Reflex Reaction to a Fall

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Building codes limit the height of a step to a minimum of 4 inches. This is mainly to insure visibility and prevent tripping but there is another reason to prescribe a minimum step height. When encountered unexpectedly a step down of less than 4 inches may be more dangerous than a higher step.

In 1971 two researchers (Jones and Watt) knew that during unexpected falls, people in part control their landing by means of a reflex stretch response that extends the foot and decided to learn more. A reflex stretch response describes the contraction response of a muscle to resist a sudden extension or other stimulation. They set up an interesting experiment in which they unexpectedly dropped people and measured muscle response times. They suspended the subjects from an electromagnet and released them without warning. They also monitored the "gastrocnemius electromyographic (e.m.g.) response." In English that means they monitored the electric signals produced by the calf muscle. They found that the test subject would attempt to extend his toes before he touched down (prior to calf stretch) but did so much faster than a conscious process could account for.

A diagram of an unfortunate stick man illustrates the setup of their experiment:

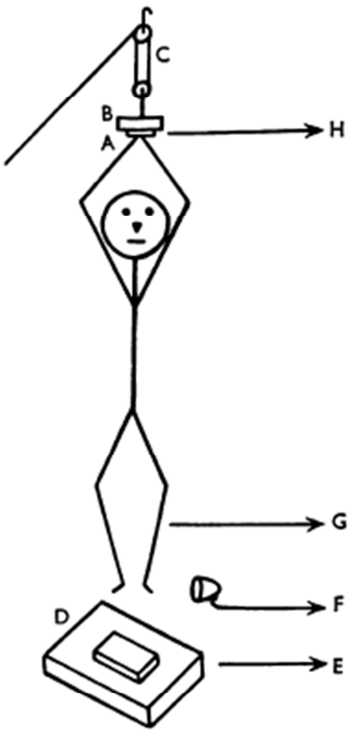

Fig. 1. Diagram of apparatus used in the present experiments. Subjects grasped a handle (A), which could be released from an electromagnet (B) after the individual was lifted above a force-transducing platform (D) by a block and tackle (C). Recorded were: force exerted by feet on landing (E), sound of moment of landing (F), gastrocnemius e.m.g. (G), and, moment of release (H).

When a person suspended in this manner experiences an unexpected drop, the calf muscles contract to extend the toes in an effort to control and soften the landing. The researchers measured this calf muscle reflex response to two stimuli: the inertial effect of a drop and the stretch reflex due to a tap on the Achilles tendon. They found that the calf muscle responded to the drop in just 74 milliseconds (0.074 s). Curiously, the response they measured for the tendon tap was only about half as fast at 163 milliseconds (0.163 s).

These reflex responses are an order of magnitude faster than the reaction (0.75 s) plus response (0.75 s) time required for a more conscious process such as a driver applying the brakes due to an unexpected obstacle in the path of his vehicle. 74 milliseconds is 20 times as fast as the combined reaction response time of 1.5 seconds.

People driving cars or operating machinery also utilize reflexes in response to inertial input. For example, if a person in a car experiences an unexpected inertial input such as braking or impact, the reflex response is probably something protective such as throwing up the arms rather than something more complex and conscious like applying the brakes.

The authors suggest that the leg muscle response is a reflex originating in the otolith. Otolith literally means “ear stone” and refers to a small bone suspended in the inner ear which acts as an accelerometer. We have two of these stones in each ear; the utricle is sensitive to a change in horizontal movement and the saccule gives information about vertical acceleration. This means we have two sets of what amount to accelerometers in our head from which we can determine head attitude for balance from gravity and inertial data for navigation.

I am not certain why the stretch reflex takes twice as long as the inertial reflex but it may simply be that the nerve signal has to travel twice as far. The inertial drop signal travels from the ear, to the brain and down to the calf while the tap signal begins at the Achilles tendon, travels to the brain and back down to the calf.

The authors state that a drop of less than 5 cm (2 in) will result in a jolt because there is no time for a muscle to react to and soften the impact of the unexpected drop. This may explain why people are injured when they encounter small walkway offsets. Up to about an 18 cm (7 in) drop reflexes are the only activity available to control the impact since there is not enough time during the drop to react in a conscious way. In a drop of more than 18 cm (7 in), voluntary response comes into play since there is time to react in a conscious way.

The 4 inch minimum step height allows enough time for the reflex response and extension of the foot. Although a 4 inch high step is not high enough to allow a conscious response, there is enough time for a reflex response that will hopefully soften the landing and prevent injury.

Jones and Watt, Muscular control of landing from unexpected falls in man, J Physiol. 1971 December; 219(3): 729–737