Applying Ergonomics to Bathing Safety: Including adoption of unorthodox practices for slip-resistant underfoot surfaces of bathtubs plus showers and provision of effective points of control

Jake L. Pauls[1] and Daniel A. Johnson[2]

[1] Jake Pauls Consulting Services, Toronto, Canada
bldguse@aol.com
[2] Daniel A. Johnson, Inc., Olympia, WA, USA
dajinc1@mac.com

Abstract. Of four key factors in bathing safety, related to fall prevention and mitigation, slip resistance is relatively easily addressed. However, in the field of underfoot slip resistance, water is not typically considered as a "friend." Surprisingly, when applied to an underfoot terry cloth towel, water dramatically improves slip resistance in otherwise slippery dedicated showers and in bathtubs used for standup showers. This is now empirically established but, as it defies convention and occurs in a relative research vacuum, there is reticence about adopting the practice of simply having a wet—*or even better*—damp towel underfoot while entering, using and exiting a shower facility. This paper presents what is known and what remains to be learned about the extent to which—*plus why*—water and terry cloth are a potent slip-resistance combination that, qualitatively, solves one-quarter of the shower safety problem with conventional bathtubs and even more with dedicated showers. Regarding potency, we have learned that thin towels are more effective than thick ones and contaminants such as shampoo appear not to affect slip resistance. Combined with code-required improvements to another factor—*effective points of control through the addition of grab bars or stanchions,*—a new, cost-effective practice can greatly reduce the large injury toll.

Keywords: Bathing Safety, Slipping, Points of Control.

1. Introduction to Epidemiology, Etiology and Economics of the Problem

US injury statistics, including national annual estimates of hospital emergency department (ED) visits, from the US Consumer Product Safety Commission (CPSC) National Electronic Injury Surveillance System (NEISS) provide a useful picture of the size and nature of the injury problem with bathtubs, bathtub-shower combinations and showers. For example, using US CPSC NEISS data for 2010 (a year for which there are other useful data, noted below), an estimated 263,000 ED visits occurred due to bathtub and shower-related injuries. Note that NEISS deals separately with injuries associated with hot water scalds. (For convenience, the generic terms "bathing" and "bather" are used in this paper in relation to use of these facilities generally.) Examination of a convenience sample of short narratives available for the over 7,500 documented ED visits, on which such national estimates are based, revealed that falls are a typical mechanism leading to injuries, many of which occurred with bather movement before, during and after bathing when combinations of four key dangers are present:

1. Geometry of the impediments over which one must transfer (e.g., bathtub walls and high sills for dedicated showers)
2. Hard, unforgiving surfaces
3. Insufficient, effective points of control
4. Slippery underfoot surfaces.

Most dangerous are activities entailing transfers, both ambulatory—stepping in and out of a bathtub or dedicated shower—and stand-to-sit plus sit-to-stand transfers when horizontal forces underfoot increase relative to vertical ones.

Indeed, if bathing-related falls are compared to falls occurring on stairs, the exposure time-corrected risk of falls associated with bathing exceeds such risk for stairs. In other words, a single step into or out of a bathtub imposes a higher risk of a misstep and fall than occurs in a person's typical single step on stair flight—which entails moving ones foot the height of two risers. Each entails traversing about 400 mm vertically on a typical home stair.

Stairs accounted for the largest number of ED-treated injuries associated with consumer products typically found in buildings, according to the US CPSC NEISS data, with most occurring in homes. For 2010 in the US, stairs accounted for an estimated 1,232,000 visits to hospital EDs. Such stairs would likely be used for on the order of 100 steps per day per person, on average, versus on the order of one transfer step per person daily, on average, associated with bathing.

The relative growth of bathing-related falls versus those associated with stairs is also notable. Bath and shower-related injuries in the US grew in the two decades between 1991 and 2010 by a factor of two for those resulting in an ED visit and by a factor of three for those resulting in hospital admission after first going to the ED. For 2010, in the USA, there were about 263,000 ED-treated injuries associated with bathtubs and showers and about one million treated by medical personnel in all settings. Generally for all ages, stair-related injuries grew by about 65 percent over all ages for hospitalized cases between 1991 and 2010. Although outside the scope of this paper, toilet use involves some similar transfer issues to bathing with comparable mitigation measures, namely improving points of control. The vulnerability of older adults and their inability to forego toilet use, contrasted with bathtub and shower use, leads to larger proportions of older person injuries from toilet use. Thus dual use—for both bathing and toileting—of some points of control discussed below, is very important.

Most of the foregoing epidemiological and etiological data come from the author's own analyses using, , the readily accessible US CPSC NEISS Web site (https://www.cpsc.gov/cgibin/NEISSQuery/ last accessed 2018/05/27) and his own survey of hotel bathing facilities and bathing experiences during extensive, world-wide travels.

There also are more-formal literature resources. A listing of 50 documents is available directly from the first author; these were examined in the course of preparing a bathroom usability and safety policy statement for the American Public Health Association in 2016.

A smaller set of references was examined in 2015 for a set of proposals to the National Fire Protection Association (NFPA) for new requirements covering all new bathing facilities within the scope of NFPA's model building code, NFPA 5000 and NFPA's *Life Safety Code*, NFPA 101.

US government epidemiological analyses are somewhat more dated than those presented here; e.g., US Centers for Disease Control and Prevention (2011). The best etiological studies are also dated; e.g., Aminzadeh, *et al.,* (2000); Kira (1966); Stone, Blackwell and Burton (1975).

Especially recommended are synopses focused on both epidemiology and economics: e.g., Lawrence, Spicer, Miller (2015); Miller (2016). Miller (2016) provides some of the basic information needed to make the cost-benefit case for improved bathroom safety. In a later presentation, Miller (2017) provides more detail on cost-benefit analysis which was used by Pauls (2017) in a presentation video, focused on home bathroom safety. The economic bottom line of this is a close match in the annual societal cost per household, of bathing and toileting-related fall injuries in the US, and the cost of installing points of control, such as grab bars and, as a cost-effective more versatile innovation, stanchions. The latter, especially, could serve users of both the home bathing and toileting facilities that, in many small bathrooms, are often adjacent (as shown in Fig. 1).

2 Practice Innovations Addressing 3 of the 4 Types of Dangers

2.1 Points of Control to Mitigate Transfers over Impediments

See Fig. 1 for a two-option, demonstration installation in a traditional, small (2.1-meter by 1.5-meter) bathroom with bathtub-shower combination, a toilet and a lavatory (off the right side of the photo).

Unlike the conventional grab bars, wall-to-wall horizontal and tub-to-ceiling vertical stanchions do not require screws into the structure behind the ceiling, tiled walls or tub wall. They are not cantilevered out from walls but are held *between* wall, ceiling and other surfaces including, as in Fig. 1, the bathtub rim. Stanchions are typically seen on buses and trains, especially those used for commuting, and are typically within easy reach of most passengers, whether seated, standing or moving from one position to the other. The innovation here is to use stanchions in bathrooms.

In a typical small bathroom, the stanchion (the vertical one, with its bottom fixing on the bathtub rim, in Fig. 1) serves toilet plus shower and immersion bathing users. Either of options would meet the new NFPA requirements for locations of grab bar for new bathtub-shower combinations.

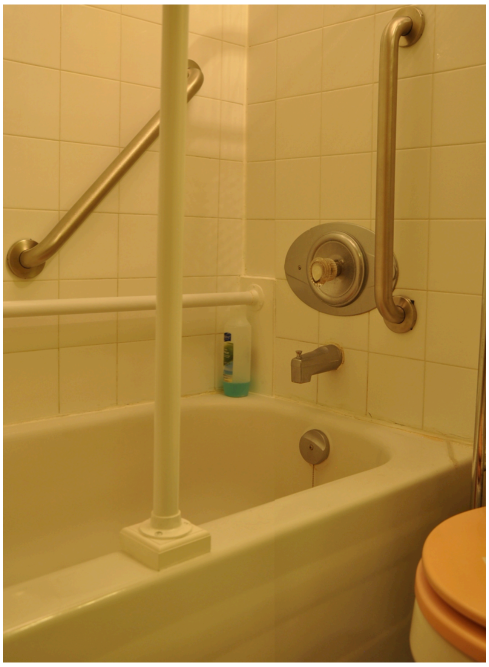


Fig. 1. Two options, one with stanchions (informally referred to as “poles,” usually straight lengths of graspable tubing) and the other employing conventional grab bars providing two points of control.

Although included as an option, as effective as conventional grab bars, stanchions are not required by the new NFPA rules where, in the 2018 edition of two codes, they are referred to as “poles” (NFPA 2018a, b). Stanchion-type bars are a relatively straightforward, cost-effective, NFPA-complying installation on existing bathtub-shower combinations, even in rental apartments. They can be easily installed and removed without wall, ceiling or tub damage as they can be held in place by special (automotive-grade) adhesives rather than screws into walls. The structural criterion applied is performance-based—a load of at least 250 pounds must be sustained through the life of the installation. Similar requirements are currently being processed through two other national model building code organizations in both the US and Canada.

The costs of installing the two points of control (horizontal or diagonal and vertical) are comparable to the average USD280 societal cost of bathing and toileting-related injuries—expressed on an average, per-household basis—over a one-year period. Even a relatively expensive installation cost, say double the USD280 (e.g., for retrofitting conventional grab bars), would still make the cost-benefit very acceptable given the years of service possible with the two points of control.

The foregoing information deals with the points of control involving ones hands although the vertical pole can also provide support at ones back, for example when standing on one leg and drying the other leg with a towel. Feet typically provide one or two points of control. Table 1 shows options for points of control dealing with gravity and lateral loads. For bathing, we need two or three points of control for comfort and safety; hence the need for proper handholds for transfers.

Table 1. Minimum number of points of control currently provided with typical practices or imposed design rules.

Number of Points of Control	≤1	1	2	3	3-4
Standard walker for older adult					√
Occupational settings with risk of worker falls from heights				√	
Stairs			√		
Bathtubs with slip resistant underfoot surfaces when wet		√			
Bathtubs with slippery underfoot surfaces when wet	√				

2.2 Hard, Unforgiving Surfaces, Including Those of Impediments

The first two of the key dangers listed above are relatively difficult to prevent and, thus, mitigation approaches are needed. These dangers are geometry of the impediments one must traverse by stepping over (e.g., bathtub walls and high sills for shower enclosures) and hard, unforgiving surfaces (e.g., enamel surfaces of rigid tub walls, ceramic tiles on walls and floors, and metal water controls plus spouts). An additional complication affecting step-over of the tub wall is the difference between floor and bathtub bottom elevations; this can be as much as 100 mm. Retrofit cutouts of tub walls are one partial solution and another expensive solution is a purpose-designed, walk-in tub. These pose operational complications and do not entirely eliminate elevation differences and step-over dangers. Hence points of control are still important.

With the best dedicated showers, the step-over danger can be eliminated through design and construction of a water-draining shower pan and attention to confining water spray, including fixed enclosures (e.g., use of safety glass). Such showers offer additional benefits to users requiring a roll-in design. Some hotels have begun retrofit programs, replacing conventional combination shower-bathtubs with walk-in / roll-in showers.

Many newer showers are delivered in one or a few pieces with resilient material for walls (instead of hard tiles) providing some cushioning in case of impact as well as controls and water spouts that would not be contacted so injuriously in a loss of balance or fall. However, even with newer materials, such showers share the danger posed by underfoot surfaces.

Showers require careful attention to underfoot slip resistance that is often inherent in wet conditions, even with certain tiles and surface roughness treatments underfoot. Adequacy of slip resistance should be confirmed, by competent expertise, in design and operation of such facilities. Unfortunately, for conventional bathtubs with their smooth surfaces, another approach to slip resistance is needed and this is the largest focus of this paper, especially as the recommended intervention is somewhat unorthodox, even heretical to some objecting to a virtually no-cost, simple solution to a complex problem.

3. Provision of Effective Underfoot Slip Resistance

3.1 Recent and Current Safety Standard Situation

Efforts to deal with slippery underfoot surfaces of bathtubs with manufactured surface treatments have not been successful (in the view of many safety professionals). An early effort to specify a minimum slip resistance criterion for new bathtub surfaces has floundered for multiple reasons including (as only several of many problems):

- Highly questionable minimum slip resistance (SR), also called static coefficient of friction (COF) of 0.04 originally specified in a ASTM standard, F462—79 (ASTM 1979) using a NIST-Brungraber portable slip-resistance tester.
- Application only to *new* bathing surfaces, for the duration of the warranty.
- Discontinued production of the single specified tester.
- Withdrawal, without replacement, of ASTM F462.
- The test foot material, used for original testing with the tester to simulate a bare foot, no longer being available.

As recently as early 2017, the situation was confused among bathtub manufacturing representatives and slip resistance experts (at the meeting of ASTM F15.03 committee responsible for safety standards for bathtub and shower structures). It was noted that the original decision on the 0.04 COF or SR threshold for "safe traction" was based on twice the traction from the best tested, untextured (wet) surface—which was also twice the traction of the worst textured surface. The threshold was *not* based on reasonable safety as determined with human subject testing, for example, to determine actually utilized (needed) slip resistance when stepping in and out of a bathtub (as discussed below).

The foregoing points and others, such as the summation that "F462 is only barely better than nothing," were presented within an ASTM's F15.03 Committee on January 31, 2017. One authority on the topic stressed what a replacement for F462 should be based on and how it should be employed to improve bathing safety from slip-related falls.

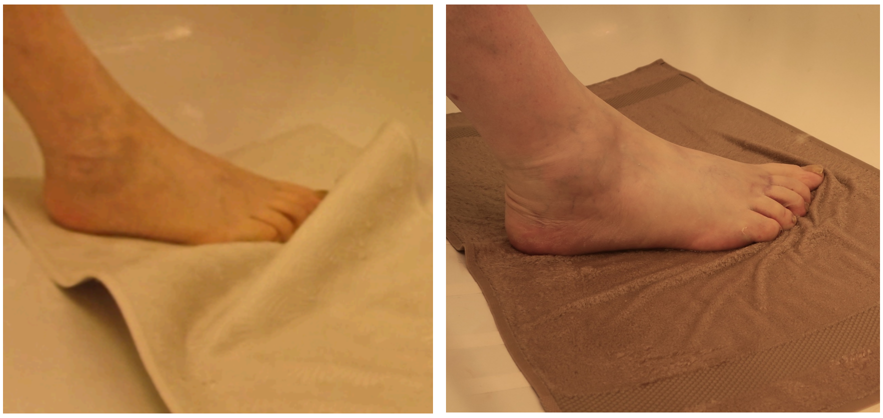
3.2 Study of Utilized Slip Resistance

Siegmund, *et al*. (2010) performed a study to "quantify the friction used by barefoot subjects entering and exiting a typical bathtub/shower enclosure under dry and wet conditions." The study involved 60 subjects, equally divided by gender, from three age ranges, younger, middle age and older adults. Force plates with slip-resistant surfaces (with SR of 0.55 to 0.90) provided data to derive utilized friction which was lower, by about 0.06, in wet conditions than in dry conditions. Older subjects used less friction than young subjects (p=0.01 to p=0.001 depending on complexity of the required movement*)*. The range of utilized friction was 0.102 to 0.442, with a median of 0.23. Between the highest and lowest mean plus/minus one standard deviation, the range of utilized friction was 0.13 to 0.36. Utilized friction was lower, by 0.058 ± 0.04, for wet conditions than for dry conditions. There were differences among age groups only for exiting the bathtub when young subjects used more friction. These results were significant at p =0.001 and 0.006. The only grab bar provided was on the back wall and subjects were instructed to only use it in case of a slip or loss of balance (which did not occur); so, generally, it was not reported as a factor in stepping in and out of the bathtub during the testing.

Selected ‘take home messages’ from the paper’s conclusions (with the following quotes taken out of order): “Overall, these findings suggest that subjects entering and exiting a bathtub adjust their utilized friction based on a perception of surface slipperiness.” Referring to the outdated standard (described in the prior section) governing bathtub stipulating a “minimum friction of 0.04” [ASTM, 1979], this is much “less than the friction subjects used here when entering a dry or wet bathtub.” The authors also noted “the importance of using mats, textured or etched surfaces to increase the friction of smooth bathtubs.”

3.3 Unreliable, Yet Widely Recommended Slip Resistance Interventions

The advice given in the quote above, regarding “mats, textured or etched surfaces” is questionable based on the authors’ personal experience with many bathtubs and showers worldwide. Some of the consumer-purchased mats, including those relying on suction cups, are relatively unreliable (compared to wet terry cloth towels addressed in this section), even if installed and used in accordance with product instructions. See Fig. 2.



A B

Fig. 2. Failure of (A) properly installed rubber suction cup mat, compared to a (B) wet terry cloth towel, during entry to wet bathtub with smooth enamel surface with relatively similar foot forces exerted.

Unreliability of both bathtub surface treatments and consumer-installed stick-on friction strips or rubber or vinyl mats relying on suction cups has been the expectation of the lead author for many years, buttressed by his many experiences with on the order of a hundred different bathtubs, combination bathtub-showers, and dedicated showers annually in the course of extensive international travel. Moreover, no relationship (except perhaps an inverse one) has been noted between price or opulence of a hotel room and the safety of its bathing facilities. This included one serious, injurious fall, he suffered decades ago, when attempting to get out of a bathtub, in a posh hotel room bathroom.

Only rarely—on the order of a few out of a hundred times—has a sufficiently slip-resistant, underfoot, bathtub surface been encountered in the daily showering experience, most notably with typical bathtub-shower combinations. When wet, etched surfaces and textures (which can be compromised with abrasive cleaners) almost always provide no better perceived slip resistance than does smooth enamel; i.e., with provided slip resistance less than a tenth of what is required for utilization (SR or COF in the 0.1 to 0.44 range) as discussed above in the subsection on utilized slip resistance.

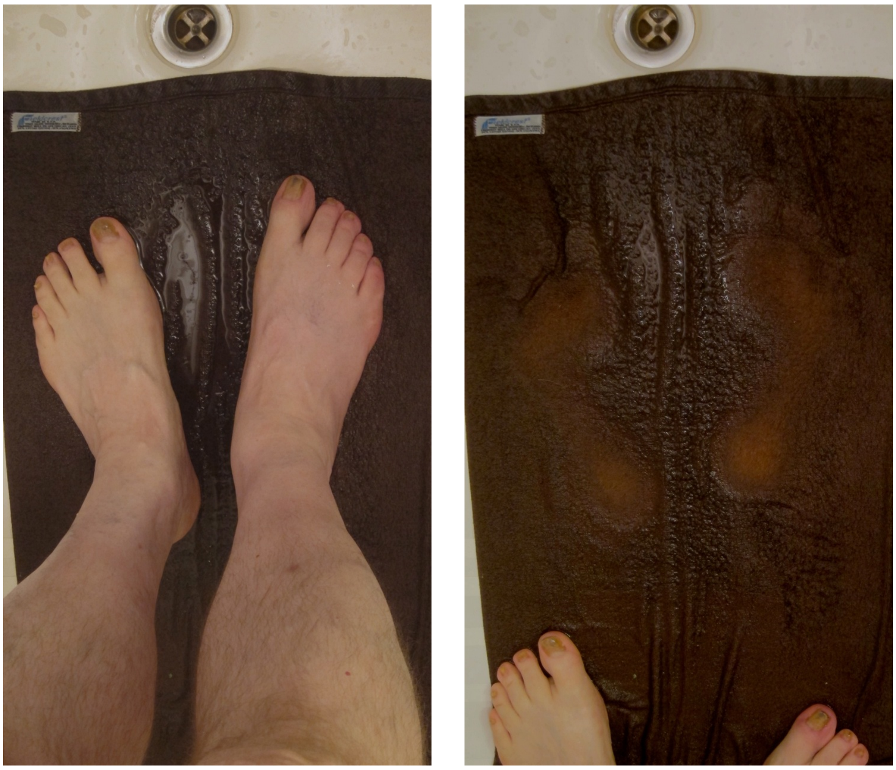
Other solutions to achieving slip resistance, not relying on ineffective industry treatments of underfoot surfaces, were clearly needed (at least in the authors' view).

3.4 Underfoot—Dry, Damp and Sopping Wet—Terry Cloth Towels

The idea about use of wet terry cloth towels for bathtub mats likely came to the lead author from the usual hotel room mat for use on the floor outside a shower or bathtub. On smooth ceramic or stone flooring, such mats—often of somewhat thicker terry cloth construction, usually slide easily underfoot except when, if some water was splashed outside the tub or shower, the mat was thrown or placed on top of the wet floor. Result: the terry cloth mat no longer slid on the smooth floor. As soon as ones weight began to be applied to the mat, it stayed in place, *very reliably!* The water film under the mat had an adhesion effect. Soon the practice moved to insuring that there was some water on the floor before such a mat was set in place.

The full *Eureka* moment came when a standard hand-size, terry cloth towel was thrown into the wet, smooth enamel-finish bathtub being used for a shower. It was easy to position and smooth out the sopping wet towel with a light touch from one foot. As soon as (half) body weight was applied underfoot, there was no movement of the towel under wet conditions even when a horizontal force was exerted at about a 60-degree angle of one leg and the underfoot surface.

Experimenting with combinations of horizontal and vertical forces with one foot revealed what happens in the fraction of a second when the bare foot compresses the terry cloth towel. This expels excess water from underneath the ball and heel of the foot (as shown in Fig. 3B) so that the foot moves horizontally 1 to 3 cm before locking in place with no slipping between foot and towel as well as between towel and smooth bathtub surface. A similar effect is shown in Fig. 4 where the vertical force from the bather's body weight is applied to a curved portion of the bathtub so that there are both tangential and normal forces on the surface which varies in slope, underfoot, from 5 to 45 degrees from horizontal (equivlent, as the angle tangent, to SR of 0.09 to 1.0).



A B

Fig. 3 Sequential views of (A) feet compressing the sopping wet terry cloth towel and (B) immediately after the feet are repositioned, the compressed towel—while briefly only damp—has visible impressions of the feet.

Testing with Variably-inclined Surfaces. Subsequent, systematic testing of wet towels on a polished glass ramp surface of variable inclination confirmed that the wet towel, underfoot, is stable to nearly a 30-degree inclination. (See Fig. 5) At such high slopes the towel moves slowly, in a creep fashion (at about one cm per second), not precipitously. Note, unlike in the European Ramp Test (discussed by Di Pilla, 2003), subjects here do not walk on the sloping surfaces; they stand in place. Effective SR up to about 0.5 can be tested with the adjustable slope available to the lead author.

Fig. 4. Foot carrying all of bather's weight on the curved portion of the bathtub, where the slope ranges from 5 to 45 degrees with a damp terry cloth towel interface. Note that the towel has only shifted less than a centimeter.

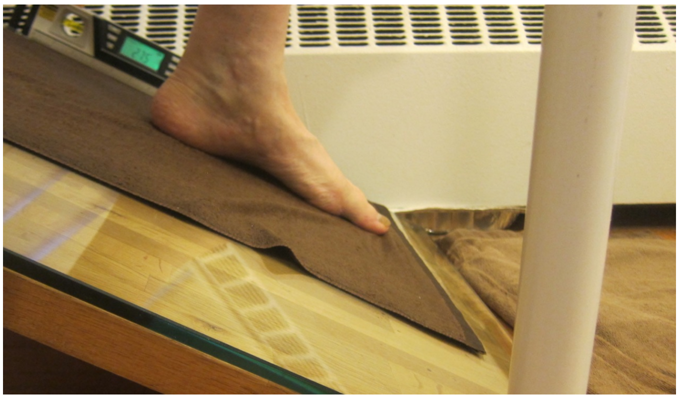


Fig. 5. 27.5-degree (tan 0.52) slope glass ramp surface with damp terry cloth towel showing slow creep just beginning.

Further testing, with an adjustable glass surface, as well as a polished surface comparable with plastic tub construction, is contemplated to provide more quantitative data, with multiple subjects, and to video record (in high-definition) the underside of the clear glass ramp to understand better the mechanism based on intimate interface of smooth glass, a film of water and the compressed, highly fibrous towel under bare foot pressure. But first, it is important to describe findings by the second author to complement the first author's empirical findings reported here.

Testing Slip Resistance of Terry Cloth Towels with a Tribometer. The second author of this paper, who is certified in the use of a tribometer (the Variable Incident Tribometer, VIT) has, independently been testing comparable terry cloth towel samples with a smooth granite surface as well as a calibrated test tile of known slip resistance (SR) comparable to what a glazed enamel tub provides under dry, damp and sopping wet conditions. As demonstrated in the following findings, these standard measurements corroborate what has been found in field settings with actual bathtub and shower surfaces and standard, hotel-supplied terry cloth towels (that are similar to towels used very widely in other residential settings, among others). The tribometer studies also considered the effect, to slip resistance, of various thicknesses, measured as weight per unit area, of terry cloth towels in addition to fiber composition, which is typically cotton but could include other materials such as bamboo and some synthetics.

One relatively early tribometer consisted of a weighted object being pulled across a dry, flat, horizontal surface. Slip resistance (SR) was simply the ratio of the horizontal force needed to start the object in motion divided by the weight of the object. But if there is moisture between the weight and the surface, then adhesion, called "stiction", can cause erroneous readings so that this method does not give valid readings (English, 1996). Stiction appears to result when there is some residence time after the weight is placed on the surface and the horizontal force is applied.

Variable Incident Tribometer. An alternate method is to determine the tangent of the angle at which a force is applied to an object to just start the object sliding over the surface. If, for example, the object starts to slide when a force is applied at an angle of 26.6°, the slip resistance = tan 26.6° = 0.5 (Templer, 1992). If the force is applied to a wet surface in such a manner so that no stiction is allowed to form, the readings of slip resistance are consistent with human experience (English, 1996).

The English XL, commonly referred to as the Variable Incident Tribometer (VIT) (see Excel Tribometers), overcomes this problem and was used in subsequent tests reported below.

Slip Resistance Criteria. Slip resistance of a walkway can range from a theoretical zero up to and sometimes greater than 1.0. A slip resistant surface for those who do not expect to be walking on a slippery surface is generally considered to be one that provides a slip resistance of 0.5 or higher (Ekkebus and Killey, 1973; Sacher, 1993; Nemire et al., 2016). But one can walk without falling on a surface with a somewhat lower slip resistance, especially if one knows or expects the surface to be slippery.

Most dry surfaces provide adequate slip resistance while some of those same surfaces are dangerously slippery when wet (Templer, 1992).

Initial Test of Concept with Smooth Granite Surface. A smooth granite counter top was initially tested both in a dry and wet condition, and with and without a towel between the VIT test foot and the granite. A VIT, recently calibrated by the manufacturer, was used for all tests.

Not surprisingly the wet granite exhibited a low SR (0.188) compared to the dry granite (SR = 0.864). The difference was highly significant (t test, $p<.01$). This result is consistent with reports that smooth hard surfaces, such as granite and marble, when wet, are slippery and associated with falls (e.g., Di Pilla, 2003, p.128).

The corner of a thin towel was inserted between the VIT foot and the granite. When a slip occurred, it was noted that the towel slipped on the granite rather than the test foot slipping on the surface of the towel. Distilled water was applied to the surface of the granite, or the top of the towel. The SR of the towel on the granite under dry and wet conditions is recorded in Table 2.

Table 2. Effect of towel, wet or dry, on slip resistance of smooth granite counter top

Surfaces	**No Towel**	**No Towel**	**With Towel**	**With Towel**
Condition	**Dry**	**Wet**	**Dry**	**Wet**
	0.86	0.2	0.2	0.35
	0.86	0.16	0.24	0.41
	0.9	0.18	0.25	0.41
	0.85	0.21	0.26	0.4
	0.85			0.41
				0.4
Means	**0.864**	**0.188**	**0.238**	**0.387**

The difference between the towel on the dry granite vs towel on the wet granite was highly significant: t test: p=8.13 E-.06. The difference between the Wet condition, with and without towel, was also highly significant: t test: p=6.12 E-.07. The relatively higher SR on the wet vs the dry surface confirmed what Pauls had demonstrated; the foot did not readily slide when it was on a wet towel on a smooth hard surface.

SR Testing on a Calibrated Test Tile. Further testing on towel density as well as when there were likely contaminates was conducted. A recently calibrated Certified Test Foot Calibration Tile from (Excel Tribometers, Tile #219) was used as a base upon which a portion of each towel was placed during testing. When tested wet without any towel the tile exhibited a SR of 0.188, a value within the range of 0.17 (+/- 0.03) that was consistent with the range reported by Excel Tribometers for that calibrated tile.

With Soap and Shampoo Contaminants. Though expecting some effect on SR when the towels were contaminated with soap and shampoo, it was found that there was no significant effect on SR when testing towels that had been placed on a tub surface following bathing and the bather used either soap (Ivory® hand soap) or hair shampoo (Suave®). The testing was not done in that shower but, instead, on the calibrated test tile.

Towel Thickness. According to the Turkish Towel Company (2016) plushness is associated with its density, its weight and size. A towel's grams per square meter (GSM, or g/m^2) represents how many grams the dry towel weighs per square meter:

> "The higher the grams per square meter (GSM), the denser the fibers of the towel are, making it softer and more absorbent. A GSM between 300 and 400 makes for a thinner towel, whereas a GSM of 450 to 600 is plush. A GSM of 700 or higher is considered luxury hotel quality." (Turkish Towel Company, 2016)

The granite counter top was then tested with a thin hand towel (GSM = 406 g/m^2). SR with the dry towel (0.238) was relatively slippery but when distilled water was applied to the towel a SR of (0.397) was recorded. The difference was highly significant (t test, p<.01). It was decided to evaluate the concept using towels with characteristics, similar to those found in hotels and other commercial establishments, and to study any effect that contaminants (i.e., soap or shampoo) or how the use of thicker towels might affect the results.

Two towels of similar size (~ 410 mm by 460 mm) were measured with a tape measure and weighed on a digital scale so that the plushness of each towel could be calculated. Both towels had a GSM > 600 and so are considered "plush".

The SR of both towels on the certified test tile was ascertained under dry**,** damp and sopping wet conditions. The "damp" condition occurred when distilled water was applied to the towel but the water did not appear to pool above the base of the threads. The "sopping wet" condition was when the water was visible above the base of the fibers at the start of the test (see Table 3).

Table 3. Slip Resistance of Thin vs Plush Towels When Dry, Damp, and Sopping Wet on Test Tile

	A	**B**	**C**	**D**	**E**	**F**
GSM	643	683	643	683	643	683
Conditions	Dry	Dry	Damp	Damp	Sopping	Sopping
Thickness	Thin	Thick	Thin	Thick	Thin	Thick
	0.18	0.21	0.36	0.28	0.27	0.21
	0.17	0.2	0.33	0.26	0.26	0.23
	0.17	0.2	0.32	0.28	0.28	0.24
	0.19	0.19	0.31	0.31	0.29	0.24
				0.34		
				0.31		
Means	**0.1775**	**0.200**	**0.33**	**0.297**	**0.275**	**0.23**

Significance:

A vs B Thin vs Thick - Dry: significant i.e., p<.05 (t test, p = 0.0117)

C vs D Thin vs Thick - Damp: not significant (t test, p = 0.085)

E vs F Thin vs Thick - Sopping: significant (t test, p = 0.003)

Dry vs Wet Towels Data pooled: Thin vs Thick (Damp & Sopping Pooled)

C+D vs E+F not significant (t test, p = 0.092)

Wet vs Dry highly significant (t test p <<.001)

Tests in Porcelain Tub. Damp and sopping wet towels did not exhibit a statistically significant difference ($p=0.26$) when tested in a nine-year-old bath tub that had been used almost daily. When data were pooled the damp and sopping wet towels had a higher SR (Mean = 0.296) than the wet tub with no towel underfoot (SR mean = 0.24). The difference was statistically significant ($p < 0.004$). The 95% Confidence Interval for the porcelain tub with a wet towel (damp or sopping wet); SR = $0.26<0.3<0.34$.

4. Conclusions

Generally, the practice of using ordinary terry cloth towels to solve one of the main problems with bathing safety, along with installation of effective points of control—for example, using stanchions that integrate well with bathroom décor at low cost—should make bathing a less dangerous activity, at modest cost and low installation complexity in both new bathrooms and existing ones.

One bottom line is somewhat unorthodox, even heretical. Whereas in much of the work on slip resistance, water is considered an "enemy, it turns out that for slip resistance of smooth, wet surfaces typically found underfoot in a bathtub or shower, the combination of ordinary terry cloth towels and water is your "friend." Towels are ubiquitous and readily available in bathrooms in most homes and hotels. If people were advised to place damp towels on the floor of tubs and showers, as well as on the floor outside of the tub in a location where they would expect to be stepping when entering or exiting the tub, the probability of slips and related missteps could be greatly reduced.

Solutions to the slipping and other problems for bathing—especially showering—can be elegant, counterintuitive, inexpensive and immediately at hand (or should we say also "at foot") in every bathroom. Such solutions are addressed in freely accessible videos and, increasingly, those requiring structurally adequate installation of points of control are being enshrined in North American safety standards and building codes. Thus improved bathing safety could be a success story in applying ergonomics to heretofore inadequately addressed public health problems.

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