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The Application of Forensic Biomechanics to the Resolution of Unwitnessed Falling Accidents*

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ABSTRACT: Following a brief review of the biomechanics of walking and slipping, vis-à-vis, tripping and stumbling, the application of forensic methodology is demonstrated in an alleged slip and fall accident. The three types of missteps which lead to falls, viz., slips, trips and stumbles, are defined and clearly distinguished, not only by mode of initiation, but also by the termination step, i.e., the direction of fall, the landing distance from misstep initiation, the ground and body impact sites, the body's final position/orientation, and the nature and severity of the injuries. Such detailed information, rarely appreciated or volunteered by a plaintiff, must be painstakingly elicited or developed independently by scrupulous investigation. Further, it is important to determine whether a plaintiff's *initial* description of an accident to medical providers (EMS, ER nurse, and physician) is reasonably consistent with the litigation version, and also, our current understanding of the biomechanics of falling accidents. In this instance, an elderly female purportedly slipped and fell on a wet floor and sustained a severe neck injury which resulted in quadriplegia. The *prima facie* evidence produced by the victim's expert, a consulting engineer, was compelling, albeit simplistically limited to a comparison of the "wet" and "dry" static coefficient of friction of the subject floor with "Industry Standards." The author's examination of other salient contributory factors provided a more defensible rationale with respect to the proximate cause of the plaintiff's falling accident. After reviewing the usual litigation documents and measurements of the subject floor's dimensions and slip resistance, the investigation focused on the plaintiff's footwear, medical records, and rather limited recall or awareness of actually slipping or even falling. The author concluded that the probability was extremely small that this partly witnessed "fall" was the product of a "slip" on a wet surface, especially when compared with established biomechanical models. Instead, it is suggested that the "fall" stemmed from either a trip/stumble or a "collapse"—the sequela of the "victim's" chronic, serious medical problems and recognized age-related locomotor deficiencies.

KEYWORDS: forensic science, biomechanics, human locomotion, slip, trip, stumble, falling accidents

Historically, following a falling accident, forensic engineers were retained when monetary damage awards were potentially substantial. If a plaintiff was alleged to have slipped, the expert would measure the subject floor's coefficient of friction with a portable friction tester. On the other hand, if a fall was allegedly caused by a trip or a stumble (not previously distinguished), the expert would identify the defective construction and cite the appropriate building code violation. Rarely was the role of human locomotion biomechanics examined or even introduced as a critical component in the analysis and reconstruction of an accident. The reason? The biomechanics of slipping, tripping, or stumbling and their consequences (the central issue of this paper) had not been adequately addressed in the scientific literature until quite recently.

Human biomechanics is an interdisciplinary science encompassing anatomy, physiology, psychology, physics, and mathematics, and is concerned with the interrelation of structure and function with respect to the *kinetics* and *kinematics* of human motion (1–4). The forces produced by the human body, the forces acting on the human body, and the consequences of such motion on tissue deformation are collectively referred to as the kinetics of motion. The spatial and temporal characteristics of motion are referred to as kinematics.

The term *forensic biomechanics* was introduced by the author a few years ago to provide a clear and succinct expression for an emerging sub-area of growing importance in this so-called litigious society.

The human gait involves a complex, integrated neuromuscular skeletal activity which, when disturbed by environmental or purely personal factors, may cause large postural perturbations. These, in turn, may lead to an irreversible loss of balance. In order to transport the body safely and efficiently across the ground, whether level, uphill, downhill, or fraught with a series of man-made obstacles (steps), there are at least three critical tasks that must be controlled: (1) *posture*—the position of the total body relative to gravity, (2) *balance*—keeping the body's *center of gravity* safely within the *base of support,* and (3) *foot trajectory*—which must be adequate for safe ground clearance. The body's center of gravity (or mass) is an imaginary reference point defined by the intersection of the body's coronal (frontal), sagittal (lateral), and transverse (horizontal) planes. It is located about 55% of the body height above the ground or 15 cm (6 in.) above the crotch, nominally (5). The base of support is the area between the feet when standing comfortably in a relaxed mode with the feet apart.

A complete walking cycle, the *stride,* is from *heel contact* to heel contact of the same foot (two steps). It takes about 1 s when walking at an average pace of 1.32 m/s (3 mph) (6). Within the cycle each leg alternates between a *stance* (supporting) and a *swing* phase. Walking is initiated by the voluntary start of a forward fall by bending slightly at the ankles, taking the body's center of gravity ahead of the base of support. Then, only by the safe placement of the swinging foot, just in time to establish a new base of support, is a fall averted once every step. Accordingly, walking has frequently been described as a repetitive loss and recovery of balance, and ". . . a series of catastrophies narrowly averted" (7).

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By convention (8), the walking cycle commences with *toe-off*, the instant when/after the toe *leaves* the ground. It defines the end of the stance and the beginning of the swing phase. Following toe-off, the vertical displacement of the toe is no more than 2.5 cm (1 in.) above the ground. The foot trajectory then drops to a toe clearance of only 0.55 cm (0.2 in.) before rising to a maximum height of 13 cm (5 in.) just prior to heel contact. After heel contact, the toe lowers to the floor as the ankle plantarflexes.

At the beginning of the stance phase (following heel contact) the foot rocks forward from heel to toe. The heel is then raised (*heel-off*), leaving only the forefoot to *push-off* in a backward direction. This action maintains the body's forward motion. With respect to its trajectory, the heel reaches a maximum vertical displacement of 25 cm (10 in.) shortly after the forefoot has lifted from the ground (toe-off) and then drops rapidly during mid- and late-swing. Its drop is arrested 1 cm (0.4 in.) above ground level, after which the heel is lowered very gently during the last 10% of the swing phase—as both its vertical and horizontal velocity decrease very rapidly (to near zero), immediately prior to heel contact (3).

It is interesting to note that during the swing phase, which represents 40% of the stride, the lower leg reaches a velocity of 32.18 kmph (20 mph). In running, the velocity becomes 64.36 to 80.45 kmph (40 to 50 mph) (2). Running differs from walking in two other significant respects. First, during one phase of running, the *flight* period, neither foot is in contact with the ground, i.e., there is an overlap of the swing phases; and second, at no period are both feet in contact with the ground as occurs in walking, wherein there are two short (10 to 12% of stride) overlapping stance phases. During this *double support* period, stability is not yet very firm since one foot is accepting weight on a small area of the heel (rear edge), while the other is pushing-off on the forepart of the foot.

Definitions

With respect to the biomechanics of walking mishaps (slips, trips, and stumbles), the following definitions and expositions, which are finely honed for our specific purposes, represent the author's attempt to provide a clear and unambiguous understanding of misstep mechanisms. They are based on the prevailing state of knowledge and the author's observations of more than 30 years (9).

A *slip* is defined as a sudden loss of footing—the result of an unforeseen, unexpected and out-of-control slide of the foot. It is the end-product of insufficient friction, that is, when the biomechanically required coefficient of friction, μ_r, is greater than the available coefficient of friction, μ_a. The former, μ_r, is a measure of *all* the forces generated by an individual walking across a piezoelectric force plate *prior* to a slip. It reflects not only gait variability, an inherent component of human movement due to the large number of functional degrees of freedom, but also velocity, footwear (heel/sole composition, profile, and wear) and floor surface (composition, morphology, pitch, and condition). In contrast, the available coefficient of friction, μ_a, is simply a determination made by means of a friction tester *at/immediately after* the initiation of a slip. It is found to vary significantly (by as much as 0.3 to 0.5) with the type of friction tester, the sensor material (composition and preparation), and test procedure details (10). Finally, it is important to note that albeit μ_r and μ_a are intrinsically significant and meaningful, no direct numerical relationship has been established between the two. Perhaps none should be expected since different mechanisms and total forces are involved. As such, based on the prevailing state of knowledge, to require or even to suggest that the numerical value of μ_a be equal to or exceed that of μ_r is *naive*.

Slip resistance is that property of a surface (footwear or flooring) which denotes its ability to withstand or give protection against a slip. Accordingly, a slip may now also be defined as an involuntary foot-slide, the consequence of inadequate slip resistance. Slip resistance is essentially a descriptive term encompassing all the material and human elements that may lead to a slip. It is a function of a number of parameters, among which the coefficient of friction (static/dynamic) is only one—albeit probably the most important. It is neither a constant nor an intrinsic property of a given surface, and palpably should neither be confused with nor used interchangeably with coefficient of friction. As an ephemeral characteristic slip resistance varies with surface position (spatial configuration), texture, hardness, wear, and contamination (in addition to fit and heel height for footwear), and also activity—whether walking (in a natural, slow or fast cadence), running, turning or pivoting, pulling or pushing, ascending or descending (ramp or steps). It is further influenced by intrinsic factors, such as an individual's physiological, perceptual, and behavioral condition. Frequently, slip resistance is merely an individual's perception—a subjective, qualitative assessment of the degree to which a particular floor resists the movement of one's shoe sole across its surface, wherein the co-equal contribution of the footwear is either ignored or not even considered.

It has been shown that a fall will occur $\approx$0.05 s after heel contact (when the vertical load is about 60% of body weight) if the shoe slides forward at the beginning of the stance phase (but never when it slips backwards at push-off) and the *distance* of the slide is greater than 10 to 15 cms (4 to 6 in.) or the *velocity* of the sliding foot is greater than 0.5 m/s (1.6 ft/s) (11–13). Under these classic conditions, as the sliding foot accelerates forward the same side of the body rapidly falls in a posterior or posterolateral direction with concomitant protective extension of arms. The victim lands squarely on the buttocks or on the side of the buttock, hip, thigh, shoulder/arm. The final position after impact is either sitting or lying (on the side or supine), depending on distance, velocity, and angle of the foot slide. It should be noted that the body's center of mass always lands close to or directly over the slip situs. If the contralateral foot has already toed-off and moved ahead of the body (prior to its impact with the ground), that leg will also be in a forward position, lying "normally" or bent/distorted under the slipping leg. If the contralateral leg has not moved ahead of the body, it may become pinned beneath the body or twisted at the knee away from the body. But if it has remained steadfast, an acrobatic-type "split" may occur, especially if the heel is almost level at slip, or the individual has an equinus gait (lands on the ball of the foot instead of the rear outer edge of heel) (14).

A *trip* is defined as a sudden loss of footing, the sequela of an interruption in the natural, rhythmic movement of the swinging leg. It occurs at any point where an obstruction impedes or checks the smooth completion of the step, causing a momentary hang-up of the foot. In a study of the critical kinematics of the foot trajectory, it was pointed out (3) that an obstacle as little as 5 mm in height at the time of minimum toe clearance (when the forward velocity is at its maximum, 4.5 m/s) has the potential for causing a trip. If balance is not restored during the stumbling phase, the body starts to fall in an anterolateral direction, the reflex and equilibrium reactions are activated, the head and trunk are arched back to counteract the forward momentum, and the arms are abducted to assist in regaining balance. The victim may land prone (arms abducted), sideways or on hands and/or knees with injuries to the head(face)/neck, shoulder/elbow, hands/wrists, hip, thigh, knees, ankle or foot. Landing distance from the obstacle and the extent of injury are consistent with the body's orientation vertical force, kinetic energy, momentum, and the hardness of the ground impact site (14).

A *stumble* is an unstable, erratic, arrhythmic and asymmetric foot movement, following a loss of footing due to extrinsic or intrinsic factors. The former may result from a trip, collision or push; the latter from fatigue, medication, alcohol, surgery, illness, or age-related declines in visual, vestibular, proprioceptive or musculoskeletal functions. A consequence of these intrinsic factors is the atypical or pathological variation from normal walking patterns, including the degenerative gait of the elderly (15,16). All aberrant gait patterns are manifestations of changes in timing, misalignment of body parts, and difficulty in executing movements (slowed reaction times and coordination problems). They can result from responses to pain, muscle weakness or paralysis, spasticity or contactures of muscles, sensory disturbances, and disease (17–19). Clearly, any of these conditions may affect the control of the foot during the swing or the stance phase, despite redundancy and synergies. It has been shown that a relatively small change in joint angular degrees of freedom (during swing) can strongly influence the end-point of the toe/heel trajectory, and if this results in inadequate ground clearance (3), a stumble may be initiated. Patently, a stumble will terminate in a fall direction, landing distance and injury—governed by and consistent with details of its etiology (14).

Parenthetically, parallel, in-depth studies of slips, trips, stumbles and falls involving stairs and ramps have also been made (20,21). It is interesting to note that the biomechanics of ascending and descending stairs and ramps differs markedly from walking on level surfaces, and is, moreover, dependent on the direction and steepness of the gradient (11,13).

Mobility Impairment in the Elderly

It has long been recognized that as one grows older, there is an increase in chronic and disabling conditions which affect the musculoskeletal system. A primary consequence of this problem is a progression from physical impairment and attendant limitations to physical disability itself. One of the most pernicious outcomes of this process is an increased predisposition to falling. A study of the causes of such falls in the *healthy elderly* (18) identified ten personal factors which, if present, increased the likelihood of such a mishap. These included, to name just a few: disturbance of gait following a rest period that is followed by a lighting change (in persons aged 70 and over); the presence of a foot problem; and, a sustained drop in pulse pressure 5 min after cessation of a rest period. Interestingly, among the types of falls described by patients in this study, a *collapse* ("found myself on the floor") adjudged to be illness related, occurred indoors more frequently than either slip or trip accidents. Other critical elements of mobility impairment in the elderly that affect their ability to walk are: changes in cognition and central nervous system processing; the effects of physical inactivity and disuse; and the effects of medications (17). With respect to the latter, it was found (19) that the use of at least four prescription drugs contributed significantly to falls among the elderly (>70 years of age). Another study (22) of particular interest in this case, involved the kinetic and kinematic measurements of an individual's "response" to large postural perturbations following an unexpected (induced) trip.

Case History

Briefly, the circumstances surrounding the subject accident are as follows: In December 1990, at approximately 2:30 pm, the plaintiff, a 78 year old, 1 m 70 cm (5 ft 7 in.) tall, "obese" (hospital notation), unmarried, retired female, was driven by her two older maiden sisters to the parking lot of her doctor's office (located in a single-family home), a 20-min trip. The plaintiff had been visiting her doctor every six to nine weeks for many years, not only for routine podiatric care (corns, calluses, nail trimming, etc.), but also for "multiple foot deformities," i.e., bunions, hammer toes, dislocation of the second metatarsal phalangeal joints, and painful, debilitating ulcerations ("open sores") under both feet, the problem that was to be treated on the day of the accident.

It had been snowing lightly until about 6:00 am that morning, with a 24-h snowfall measuring 7.6 cm (3 in.), and a total accumulation of 15.2 cm (6 in.). Although the snow had been removed from both the parking lot and the (indoor/outdoor) carpeted walkway leading up to the office landing, they were "very wet" according to the plaintiff and her sisters. Interestingly, the temperature remained below freezing until noon, and even then, only rose slightly to 1 to 2°C (34 to 35°F). The plaintiff was warmly dressed and wearing rubber-soled boots. While still on the landing, the plaintiff opened the entrance door to the building, stepped up 17.8 cm (7 in.) onto the carpeted doorstep and then over the threshold directly onto the rubber tile floor of the waiting room. There was *no* entrance or safety mat. The plaintiff could only remember "... putting [her right] foot down on the floor ..." She then stated that she fell but "... didn't know [she] was falling ..." The first time she knew she fell was when she found herself flat on her face. Furthermore, she testified that she didn't "... remember having that [left foot] in [the room] at all ..." She also didn't remember putting her weight onto her right foot at the time she fell.

On the other hand, one sister, who was walking just two feet behind her, stated that the plaintiff fell forward onto the floor, landed face down, arms at her sides. According to another witness, an attorney, the plaintiff landed with the top half of her body on the carpeted portion of the floor, which began 2 m (6 1/2 ft) from the door, with her legs on the tiled floor, about 1.2 m (4 ft) from the door.

Her doctor heard a commotion, ran to her aid, and later stated that he "... wasn't sure whether she was conscious, unconscious ... whether she was breathing at this point ... whether she had a heart attack, [or] whether she had a stroke." Further, when he asked her if she was okay, the doctor stated "... there was no movement, none at all. She had made no attempt to do anything." However, when the doctor tried to turn her over, the plaintiff "moaned." Ultimately, they did succeed in rotating her onto her back and found that she was bleeding from and across the bridge of her nose.

According to their deposition testimony, neither the plaintiff nor her sisters knew why she fell, nor did the sisters state that they saw her slip. Moreover, neither the plaintiff nor her sisters ever stated that they saw any water on the floor, but assumed that it was there because they observed someone wiping the floor "near the door" with a towel, but that was some time after the paramedics had arrived.

The plaintiff was taken to the hospital emergency department where her condition was diagnosed as "spinal trauma," and ultimately, quadriplegia. The report indicated that she had been taking "water pills" for fluid around her ankles; that, in addition to ulcerations on the soles of her feet, she had a rash with "blistering" on the pre-tibial area with "yellowish scaling," "crusting" and "plaque." The hospital records also showed that she had a history of temporal (giant cell, cranial) arteritis—a serious, debilitating disease.

Inspection

The plaintiff's investigator inspected the accident site about four months after the incident. He prepared a "forensic diagram" (to scale), took photographs of the waiting room floor, and also interviewed (confronted) the "young attorney" who "allegedly" witnessed the accident. The investigator reported that this witness claimed ". . . [he] was able to see [the plaintiff] trying to enter the door [while he was still behind the glass door of the nurse's station] . . . [and that] she stumbled over her own feet and the reason that she fell [was] that she did not get her foot up over the threshold high enough, but tripped herself as she was trying to get in and fell on her face." The investigator, with his "forensic diagram" in hand, challenged the witness's statement "on the basis . . . that if [he] were standing inside the nurses station . . . [he] would have no visibility whatsoever due to the entrance door itself blocking that view while open." The investigator further stated that ". . . the stone wall, which effectively blocks visibility in that direction, would also prevent visibility of a person entering the door until they got inside the room to a distance of three and a half to four feet or beyond the extended door itself." So convincing was the investigator, that the witness modified his original statement when deposed, stating that he was uncertain of the beginning of the accident, but, did in fact, see the plaintiff stumbling and falling forward into the waiting room.

Two years later the plaintiff's expert, a consulting civil engineer, inspected the accident site and performed ". . . tests on exemplar . . . rubber tiles . . . in both a dry and wet condition [using the Mark II Slip Tester,[2] which] . . . revealed an average coefficient of friction of 0.47 and a wet coefficient of friction of 0.28." The tile manufacturer ". . . using a James Machine[3] . . ." obtained an average coefficient of friction of 0.51 (24 tests). Despite the tile manufacturer's reported (quality control) results, the expert concluded that the tile ". . . [was] hazardous and dangerous when contaminated or wet . . . [that] there [was] no explicit warning of the danger of walking on a tile when contaminated or wet, nor [was] there any instruction given to use a floor mat . . . Additionally, [that] the tile in a dry condition [did] not meet the minimum standard of care recommended by USATBCB."[4]

The author inspected the accident site approximately three and one-half years after the incident and made both dimensional measurements of the doctor's waiting room, and slip resistance evaluations of its dark gray "slate" rubber tile floor [in accordance with CSMA Bulletin No. 245-70 (23) it was rated 4+]. It is important to note that the photographs, taken by the plaintiff's investigator about four months after the accident, accurately depicted, in every detail, the waiting room floor as found by the author during his inspection.

An examination of the plaintiff's footwear showed them to be ankle-high boots with a molded, one-piece (no separate heel), striated (ribbed) rubber outsole construction—considerably worn at the rear outer edge of the heel (>50% material loss), as well as the medial edge of the ball break and the toespring (the raised portion under the toe tip).

[2]Available from Slip Test, Spring Lake, NJ.
[3]Available from Quadra, Racine, WI.
[4]United States Architectural and Transportation Barriers Compliance Board.

Discussion

The Plaintiff investigator's so-called "forensic diagram" proved to be spurious. Dimensional "inaccuracies" were easily discernible in the investigator's own photographs, wherein the floor tiles of known dimensions could readily be counted and distances ascertained. These inaccuracies, whether due to incompetence or guile, created an illusion of an elongated wall which extended farther into the Doctor's waiting room, thereby narrowing the witness' span of vision. As a result, the young attorney was led to believe that he could not possibly have witnessed the initiation of the Plaintiff's trip.

With respect to the consulting engineer's coefficient of friction measurements, suffice it to say, to date there is *no* standard test method for the instrument used by him (Mark II), *no* required compliance criterion, and *no* correlation of its friction values, dry or wet, with slipping accidents. Further, the engineer's reference to "Slip Resistant Surfaces Advisory Guidelines" (24) as an "Industry Standard" is apochryphal—it neither emanates from industry nor is it a standard. In fact, the pamphlet was prepared by Penn State University researchers for the USATBCB and ". . . disseminated . . . in the interest of information exchange . . ." Further, the introduction states that ". . . The guidelines contained in this document are advisory only . . . based on limited testing . . . [and] provide a first approximation . . ." The researchers' recommendation that the static coefficient of friction for level surfaces (μ_a) should be 0.6, the same as μ_r (in order to accommodate the mobility-impaired, as opposed to only 0.2 to 0.3 for the able-bodied) was based on an erroneous assumption previously addressed in the paragraph on *Slip* (that a direct numerical relationship exists between μ_r and μ_a). On April 27, 1995 the USATBCB Subcommittee on Accessible Routes recommended (25) that all numerical references to static coefficient of friction "requirements" be deleted in order to avoid the misinterpretation and misapplication of force plate measurements, already in evidence. (In addition, all references to portable friction testers will be deleted.)

The expert's "wet testing" was baseless, in that there are no standard definitions for a "wet" surface and no standard procedure for preparing a "wet" surface. Moreover, coefficient of friction is a measure of the interaction between two interfacing, solid surfaces without an interposed layer of a third component, which would interfere with surface roughness, intermolecular forces, and their viscoelastic properties. The subject of "quasi-coefficient of friction" (qCOF), that is, the measurement of friction in the presence of a "contaminant," has been addressed elsewhere (26). The engineer's seemingly naive assertions that warnings should have been issued with the floor tiles to indicate that they are hazardous or dangerous when wet and that the tile manufacturer should have instructed customers on the use of floor mats under these conditions, need not be seriously considered. The engineer's only valid conclusion was that there should have been a floor mat present at the entrance (27).

It should be noted that, according to ASTM Subcommittee D21.06 on Slip Resistance, a floor surface, coated or uncoated, having a static coefficient of friction of not less than 0.5, as *measured* by the James machine in accordance with ASTM D 2047(28), has been recognized as providing a nonhazardous walkway by the Government (GSA) (29), the American Society for Testing and Materials, and the Polishes and Floor Maintenance

Industry (CSMA). ASTM D 2047 remains, to date, the first and only voluntary consensus standard that specifies a compliance criterion, namely, the 0.5 static coefficient of friction (30). This value was derived from a correlation of laboratory test results and the *actual* slipping experiences of large numbers of people (able-bodied and disabled) walking on floors of every type (resilient, wood, mineral) over a period of many years. These "real-world" floors were not always new, freshly prepared, scrupulously clean or dry, or even level (<1:20, rise:run) (9).

Additionally, it is noteworthy that the slip resistance rating of 4 + (23) for the in-situ flooring of the waiting room exceeded ("greater slip resistance") that of the "control" tile (James machine static coefficient of friction value of 0.5).

With reference to the plaintiff's footwear, it has been established that the static coefficient of friction of rubber (the composition of the subject sole/heel) is typically 0.3 to 0.5 higher than that of leather, the sensor material used with the James machine (10).

In addition to the "normal" mobility impairment of the elderly, this 78-year-old plaintiff suffered from a peripheral vascular disorder which was clearly relevant to her "falling" accident. Arteritis is ". . . a chronic generalized inflammatory disease of unknown etiology . . . characterized by aching and stiffness involving mainly the trunk and proximal muscle groups . . . such as the hip-pelvic area. Synovitis may occur (with viscid fluid accumulation), especially in the knees. The characteristic headache is a severe, throbbing . . . pain in the temporal area. Serious complications include blindness, stroke, . . . and arterial insufficiency of the upper and lower extremities" (31). The plaintiff did, in fact, lose the sight in her right eye within one month of the accident. Further, both her doctor and nurse were aware for some time that the plaintiff walked "bent"/"hunched over", "her head down," with a "slow, shuffling" gait, "not lifting her feet very much."

Conclusions

The author's conclusions, based on a reasonable degree of scientific and engineering certainty, were predicated on a detailed analysis and careful assessment of: (1) the information provided—police report, hospital emergency department records, National Weather Service records, interrogatories, depositions, witness statements, investigator's report, plaintiff's footwear, plaintiff's "expert" reports, ASTM D 2047 static coefficient of friction test results; (2) inspection of the accident site; and (3) various technical references (previously cited).

The author's opinions, supported by many years of "hands-on" professional experience as a scientist/engineer, specializing in: (1) floor maintenance-chemicals, -equipment, -procedures and related test methods, standards, and trade practices; (2) the biomechanics of human locomotion with respect to slip, trip, stumble and fall accidents; and (3) the evaluation of walking, working, and recreational surfaces for the purpose of identifying and suggesting remedies for potentially hazardous conditions stemming from insufficient traction, defective construction, or faulty maintenance practices, are as follows:

1. The plaintiff's description of the alleged "slip and fall accident" was not consistent with: (1) the biomechanics of an out-of-control forward slide of a foot on a wet, slippery, low-tractive surface; (2) her forward falling pattern—she would have fallen backwards, out of the entrance door; and (3) her body's impact site and the nature of the injuries to her nose and neck—she would have landed posteriorly with attendant injuries.
2. The in-situ resilient floor met the slip resistance requirements of ASTM, Government and Industry, viz., CSMA No. 245-70 (23). Also, the static coefficient of friction of the "slate" rubber tiles met the required compliance criterion of ASTM D 2047 for a *nonhazardous walking surface*, viz., 0.5 or higher.
3. The typically high slip resistance afforded by the plaintiff's striated, rubber outsole footwear would have provided a relatively high degree of protection against a slip, even while traversing a wet floor.
4. There is no engineering standard, national, state or local code, regulation or guideline which requires a flooring manufacturer (resilient, mineral, wood, etc.) to instruct users, in perpetuity, that wet floors are hazardous or dangerous, and further that floor mats shall be used under these conditions.
5. Finally, it is the author's opinion that the proximate cause of the plaintiff's tragic accident was: (1) her body's response to pain; (2) muscle weakness; (3) sensory disturbances and increased glare adaptation time (as a result of the 20 min drive along bright, snow-laden roadways, prior to entering the comparatively dim-lit waiting room of the doctor's office); and (4) disease (arteritis), together with the inadequacy of her compensatory gait ("open-sores" under both feet) when she attempted to step over the threshold. Alternatively, it is suggested that the plaintiff suffered a syncopal episode (a loss of consciousness), a not too uncommon problem among the elderly (18). This conclusion is based on her lack of stimulus detection, response selection or response execution, which would normally be expected following a large postural perturbation (22). The rationale is consistent with the plaintiff's own testimony and the observations made by her doctor, the nurse, and the witness immediately after the fall.

The methodology employed in this case study clearly suggests that the resolution of a falling accident, witnessed or not, requires substantially more information than is normally found in file documents—even when augmented by *appropriate* building codes, industry and/or engineering standards, and measurements of various parameters—in order to establish or refute the existence of construction defects, "slipperiness," etc.

The need for obtaining and assessing records of a plaintiff's prior state of health and accident history is of paramount importance if one is to propose a nexus *between* prior illness, surgeries, injuries, and age-related disabilities, *and* problems of balance, stability, and gait at the time of an accident.

Ultimately, the description of a falling accident—from initiation to termination—which should include alleged type of misstep (slip, trip), direction of the fall, landing distance (from the misstep), body and ground impact sites, and the nature and severity of the injuries, must be consistent with the alleged accident causation, and our knowledge and understanding of the biomechanics of slips, trips, stumbles, and falls.

Epilogue

Christian Huygens was one of the first researchers to apply mathematics to physical problems consistently and systematically. His accomplishments helped revolutionize science, so that by 1710 Johann Bernoulli could boldly declare (32): "He who undertakes to do physics without understanding mathematics truly deals with trifles" (33). The author believes that it would be fitting and appropriate to paraphrase this remarkably prescient maxim, to wit: "He who undertakes to do *slip, trip, stumble, and fall* analysis and reconstruction without understanding the biomechanics of human locomotion truly deals with trifles."

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