D11 *In Vivo* Tribometry: An Analysis of Muscle Activity Using Electromyography (EMG) During a Passive Leg Drop

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Learning Overview: The goal of this presentation is to give the attendee an appreciation of the importance of considering muscle activity levels when using *in vivo* tribometric measures to quantify slip resistance.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by showing how current tribometric methods are insufficient for quantifying barefoot friction, as surrogate barefoot test feet lack biofidelity. If *in vivo* methods are used, an understanding of the test subject's muscle activity and its effect on tribometric measurements is essential.

Background: Floor slip resistance is routinely evaluated using walkway tribometers. These devices use samples of the floor surface and outsole materials to measure utilized friction, either in a laboratory setting or *in situ*. When artificial outsole materials are being evaluated, it is feasible to obtain multiple samples of the material for testing. But difficulties arise when evaluating barefoot slip resistance. At present, there is no recognized surrogate for barefoot human skin. In order to develop such a surrogate, we need to evaluate a diverse population of human subjects *in vivo* to accurately determine the inter-subject variability in skin-slip resistance.

A StepMeter has been designed and constructed to allow *in vivo* testing of barefoot subjects in a controlled manner.[1] In this device, a seated subject has their leg and foot passively raised 2cm, then dropped onto the floor or a test surface. The test surface is inclined, and the test is repeated until the foot slips on contact, to determine the slip resistance of that foot-surface system. Before using this device to evaluate the larger population, this study was conducted to ensure that the seated subject did not involuntarily tense their leg, which may affect the determination of slip resistance. EMG was used to determine muscle activity of four muscles (tibialis anterior, gastrocnemius, rectus femoris, and biceps femoris) as a percentage of the subject's maximum voluntary contraction.

Methods: This study was approved by the Institutional Review Board (IRB) at Penn State University. Subjects were recruited from the student population at Penn State University Abington campus. Adult subjects were excluded if they had any right leg or foot pathology that would preclude participation. Informed consent was obtained, subjects donned shorts, and EMG electrodes were placed on the four muscles, using the locations described in a reference on surface EMG.[2] Maximum Voluntary Contractions (MVCs) were elicited from the seated subject by a researcher manually applying resistance as the subject was instructed to extend or flex "as hard as they can."

After MVC data were collected, subjects were seated in the StepMeter. Their leg was constrained with a modified knee brace to support the leg and prevent internal or external rotation of the calf. Ten "drop trials" were collected; the subject's foot was raised so that their heel was 2cm above the floor, then was dropped. Five second trials of EMG data were collected; the drop was initiated by the researcher at an arbitrary point during that five seconds and was varied from trial to trial to prevent subject anticipation of the drop.

Results: Data were collected on 27 subjects; one subject's data were not included in the analysis due to instrumentation problems.

EMG data (MVCs and drop test) were high-pass filtered (6Hz), rectified, and low-pass filtered (6Hz) to obtain a linear envelop. Each subject's data were normalized to 100% MVC. Means and standard deviations were calculated within subjects to evaluate intra-subject variability. Means and standard deviations were calculated across the subject population to evaluate muscle activity during passive leg drop. Intra- and inter-subject variability were evaluated. The posterior muscles showed much greater activity than did the anterior muscles, but this result was not consistent across all subjects. From the raw data, one can see significant background EMG activity on the posterior muscles on many subjects; it is thought that this may be an artifact of the brace used to control the lower leg.

Conclusions: For anterior muscles, the level of muscle activity is low enough to provide confidence that this activity will not affect evaluation of slip resistance for barefoot walking. While posterior muscles showed higher levels of activity, it is suspected that this is artifact, due to interference from the brace used to control leg movement, and muscle activity will not affect slip-resistance evaluation.

Reference(s):

1. Besser, Marcus P., Mark Marpet, Howard Medoff. Can Barefoot Slip Resistance Be Quantified Using the ASTM F2508 Standard for Tribonometric Testing? *Proceedings of the American Academy of Forensic Sciences*, 67th Annual Scientific Meeting, Orlando, FL. 2015. D16.
2. Hermens, Hermie J., Bart Freriks, Roberto Merletti, Dick Stegeman, Joleen Blok, Günter Rau, Cathy Disselhorst-Klug, and Göran Hägg. European Recommendations for Surface Electromyography. *Roessingh Research and Development* 8, no. 2 (1999): 13-54.

Barefoot Slip Resistance, *In Vivo* Tribometry, Muscle Activity

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