussion

The search identified six studies dealing with the development of whole shoe tribometers [4-9]. [9] described an electro-magnetic driven tribometer, showing strong correlation to force plate measurements. This tribometer design was refined by [4] and validated using human testing and logistic regression, linking results to real-world slip events. Studies [5] and [8] presented the same portable tribometer, driven by an electric linear motor, however with different focus. In [5], the focus was on technical repeatability ($R^2 > 0.90$) but without direct correlation to human slips, while [8] emphasized cost-effectiveness and biomimetic design. In [7], a pneumatic driven portable shoe slip tester was described and compared to traditional ramp tests, showing strong correlations but highlighting higher friction coefficients for the shoe slip tester. In [6], a stationary robotic setup was developed, with high-precision and testing parameter flexibility, even though it was missing the ability to conduct field measurements. Recent advancements in portable tribometers have shifted from simple devices using outsole cut-outs or rubber specimens to those enabling the testing of whole shoes. However, discrepancies in testing parameters, such as normal loads, sliding velocity, and shoe-surface contact angle, hinder alignment between different tribometers. Additionally, existing certification testing parameters [1,3] do not align with research recommendations, raising concerns about their real-world relevance. Future tribometers and testing protocols should prioritize validation between devices and adopt standardized parameters (e.g., ISO, ASTM) to meet industry needs, potentially forming the basis for updated testing standards to reduce slip and fall risks.

Conclusions

Advancements in whole shoe tribometers have been made, but standardized testing parameters and validation methods across devices are demanded. This must be done to ensure real-world relevance and alignment with the certification requirements that footwear manufacturers must meet

Acknowledgments

This study was funded by the Danish Work Environment Research Fund (grant number: 20235100802).

References

[1] Blanchette & Powers (2015). *J. Test. Eval.*, **43:** 491-498
[2] Chang et al. (2001). *Ergonomics*, **44**: 1233-1261.
[3] Iraqi et al. (2018). *Appl. Ergon.*, **70**: 118-126.
[4] Beschorner et al. (2023). *Appl. Ergon.*, **106**: 103854.
[5] Gupta et al (2022). *Surfaces*, **5**: 504-520.
[6] Jakobsen et al. (2022). *Int. J. Ind. Ergon.*, **88**: 103253.
[7] Lewis et al. (2020). *Tribol. Int.*, **151**: 106500.
[8] Malviya et al. (2024). *J. Eng. Res.*, **12**: 268-274.
[9] Aschan, et al (2005). *Appl. Ergon.*, **36**: 585-593