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The Study of Microslip Using A Signal Detection Theory

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ABSTRACT

Since slipping has been identified as a major hazard, it is important to understand the mechanism of a slip. Many researches, based on biomechanical studies, had been attempted to do that. However, the correlation between the mechanism of a slip and psychophysical behaviors of people had rarely been verified. For example, the existence of small slips in a forward direction, which do not normally perceived by human subjects, has been established by several experimenters. However, the term "microslips are not perceived by the walkers[4]," has not been examined precisely by any experiments. The objective of this study is, using a Signal Detection Theory(SDT), to define a microslip and slip more quantitatively with the biomechanical measurement of slip distance. The result showed that, the slip distance around the 3 centimeters, there was a obvious change in the accident detectability of the subject. The conclusion is that it is possible to identify the boundary of a microslip and slip around the 3 centimeters of slip distance.

Introduction

Epidemiological studies of accidents have established the economic and social significance of falling. Strandberg[5] reporting on the Swedish experience(described by [1] in ISA(Informationssystemet om Arbetrsskador) indicated that slipping was included in eleven percent of the occupation accidents recorded by ISA in 1978. Strandberg also pointed out that less than half of this number actually generated an entry in the classification "fall at the same level" thus suggesting the importance of slipping extends across other categories of occupational accidents. Strandberg also observed the occurrence of small slips, normally not perceived by the human subjects, which were termed microslips by Perkins in 1978.

The terminology involved in slipping studies may be relevant to the classification of an accident, namely a slip, or may be descriptive of the process involved in the foot sliding on a walking surface. Perkins[3] originally coined the expression "microslip" to identify the sliding movement which began but then was brought under control within a short distance of approximately one centimeter. These slips are frequently, if not normally, undetected by the subject. However, as a slipping distance approaches 10 centimeters, subjects are well aware of slipping and take corrective action of various forms in order to arrest the slip. Strandberg attempts to describe

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these as a "slip stick." This appears to be inconsistent with the use of microslip, and consequently, it is proposed that the description "slip(2)" be used for such events, which thus is a natural extension of the term "microslip." In the third case, when the slip becomes an uncontrolled forward movement of the leading foot(the consequence of which is normally a fall) this will be termed a "slide(2)," which is consistent with the previous definition of progress along a smooth surface.

This then leaves the question of the more explicit definition of a microslip in accident statistics. As has been indicated, how the boundary between the microslip and the slip will thus be defined! It should be noted that several authors have indicated the role of a microslip and a slip in accident classifications. Thus, it is necessary to make a more formal categorization which may well enable a incisive analysis to be carried out on these two kinds of accident event. This paper seeks to construct a more explicit definition of a microslip and a slip with the aid of a Signal Detection Theory.

Method

When human subject walks on a slippery surface, a slip can be treated as "signal" to him. The relative movement between the shoe and the foot as well as the random neural activities play the role of "noise" to the subject. When the slip occurs, we say he "hit" the signal if he detects the slip. He "miss" if he fails to detect the slip. When there is no slip and he feels the slip, it is a "false alarm." He makes an "correct rejection" when no slip occurs and he says no. The conditional probabilities can be presented by a response matrix:

		Response: yes	Response: no
Stimulus	slip	Hit P(S/s)	Miss P(N/s)
	no slip	False Alarm P(S/n)	Correct Rejection P(N/n)

An Receiver Operating Characteristic(ROC) curve is obtained when we plot P(S/s) versus P(S/n). The area under the curve, let say P(A), represents the capability of the subject to make correct judgments and avoid incorrect ones. In this slip/fall problem, whether the stimulus was a signal or a noise can be determined by picking up a specific slip distance. For example, if 2 centimeters is chosen, then all slips greater than 2cm are considered as a signal(or a stimulus), any slips less than or equal to 2cm are considered as a noise.

The subject was notified to pay attention to whether his left foot slip on the first step after he hears a audio signal which was triggered by a photo-electric switch. After each trial, a question was given and asked to choose the most appropriate one. All the five categories were encouraged to be used which were:

Did you slip or not?

( ) 1. 'Slip Definitely'
( ) 2. 'Slip - Probably'
( ) 3. 'Uncertain either way'
( ) 4. 'No slip - Probably'
( ) 5. 'No slip - Definitely'

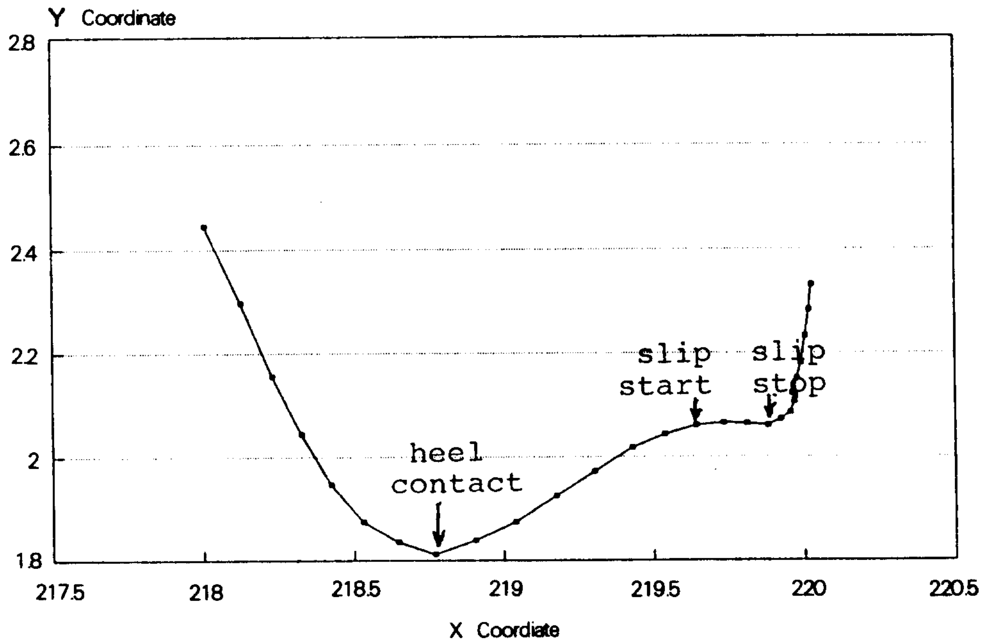
Five male Subjects, who were supported by whole body harness, were walked in a race track configuration, arranged such that, during the data collection portion of the experimental treatment, they walked a straight line. The subjects were arranged in a randomized order for two conditions of floor slipperiness(clean and greased steel plate) and two walking velocities(3km/hr and 6km/hr).

Subjects wore retro-feflectors at significant anatomical indicators such as heel, toe, ankle, knee, hip, shoulder, elbow, and wrist of the left side of the subject. The retro-feflectors which were used in the current experiment are ping pong balls of 1 inch diameter. The position of these reflectors was recorded and analyzed using the Motion Analysis ExpertVision system. This system capacity extends to sampling rates up to 200 Hz. The videoimages of the targets were collected by three high speed cameras which were triggered by the photo-electric switch. The images were then processed VP-320 video processor and analyzed by the Motion Analysis Expertvision System. As to the validity of the Rig System, the author's previous experiment showed that the degree of influence is dependent on the subject; however, in all cases, the use of preliminary warm-up trials appeared to remove this kind of influence of the Rig.

Results

Originally, the data for one cycle from each subject(13 trials) were collected in each experimental condition such as slow: high friction, fast: high friction, slow: low friction, and fast: low friction. Then, a plot of X versus Y coordinates for each cycle around the heel contact point was attempted in order to determine the "slip start" and "slip stop" point. However, an unexpected problem occurred which has been largely ignored in the literature, such as those of Perkins and Wilson[4]. At the discrimination of the current system, a certain amount of measurement noise is obtained and the definition of the end of a slip is not immediately recognizable. Thus, by looking at a plot, the slip start was normally identified as the point at which a

Example of Identification for Slip



Plot of X vs. Y around the heel contacte

Figure 1 : Example of the identification of slip distance

change of the horizontal displacement continued at constant position in the vertical axis. The slip stop was defined as the point at which a change in vertical axis occurred, without a change of the horizontal axis. Figure 1 shows one example of such an identification of a slip start and a slip stop point. The "slip distance" is defined as the change of the horizontal coordinate, between the slip start and slip stop points.

A previous study[2] showed that walking speed was a most significant factor in slip/fall accident rather than others. Therefore, the data of slow walking was analyzed first and then of fast walking was done later. One hundred and thirty trials were collected for slow walking speed test(from both slippery and non-slippery floor). Seven ROC curves were then made. The slip distances which chosen as the upper limits of non-signal are from 1 to 4cm with increment of 0.5cm. There were empty cells except for the case of slip distance of 1 and 1.5cm. The results of the seven ROC curves are summarized as P(A) versus upper limits of non-signal of slip distance of 1 and 1.5cm. The results of the seven ROC curves are summarized as P(A) versus upper limits of non-signal of slip distance(Figure2). This curve shows that the capabilities of the subjects to detect the slips of 1 to 2cm level are weak. The sensitivity(P(A)) shows an increase pattern before slip distance(SD) equals to 3cm and then decreases after that. Therefore, it seems reasonable to define a microslip as any slip that less than 3cm.

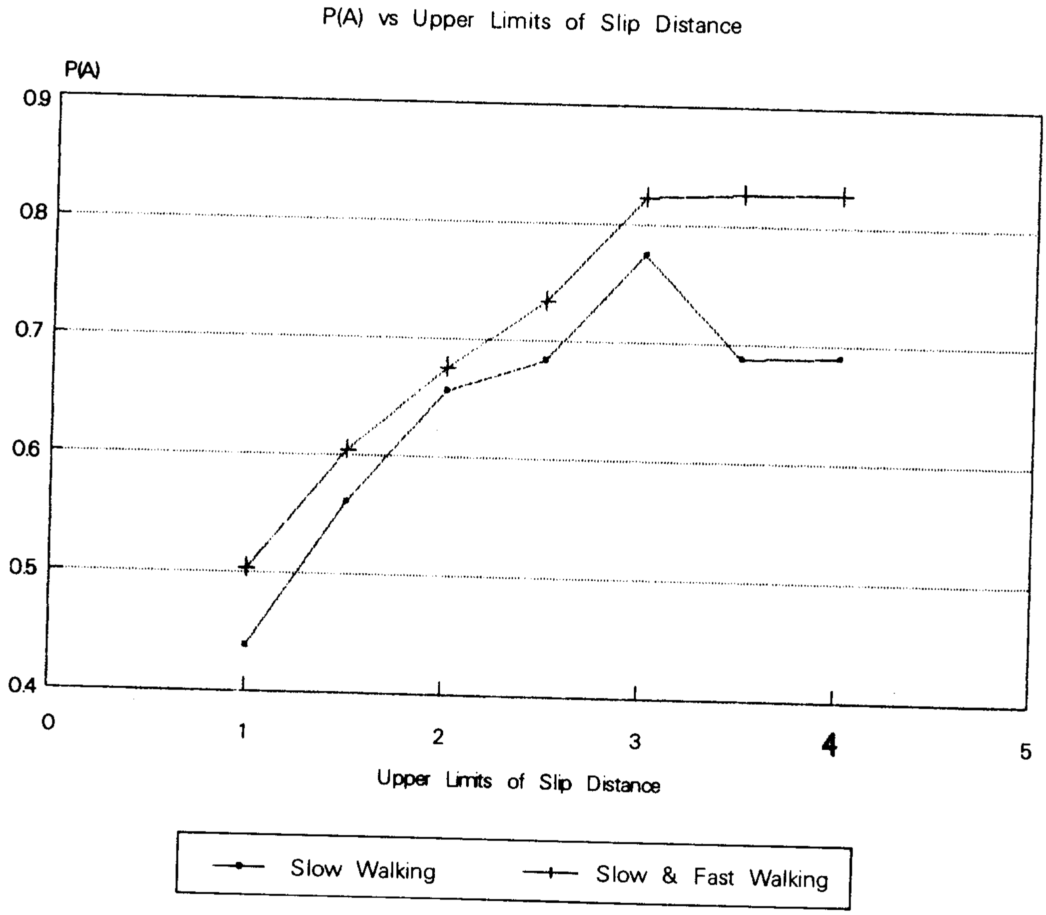


Figure 2 : P(A) versus upper limits of non-signal of slip distance

Same analysis was performed on the data of a fast walking speed. After putting all the data together(both slow and fast walking speed), we got 260 trials. Seven ROC curves, which have the upper limits of non-signal of 1 to 4cm with increment of 0.5cm, were then plotted for these data. The P(A)s of these curves were higher than those of the corresponding curves we got from slow walking speed. This is the effect of less empty cells. At this time, empty cells presented only in the cases of SD=3.5cm and SD=4cm. The results of these ROC curves are also summarized in the P(A) versus upper limits of non-signal of slip distance(Figure2). This curve also shows that the sensitivities of the subjects are low when the slip distance is less than 3cm. That is, the P(A) increases rapidly from SD=1cm to SD=3cm and slows down or even decreases after SD is greater than 3cm.

This experiment shows that the capabilities of the subjects to detect any slip less than 3cm are low. It is then reasonable to define a microslip as any slip that is less than or equal to 3cm. However, one fact should be reminded is that the subjects were informed to pay attention to whether they slip or not before the test. Therefore, the sensitivities should be much lower if they were not informed to do so. this means that they are even weaker to detect a microslip during their daily walking activities.

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