D20 Anomalous Initial Readings in Tribometric Testing of Barefoot Subjects

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After attending this presentation, attendees will be familiar with certain problems that appear in walkway-safety tribometry and how to statistically test for the presence of these problems.

This presentation will impact the forensic science community by alerting practitioners to potential problems in tribometric testing, how to determine if such problems exist, and how to eliminate them.

Background: A modified Stepmeter is in the process of being validated under ASTM F2508 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces.1 Briefly, the Step Meter is a cyborg-like take-off of a Slip-Test Mark II Portable Inclinable Articulated Tribometer, where a human subject's leg is constrained to move only vertically and/or rotate forward from the knee joint. The subject's constrained leg is passively lowered against an inclined test surface.2 More sophisticated statistical analysis than contained in F2508 is utilized, viz., logistic regression is used to find the point at which p(slip) = p(no slip) = 0.5.3 In the validation process, repeated tests (foot lowerings) are conducted at a given test-surface inclination angle and the sequence of slips versus no-slips is recorded. A visual inspection of the data raised the hypothesis that the initial foot lowerings in any sequence of same-angle tests appears to be somehow different from the rest of the sequence.

Experiment: To investigate this hypothesis, Official Vinyl Composition Tile (OVCT, Reference Surface C in F2508) and then Ceramic Tile (Reference Surface D) were successively installed in the modified Step Meter. The instrument's test-surface inclination angle was adjusted for each test surface so that the p(slip) was approximately 0.5. For each surface, repeated series of ten foot-lowerings were conducted (11 sequences for the OVCT and 10 for the Ceramic Tile). The slip/no-slip results were recorded in sequence (i.e., slip, slip, no-slip, …, slip). The number of slips was histogrammatically tabulated. If the probability of a slip is constant from foot lowering to foot lowering, the probability of the first slip at the kth trial will follow a geometric distribution:

$g(k;p) = p(1-p)^{k-1}; k = 1,2,\ldots,10 \text{ and } 0 \le p \le 1$ where $p = {}^{\text{number of slips}}/_{\text{number of trials}}$. For example, this study observed in total 53 slips in 110 trials for the OVCT, thus $p = {}^{53}/_{110} = 0.482$. A χ^2 goodness-of-fit test was conducted, where the expected number of occurrences was compared with the observed number of occurrences: (1) H_0: Distribution cannot be distinguished from a Geometric Distribution; (2) H_1: Distribution doesn't follow a Geometric Distribution; (3) Test Statistic: $\chi^2_{test} = \sum_{k=1}^{11} \frac{(O_k - E_k)^2}{E_k}$ $\chi^2_{test} = \sum_{k=1}^{11} \frac{(O_k - E_k)^2}{E_k}$ with k-2 degrees of freedom, and, (4) Where $E_k = 11g(k; 0.482)$.

First slip=k	$g(k;0.482)$	E_k=Expected	O_k=Observed	$(O_k-E_k)^2/E_k$
1	0.482	5.30	1	3.4887
2	0.250	2.75	0	2.7464
3	0.129	1.42	4	4.6661
4	0.067	0.74	1	0.0935
5	0.035	0.38	5	55.8059
6	0.018	0.20	0	0.1980
7	0.009	0.10	0	0.1026
8	0.005	0.05	0	0.0532
9	0.003	0.03	0	0.0276
10	0.001	0.01	0	0.0143
11	0.001	0.01	0	0.0074
Totals->	1.0	10.98	11.00	$\chi 2$=67.20

The *p-value* (i.e., pH(0)($\chi 2 \geq 67.20$))=0.0. That is, the probability that, under a geometric distribution, one could achieve the X^2 result found would be effectively zero: effectively an impossibility. For context, the 1% critical value is $\chi^2=21.7$.

The first and then the first and second foot drop results were then removed from the calculation. With the first reading in the sequence dropped, χ^2(8 d.f.)=31.4, with corresponding *p-value* of 0.0001, still highly significant. With the first and second readings in the sequence dropped, χ^2(7 d.f.)=11.89, corresponding to a *p-value* of about 10%, which is conventionally considered not significant. That is, with the first and second readings in each sequence ignored, the data could not be distinguished from a geometric distribution.

For the ceramic tile, χ^2(8 d.f.)=31.1, with a corresponding *p-value* of 0.0001. With the first foot-dropping result eliminated, χ^2(7 d.f.)=12.17, with a *p-value* of about 10%: not considered to be significant. With the first two foot-dropping results eliminated, χ^2(6 d.f.)=2.17, with a *p-value* of about 90%. (If you believed the results didn't follow a geometric distribution, you would have an approximately 90% chance of being *incorrect*.)

Recommendations: On the basis of these results, it would preliminarily be recommended that, at least for barefoot tribometry, the first two readings in any set of tests be ignored. That is, one should not record the first two test-foot drops. This study suggests that at least one of those two test-leg drops should be a slip.

Further Research: This study intends to extend this experiment to the other two ASTM Reference Surfaces (Granite and Porcelanosa Ferroker, A and B respectively). More important, perhaps, is to extend this work to testing using a Neolite® Test Liner Test Foot, a commonly used surrogate for a shoe heel. There are anecdotal reports of the same anomalous behavior in NTL tests, and thus bears investigation.

References:

1. ASTM, F2508 Standard Practice for Validation and Calibration of Walkway Tribometers Using Reference Surfaces, *ASTM International*, West Conshohocken, Pennsylvania.
2. Besser M, Medoff H, and Marpet M. "Biofidelity-based Comparison of Barefoot Slip Resistance (Laboratory) against an in vivo tribometer and a standard Tribometer," in *Proceedings of the 2010 International Conference on Fall Prevention and Protection* (NIOSH sponsored–2010)
3. Medoff H, Besser M, Marpet M. "Visual Characterization of Tribometric Reference Surfaces Using Logistic Regression" in Proceedings of the American Academy of Forensic Sciences, 62nd Annual Scientific Meeting, Seattle, WA. 2010.

Tribometry, Geometric Probability Dist., Barefoot Friction