Validity and Accuracy of a Slip Resistance Measurement Protocol for the Assessment of Slip Potential

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INTRODUCTION

Slips occur when the utilized friction (uCOF) of an individual exceeds the available friction (COF) provided by the shoe-floor interface [1]. An important issue in preventing slips and slip-related injuries is accurate assessment of the available friction provided by the shoe-floor interface. To date, the current method accepted in the footwear industry as the gold standard (SATRA STM 603) has not been evaluated in the peer-reviewed literature. The purpose of this study was to assess the validity of the SATRA STM 603 whole shoe tester using standard ISO EN 13287 [2] in predicting slip potential. A secondary purpose was to determine the accuracy with which EN 13287 predicts slip outcome.

METHODS

Five men (31.2 ± 5.2 years, 1.8 ± 0.0 m, 81.8 ± 5.1 kg) and 5 women (28.4 ± 7.4 years, 1.7 ± 0.1 m, 57.7 ± 5.9 kg) participated in this study. Each subject was provided with footwear in their respective size. Each shoe was constructed of the same upper design and material. Each outsole was constructed of the same material (styrene butadiene rubber) and hardness (62 A). The footwear tread was standardized with the following groove parameters: 3 mm width, 4 mm depth and perpendicular orientation. Available friction testing of the footwear was performed with the SATRA STM 603 utilizing the EN 13287 protocol with the following test parameters (Normal force 500 N, sliding velocity 30 cm/s, contact angle 7°) [2]. The COF of the test shoe was assessed to be 0.336.

To ensure safety, subjects wore a fall-arresting safety harness (Miller Model 550-64; Franklin, PA) attached via 8 mm climbing rope (Pigeon Mountain Industries, LaFayette, GA) to an overhead trolley that moved along an overhead track. A 2’ x 4’ dry porcelain tile was embedded in the middle of a 10 m walkway. During a single walking trial, subjects were exposed to a potentially slippery condition without their knowledge (distilled water applied to a porcelain tile). Subjects wore goggles with the lower half of the visual field blocked to prohibit awareness of the slip condition. Slips were defined as greater than 4 cm resultant translation of the heel marker while in contact with the contaminated surface [3].

Lower extremity three-dimensional kinematics were recorded at 150 Hz (Qualisys AB, Gothenburg, Sweden) and ground reaction forces were recorded at 1500 Hz (AMTI, Newton, MA, US). Utilized friction was calculated as the ratio of resultant shear force to vertical force. For each trial, subjects’ peak uCOF was determined during the first 50% of the stance phase. To avoid spuriously high friction values occurring when minimal body weight is supported by the stance limb, only uCOF data after the first 5% of stance phase was considered. To determine the relation between probability of slip and the difference between available friction and peak uCOF, a logistic regression model was generated. Validity of EN 13287 was assessed by whether the difference between available friction and peak uCOF was a significant predictor of slip outcome. Model significance was determined by a Wald test (p<0.05). Slip prediction accuracy of the EN 13287 test method was determined from the percentage of no slip and slip outcomes that corresponded to the associated positive or negative difference between available friction and peak uCOF [4]. To test for differences in anthropometrics and walking velocity between individuals who experienced a slip and those who did not, an independent t-test was performed (p<0.05).
RESULTS AND DISCUSSION

Five of the 10 subjects slipped on the contaminated surface (2 women and 3 men). There were no differences in anthropometrics or walking velocity between individuals who experienced a slip and those who did not (Table 1).

The difference between available friction and peak uCOF was not a significant predictor of slip outcome for the EN 13287 protocol (Fig. 1). All 10 subjects had a positive difference between available friction and peak uCOF, indicating no slips should have occurred. However, 5 of the 10 subjects did slip. Overall, assessment of COF with the EN 13287 protocol resulted in only a 50% slip prediction accuracy.

Available friction was assessed with the EN 13287 protocol using the SATRA STM 603. The difference between available friction and peak uCOF was not a significant predictor of slip outcome. These preliminary results are based on a logistic regression model that lacks power due to inadequate sample size. Further data collection is required. Based on the preliminary data, the EN 13287 protocol only predicted 50% of slip trial outcomes. To prevent slip related injuries, a valid test method with a high degree of slip prediction accuracy is essential.

CONCLUSIONS

The results of our study indicate that the use of the SATRA STM 603 with the EN 13287 protocol may not be a valid method to predict slip potential. Future research is required to determine if altering the parameters of EN 13287 improves model validity and slip prediction accuracy.

REFERENCES


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**Table 1**: Characteristics of slip outcome groups. Mean (SD)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>N</th>
<th>Age (yrs)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>Velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip</td>
<td>5</td>
<td>31.6 (6.6)</td>
<td>1.82 (0.1)</td>
<td>73.2 (9.3)</td>
<td>1.95 (0.1)</td>
</tr>
<tr>
<td>No Slip</td>
<td>5</td>
<td>28.0 (5.9)</td>
<td>1.68 (0.1)</td>
<td>66.3 (17.5)</td>
<td>1.83 (0.1)</td>
</tr>
</tbody>
</table>

* indicates significantly different between groups.