

Research Challenges on Slip-Resistance Measurements for Assessing Pedestrian Fall Incidents

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Introduction

Fall incidents from slips and/or trips are the second leading personal injuries and have been recognized as a major threat to the safety of individuals not only in daily life but also in industry [1]. Fall incidents are vulnerable to elderly people and one of the major safety and health risks affecting quality of life and independent living [2-4]. According to the World Health Organization, about 28-35% of people aged 65 and over fall every year, increasing to 32-42% for those over 70 years of age [5]. Significance of the incident has been globally acknowledged due to the extent of problems and associated costs. There have thus been sustained researches to understand main causes of the incident. A number of studies have found that one of the most triggering events leading to a fall is a loss of slip-resistance or traction amongst shoes, floors, and environments. Its slip-resistance property has been commonly measured as a quantity of coefficient of friction (COF) at the contact-sliding interface amongst shoes, floors, and environments.

Since the COF quantity was accepted to determine whether a slip was to occur, there have been large disagreements in the interpretation of assessed results amongst safety researchers and specialists. Importantly, its measurements, analyses, and descriptions have been often misguided in many researches and industry practices for the fall safety assessments. Although the concept of friction measurements is relatively simple and straightforward, slip-resistance properties observed at the sliding interface amongst the shoe, floor, and environment are diverse and combine various sub-mechanisms of friction behaviours [6-13]. As a result, COF readings become strident and continuously change as a function of a complex array of tribo-physical phenomena amongst the shoe, floor, and environment [2-4,6,7,14]. Thus, a simple format of friction or slip-resistance measurement seems not accurate enough to determine essential properties of slip-resistance between the shoe and floor and accordingly has evident difficulty as an indicator for the fall safety measure. Surprisingly, this issue has hardly discussed in the literature.

More concerns could be addressed that increasing traction properties of the floor surface would be desirable as a general rule, but a very high level of slip-resistance may impede safe and comfortable ambulation. This means that we need to find answers whether slip-resistance properties are linearly correlated with surface features of the floor or what levels of floor surface finishes are required to effectively control slipperiness. It is also scarce to find design information on the functional ranges of floor surface roughness required for optimal slip-resistance performance. Therefore, a fresh insight would be required to systematically approach multifaceted characteristics of friction and wear behaviours amongst the shoe, floor, and environment and their impacts on slip resistance performance. Such structured approaches

would improve overall reliability and validity to better feature slip-resistance properties than a commonly exercised simple format of mean or averaged COF readings [7,13]. It is expected that collected information on functional ranges of floor surface roughness under diverse walking environments would help to develop practical design data for floor surface finishes preventing slip and fall incidents [3,14].

Research Challenges

A simple format of friction measurement may parody the complex nature of slip-resistance properties amongst the shoe, floor, and environment [2,3,14]. Accelerated routine friction measurements from laboratory environments also could simplify indispensable aspects of slip-resistance properties [2,3,14]. Although there has been considerable research progress on the pedestrian fall safety, it would be probably true to mention that none of the COF readings reported to date could be regarded as final objective measures for any tested shoe-floor-environment combination. As long as controversies around slip resistance measurements as a simple format of COF quantity remain, improvements in the principal understanding on slip-resistance properties and related tribo-physical characteristics are urgently required.

The recent studies have accentuated the importance of surface analysis on slip-resistance assessments. A number of surface roughness parameters have been measured to identify correlations between the surface texture and slip-resistance properties [2-4,6-15]. Those studies report that surface roughness of the shoes and floors significantly affect slip-resistance performance. Despite extensive experimental and analytical researches on slip and falls incidents, no simple concept and/or theoretical model has been developed to explore the effect of floor surface finishes on slip-resistance performance. There are no internationally accepted guidelines and design reports on operational levels of floor surface finishes for effective controls of slip-resistance performance. It is also hard to find any definitive studies on wear developments of shoes and floors and their effects on slip-resistance operations.

Therefore, it is essential to develop improved concepts, theory models, and methodologies to assess the slipperiness for supplementing current practices. This should be based on thorough appreciation for the multifaceted nature of friction and wear phenomena and surface analysis techniques for characterizing the surface finishes of shoes and floors, their interactions, and effects on slip resistance performance during slip-resistance measurements.

Conclusions

To prevent pedestrian fall incidents from slips and/or trips, a suitable level of slip resistance or grip power between the shoes and underfoot surfaces should be offered and maintained. As clearly discussed in Introduction, however, a simple format of friction measurement could distort the intricate nature of slip resistance properties amongst the shoe, floor, and environment. The contribution of surface finishes to slip-resistance performance is significantly linked to friction and wear behaviours of the shoes and floors. However, to date these factors have hardly been contemplated in the slip and fall safety research area.

In this context, it is necessary to enhance our understanding on friction and wear mechanics and mechanisms of the shoes and floors, and associated tribo-physical aspects of the sliding interfaces amongst the shoe, floor, and environment. Although theoretical model developments for the shoe-floor tribo-physical system have not yet reached a stage where it would be quantitatively possible to predict the slip-resistance property from known tribo-physical characteristics, this new paradigm may provide an insight to identifying the complex issues. Therefore, factoring in wear-induced material changes with friction measurements may provide a way to enhance the reliability of fall safety determinations over the current methodology for COF readings.

This article briefly discussed the current knowledge gaps on the pedestrian fall safety measures, focusing on broadening the knowledge base, and suggesting new notions for characterizing the slip-resistance properties from a tribo-physical point of view on which advancements in the validity and reliability of friction measurements might be made. It is wished that ideas explored from this article would not only provide a sound theoretical foundation for the understanding of both frictional and wear phenomena between the footwear and underfoot surfaces but also enhances the creditability of pedestrian fall safety measurements.

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