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Forensic Analysis of Stair Descent Falls

Instructor: Peter Chen, P.E., CFEI, ACTAR

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5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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1. Introduction

Several years ago this engineer was asked to opine on a stair fall in which an individual claimed to have slid and fell while attempting to descend stairs in an apartment complex in New Jersey. The claimant was a female in her mid-20's with no acknowledge pre-existing medical conditions. The claimant had entered the stairwell landing from an exterior having walked through a parking lot that had previously been cleared of snow. The claimant was carrying her son, aged 1 to 2 years old, in one arm, and groceries and purse in the other arm.

The claimant described her foot slipping at the top of the landing or first step initiating a forward projection fall. The claimant then described falling forward and twisting so as to not land on her son. The claimant then described injuries to her left side and arm.

Having reviewed many slip or trip and fall and stairway fall videos as a course of employment and background as a forensic engineer, this engineer knew that slips on a stair descent generally resulted in a pitch and fall backwards, whereas a mis-step generally resulted in a forward projection fall. Because of legal discoverability issues with regards to active cases, videos and prior case experience could not be used for the claim.

A review of publicly available video of stair descent falls began that culminated into a multi-year and post claim research resulting in this course.

2. The Human Body and Normal Stair Descent

A review of many available literature on the topic of stair descent, one of the best descriptions of what occurs during a stair descent comes from John Templer, The Staircase, Studies of Hazards, Falls, and Safer Design, MIT Press, 1992.

“As we take our first step in descent (fig. 1.2), as the leading foot swings forward over the nosing edge (swing phase) and stops its forward motion when it is directly over the tread below. As this foot starts its descent, the heel of the rear foot begins to rise from the previous tread (or landing), leaving the weight of the body to be supported on the metatarsal heads of the forward foot (stance phase). At the same time, the rear leg begins to bend at the knee and the hip. In effect we now commit ourselves to the forward foot and start a controlled fall forward and downward toward the tread. The toe of the forward foot is pointed down somewhat in order to begin to absorb the force of the fall as soon as it makes contact with the tread (Templar, pg. 11).”

“Finally, the heel descends onto the tread, so the force of the jolt is gradually cushioned as the body’s full weight is transferred onto the forward foot (Templar, pg. 11-12).”

The forces and traction required for a stair descent is different from a normal walking gait. During a stair descent, a person commits to downward momentum and travel with a greater deal of faith that the lead foot will successfully perform a toe to heel reaction on the lower step to control the direction and speed of travel. The lead foot has to support a reaction force in the upward and rearward direction (from the view of the person descending), see Figure 1.

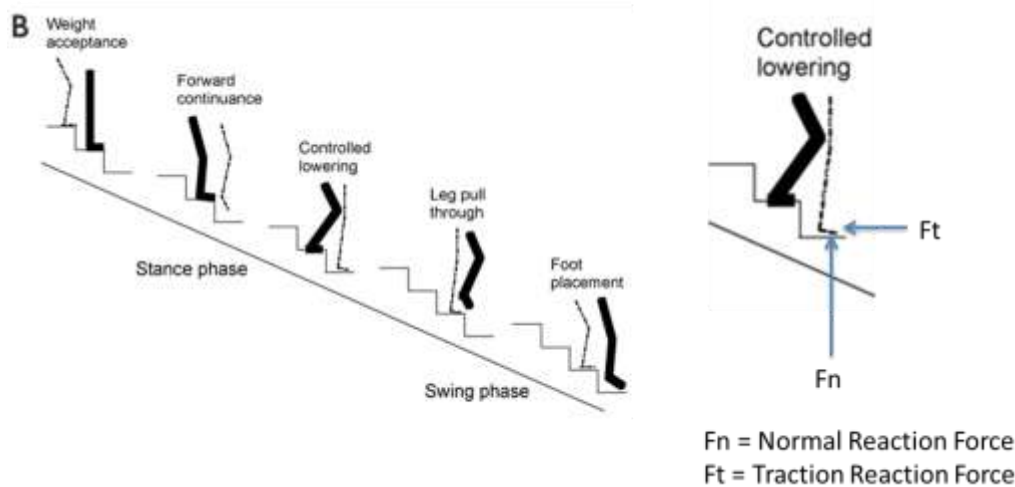


Figure 1. Force on Lead Leg
(Note Figure B from: [Stair Negotiation Alters Stability in Older Adults](#))

For more information on the difference in forces and traction required for a normal walking gait and stair descent, you may refer to Figure 2 and Figure 3 of [Load Applied on Bone-Anchored Transfemoral Prosthesis-A Pilot Study](#).

3. Slip During a Stair Descent

Slips may occur during a stair descent for a variety of reasons: low coefficient of friction, surface wetting or fouling, loose stair surface hardware, slippery footwear, and etc. An entire training course could be dedicated to the issues of slip, slip resistance, slip coefficient of friction, stair design, and stair surface hardware. For the purposes of this course, regardless of the cause of slip, we will focus on the typical resulting human body mechanics.

Rarely during a stair descent does a slip of the rear plant leg/foot occur, because the rear plant foot primarily experiences only a normal reaction force. Very little to no traction occurs because the rear leg typically only bends to transfer the persons weight in the forward direction of travel. “There is also some risk of a slip as we tilt up the heel and lift the rear foot off the step preparatory to starting its swing phase, although the risk is small because the horizontal motion during lift-off is small or nonexistent. We do not need to push off the rear foot as we do in level walking in order to move our center of gravity forward (Templar, pg. 12).”

If the rear plant foot were to slip, the result would be a rearward motion of the foot into the front face of the preceding stair riser resulting in a stabilization force. If a rear plant leg/foot slip occurs, this may precipitate a front leg/foot slip or a misstep.

A lead or front leg/foot slip is most susceptible to slipping during the toe to heel transfer of weight during the controlled lowering. Once a person commits their body to stepping down to the next step, a loss of the stabilizing traction reaction force will typically result a backwards pitch and fall (see Figure 2). The feet essentially proceeds the center of gravity the person and unless a stabilizing moment occurs, the person’s body will fall backwards.



Figure 2: Backward Pitch

Independent research of social media publicly available stair falls has been performed. The following videos were selected because they involve celebrities, politicians, or other individuals that were not falling on purpose. Please take the time to review a few of these videos to illustrate a slip during stair descent. Hit Ctrl button on key board and click on hyperlink to go to video.

- [Gerald Ford](#)
- [Lauren Alaina/American Idol](#)
- [Newscaster](#)
- [Anna and Patryk/America's Got Talent](#)– at 1:27 into video
- [Unknown Male](#)
- [Unknown Female](#)
- [Unknown Female](#)
- [Unknown Male](#)
- [Unknown Female](#)

In some of these videos, the individuals did attempt to stop their falls with the use of handrails. Successful recovery with handrails requires human perception reaction time, good timing, and the ability to grab and get enough force on the handrail(s) to stabilize the rotation. Sometimes a landing can stop the fall:

- [Successful cessation of fall](#)

In some cases, individuals may actually experience the slip and fall backward, but may overcompensate or react to the fall resulting in a forward projection. For example:

- [Beyonce Knowles](#) – Slip, pitch backward followed by an over-compensation recovery and pitch forward.

4. Mis-Step During Stair Descent

“In overstepping, too much of the foot projects beyond the nosing; the body’s full weight is transferred to the leading foot, which may slide over the edge, causing a loss of balance. The suddenness of this overstep gives us little time to recover, and we may pitch forward (Templar, pg. 12).”

Overstepping or missing the edge of the step is not the only mis-step. Occasionally, persons may misjudge the height of the step or make a human factors mistake in which they essentially trip on the lower step. This kind of mis-step also leads to a pitch forward and a forward projection fall (see Figure 3).



Figure 3: Mis-step forward Projection

Please take the time to review a few videos to illustrate a mis-step during stair descent. Hit Ctrl button on key board and click on hyperlink to go to video.

- [Fidel Castro](#)
- [Peter Andre T4](#) – note the fall recovery
- [Pasi Nurminen \(Finish Hockey Coach\)](#)
- [Bride and Groom](#)
- [Unknown Female](#)
- [Unknown Female](#) – note fall recovery because of landing

In some of these videos, a fall recovery was possible because of the presence of a landing and the room and opportunity to shorten the stride and to quick step fast enough to get the legs underneath them.

In the following video, Micha Barton had a mis-step but fell backwards due to her firm hold on a handrail:

- [Mischa Barton](#)

In the following video, an unknown female mis-steps, fall forward, and entered a twist fall due to her hold on the hand rail and over reaction.

- [Prom Girl featured on Tosh.o](#)

5. Complex Fall Mechanics

When evaluating witness statements, depositions, or videos, we should consider that there are occasionally complex stair descent fall body mechanics. In some of the videos shared in this training, we can already see that there are other factors that can change what happens when a person slips or mis-steps during a stair descent.

In the best case scenario for recovery, a person has both hands with a firm grip on handrails on both sides during a fall. Handrail use on one side results in only a small chance for recovery, and generally results in a twist.

In some cases, persons during a fall may overcompensate during a reaction to the fall (i.e. Beyonce Knowles in the video in Section 3). A person who pitches

backward may ultimately push themselves from the steps or pull themselves with handrails into a forward projection. A person in a forward projection fall may end up running uncontrollably forward in order to get their legs underneath them.

Sometimes a person may experience a complex fall involving both a mis-step and a slip. In the following video, the person's stumble forward during a mis-step was ultimately followed by a slip and fall:

- [Complex fall](#)

6. Summary

In conclusion to the case introduced in the Introduction, the stairs were inspected and measured. The subject stairs were found to be slip resistant, clean, and well maintained. Handrails were available on both sides of the steps, and also found to be in great condition.

Subsequent written discovery material revealed that the claimant had told the building maintenance super that she could not see the steps because she was carrying her child, groceries, and purse, and that she must have missed the step.

Upon providing a report that included a human factors analysis of a stair descent fall and the difference between slips and mis-steps, and supporting public domain video, the potential plaintiff quickly settled the claim.