GTD SCIENTIFIC INC., "FOOTPRINT FOR AVOIDING INJURY"

By Geoffrey Desmoulin, PhD RKin PLEng., Principal, GTD Scientific Inc.

The ASTM International test for impact worthiness of safety boots involves measuring the amount of deformation of a modeling clay cylinder placed in the toe of the boot.[1] The amount of force the impact would impart to the foot is not directly measured. Consequently, such tests cannot accurately estimate the risk of injury to the foot. Also, the test methodology does not simulate workplace scenarios since the impactor is a one-inch diameter cylinder that applies the impact to only a small region of the boot. In the workplace, objects of any size could fall on the boot, potentially producing pressure over a much larger area than a one-inch diameter circle. While the ASTM test requires all of the momentum of the impactor to be stopped by the region of impact with the boot, in the workplace, the momentum of a large falling object is more likely to be partially stopped by both the boot and the ground.

To more realistically simulate the injury risk of an object dropped on footwear, GTD Scientific, Inc. developed a rig which provides an objective measure of the impact force sustained by the foot. The rig allows the object's weight and size to be varied, as well as the height from which the object is dropped (Figure 1A). The object is mounted on the carriage of a drop tower, which slides on linear rails. The footwear is placed on a force plate at the base of the drop tower, positioned so that the object initially contacts the target region of the footwear (Figure 2B). A 3D printed foot fitted to the footwear is equipped with a force transducer to directly measure the impact force imparted to the foot (Figure 1C). The force transducer is mounted so that its height accurately represents the height of the toe. The position of the force transducer has the potential to measure the impact force applied to any of the five toes. The force impulse of the impact, measured by the force plate, represents the proportion of the object's momentum which is imparted to the footwear.

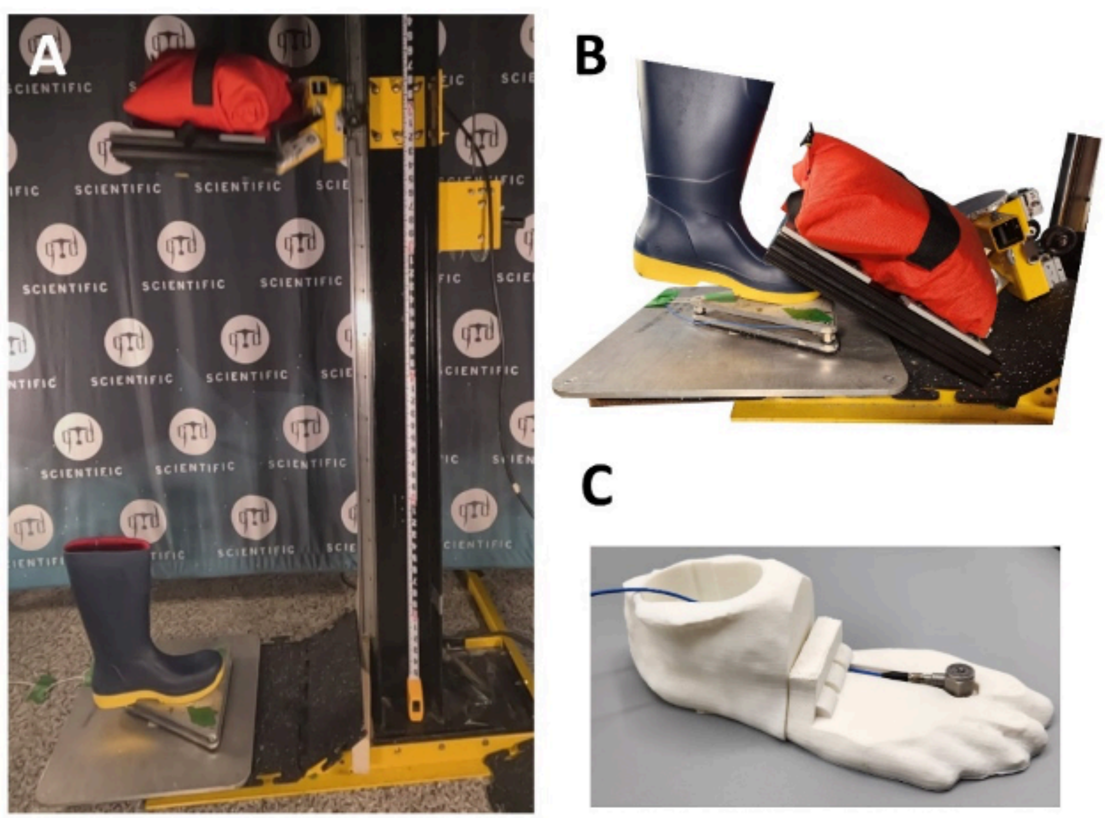

Figure 1: (A) Drop tower. (B) Boot under impact on force place. (C) 3D printed foot with force transducer.

The value of this system for forensic investigation has been demonstrated by comparing the impact resistance of work boots with steel toe caps to a work boot with no toe safety protection. A workplace scenario was simulated in which a rectangular object, similar to a loaded tray, fell from shoulder height. In this case, the tray was assumed to weigh approximately 50 lb. To ensure that the data were adequate for statistical analysis, five drops were performed for each footwear model being tested. A wet weather rubber boot without steel toes was compared to two wet weather rubber boots with steel toes, as well as the same rubber boot with steel toe safety covers. A lace-up safety boot, commonly worn by construction workers, was also tested as an aside.

The force transducer was mounted on the 3D printed foot, at the position of the big toe (Figure 1C). The mean peak impact force for the five drops is compared (Figure 2A), along with the mean peak force registered by the force plate. Because of the size of the object, only a fraction of its total momentum was transferred to the footwear, as measured by the force plate (Figure 2B).

There are several points to be made about the utility of this methodology for forensic workplace injury investigations involving footwear. First, the method allows both the force and duration of the impact to be measured. This is important because it provides information about both the peak force and the force impulse, i.e., change in momentum. Second, it cannot be assumed that the entire momentum of a falling object will be transferred to the footwear. As shown, the force impulse measured by the force plate represents only a fraction of the object's momentum at impact. The value of accurate testing, as opposed to relying on calculations, is readily apparent. Third, the methodology provides a means to accurately measure the effectiveness of safety footwear in reducing impacts under a variety of conditions.

Although the testing was applied specifically to footwear for the simulated scenario, the methodology can easily be adapted for tests involving other safety equipment, such as hard hats, helmets, hand protection, eye protection, and more. A 3D printed model of the desired body part can be equipped with a force transducer in any desired location to obtain the same data as in the footwear tests. This lessens the need to rely strictly on calculations, where the validity of simplifying assumptions cannot be guaranteed.

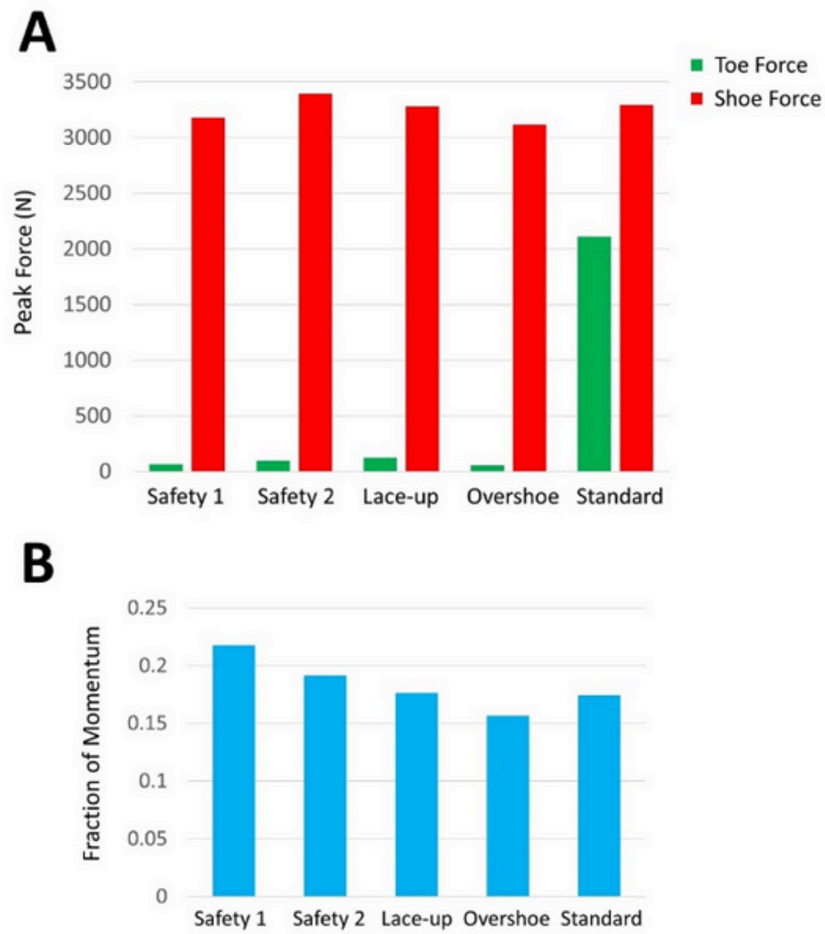

Figure 2: (A) Comparison of peak force applied to boot and toe. (B) Fraction of object momentum delivered to boot.

Geoffrey Desmoulin
PhD RKin PLEng., Principal, GTD Scientific Inc.

GTD offers Biomechanical Consulting Services to clients throughout North America and abroad. Practice areas include Injury Biomechanics, Incident Reconstruction and Physical Testing with a sub-specialty in the Science of Violence®. GTD has been retained in significant complex injury litigation cases involving municipal police department use of force, violent encounters, and TASER International. Dr. Desmoulin’s landmark testing and shooting reconstruction methodology is upheld as reliable and admissible by the U.S. Federal District Court for the 9th District of California.

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Standard Test Methods for Foot Protection, ASTM International, www.astm.org/f2412-18.html