Rider Training and Collision Avoidance in Thailand and Los Angeles Motorcycle Crashes

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Abstract

Collision avoidance skills tend to focus on braking and swerving in response to a threat, yet it is difficult to show that these skills actually have the desired effect. The Hurt study reported that the great majority of riders in 900 crashes showed very poor avoidance skills. About one-third took no evasive action at all. Most of those who did take evasive action either chose the wrong action or executed their chosen action poorly, or both. Rider training had no effect on collision avoidance performance. Similar findings were reported in Thailand, where only one rider had formal training. Half of all Thai riders took no evasive action and 64% of those who did failed to choose the best action, while 60% failed to execute properly whatever evasive action they did choose. However, Thai riders were far less likely to lose control in a braking slide-out than riders in Los Angeles (20% vs. 40%). This suggests that, for some reason, Thai riders did a better job of collision avoidance than their American counterparts.

Both the Thailand and Hurt studies concur that the time from the precipitating event that begins the collision sequence to the impact itself is so short – less than three seconds in the great majority of cases – that even a well-chosen, well-executed evasive action is unlikely to be effective. This suggests that rider training should emphasize teaching riders the knowledge and skills needed to prevent a precipitating event from occurring, rather than how to react after it has already occurred.

Keywords: Collision avoidance, motorcycle training, braking, swerve, loss of control, Thailand

1. Introduction

For many motorcyclists, the words "collision avoidance" mean skilled braking and swerving after something has gone wrong, such as a car driver violating the motorcycle right-of-way. And that's it. For example, one American motorcycling magazine recently ran an article about motorcycle crashes in which the author included a sidebar story on "how to avoid becoming an accident statistic." The recommendations focused overwhelmingly on encouraging riders to develop and practice their braking and swerving skills [Anderson, 2004].

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How often do emergency collision avoidance actions really prevent crashes? It may be impossible to answer this question scientifically because it's probably impossible to find and analyze near-miss cases to compare to collisions – at least using current accident investigation methodology. The reasons are explained in more detail in Appendix I. Of course, many riders will gladly regale a listener with a story or two about how their skills, expertly applied, saved them from sure disaster. Unfortunately, anecdotes do not make up a scientific database, no matter how many one accumulates.

Does rider training to develop collision avoidance skills actually prevent crashes? Fortunately, this question is easier to answer. This paper attempts to do so by comparing the collision avoidance performance of nearly 2000 motorcycle riders with different kinds of training, drawn from two detailed, in-depth studies of motorcycle accidents in which researchers investigated crashes on-scene immediately after the crash occurred. The first study is the Hurt study at the University of Southern California, that involved 900 crashes that occurred in Los Angeles in 1976-77 [Hurt et al., 1981]. The second study was done using nearly identical research methods in Thailand, where data was collected on 1082 accident-involved riders in 1999-2000 [Kasantikul, 2002a, 21002b].

2. Methodology

In both study areas, teams of investigators traveled to an accident scene immediately after the crash in order to conduct a detailed research investigation and analysis independent of the police investigation. Once on-scene, investigators photographed the motorcycle(s) and other vehicles involved as well as skids, scrapes, "people marks" (such as blood, cloth marks, "soft" dents in vehicles), precrash and post-crash paths of travel, etc. Investigators also measured and diagrammed the physical evidence as well as obtaining driver and witness interviews and injury information.

The Thailand study investigated a total of 969 collisions involving 1082 riders and 399 passengers in six different regions within Thailand over a twenty month period. About one-fourth of the Thailand multiple-vehicle collisions involved two motorcycles, so that there were more motorcycles than collisions. The first twelve months of the Thailand study (all of 1999) were devoted to accident investigation in Bangkok (723 cases). In the remaining months (March – September, 2000) another 359 cases were investigated in "upcountry" sampling regions of Thailand (i.e., the provinces of Phetchburi, Trang, Khon Kaen, Saraburi and Chiang Rai), which were located 150 to 700 km from Bangkok. About one-fourth of "upcountry" crashes and 8% of the total actually occurred in rural terrain. The Los Angeles study involved 900 accidents at all levels of severity in the City of Los Angeles in 1976-77. Seven percent of those occurred in rural areas within the city.

The crash investigation and reconstruction methodology used in the Thailand study was essentially the same as that used in the USC studies, and has been described elsewhere in more detail. In Thailand, over 2000 data elements were recorded, using the OECD data form [OECD, 1999]. Some data elements were simple items such as weather, roadway type, motorcycle manufacturer or rider gender. Other items were complex factors that required considerable analysis and integration of accident evidence such as precrash and crash speeds, collision avoidance performance, injury mechanisms, accident cause factors and helmet performance.

The precipitating event (PE) was the action (or failure to act) that led directly to the accident. A typical precipitating event might be something like a car beginning a turn across the motorcycle path. Or it might be a motorcyclist's failure to begin braking to stop at a red light, or it might be a rider failing to follow the curving path of a roadway – a very common occurrence among alcohol-involved riders. It is worth saying that it is sometimes debatable exactly when a precipitating event occurs or which event in a series of events actually precipitated the crash. For example, when a drunk rider continues straight off the side of the road while the roadway takes a curve, is the precipitating event the moment the rider's attention failed? Or is it the last moment he could have turned in order to follow the roadway curve? Normally it is treated as the latter, which is far easier to define than the rider's mental state.

In Thailand, "proper" choice or execution of a collision avoidance action was defined as the "best" choice or execution. For example, if a Thai rider used rear-only braking to avoid a crash, even if it was an appropriate response, it was considered "improper" because front-and-rear braking would have been best for the situation. In the USC study, rear-only braking could be considered proper if it was appropriate for the situation, even if it was not the best avoidance action.

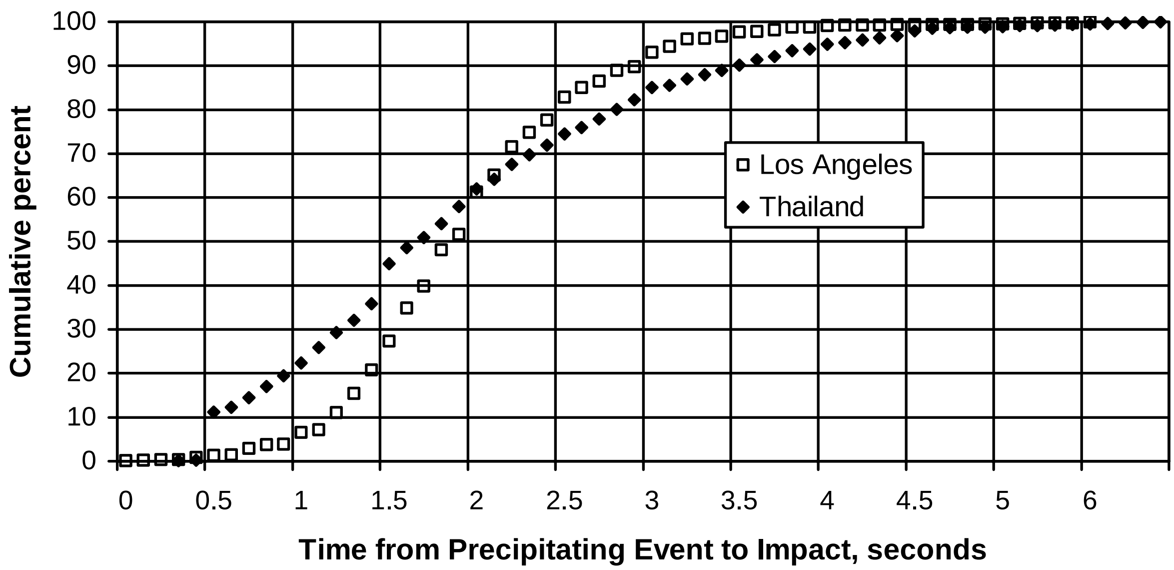
A chi-square statistical test was used for most of the analyses reported here. Two-tailed probabilities less than .05 are considered statistically significant. A rider was omitted if either one of two variables being considered was unknown; as a result there may be slight variations in the number of riders reported.

3. Results

3.1. Time from precipitating event to impact

The time from PE to impact for the Thailand and USC studies is illustrated in Figure 1 as a cumulative percent distribution. The median value in Los Angeles was 1.9 seconds; in Thailand it was 1.7 seconds. The mean and standard deviation in Los Angeles was $1.98 \pm .72$; in Thailand it was 1.96 ± 1.20. The means did not differ significantly ($t = .38$, $p = .71$, $df = 1791$). In both studies, only 10-20% of the riders had more than three seconds from the precipitating event to impact and only 1-5% had more than four seconds. If normal reaction time is one to two seconds, most riders have – at most – only about one to two seconds during which to take evasive action (assuming that they perceive the precipitating event as soon as it happens, which is often not true.)

Figure 1: Cumulative percent distribution of time from precipitating event to impact



3.2. Rider training and evasive actions

In Los Angeles the overwhelming majority – 92% – of motorcycle operators had no formal training. These riders either taught themselves (44%) or learned from family and friends (38%). In Los Angeles, the 7% of riders with formal training were mostly motor officers with California Highway Patrol or Los Angeles Police Department, who had been through rigorous and demanding rider training programs and rode a motorcycle almost daily as part of their job duties. In Thailand, only one rider had formal training, while 84% were self-taught. Therefore, analyses of the Thailand data will assume that no riders had any formal training. Table 1 shows the distribution of rider training.

Table 1. Rider motorcycle training

Rider training	Los Angeles		Thailand	
	Frequency	Percent	Frequency	Percent
Self-taught	400	44.4	911	84.2
Family, friends	343	38.1	135	12.5
Formal training	61	6.8	1	0.1
Other	4	0.4	0	0.0
Unknown	92	10.2	35	3.2
Total	900	100.0	1082	100.0

A large minority of riders in both study areas took no evasive action at all – nearly one-third in Los Angeles and nearly half in Thailand. Riders in Thailand were more likely to swerve as their only evasive action (15% vs. 8%), but they were less likely to use the brakes, either alone or in combination with swerving. Table 2 shows the collision avoidance actions taken by riders in Thailand.

Table 2. Collision avoidance actions in Thailand

Avoidance action taken	Frequency	Percent
No action	528	48.8
Braking only	247	22.8
Swerve only	158	14.6
Brake & swerve	121	11.2
Other	24	2.2
Unknown	4	0.4
Total	1082	100.0

Table 3 compares collision avoidance actions among riders with different training in Los Angeles. What is remarkable is the **lack** of difference between riders with formal training and those who were self-taught or had only informal training from family or friends (χ^2 = .340, p ~ 1, df = 2). About 30-35% of all three groups took no evasive action. Riders with formal training were no more likely to use the front brake (alone or in combination with rear brake and/or swerve) than self-taught or informally-taught riders (28% vs. 27%).

Table 3: Collision avoidance actions as a function of rider training in Los Angeles

Avoidance action taken	Rider training						Total	
	Self-taught		Friends, family		Formal			
	n	%	n	%	n	%	n	%
No action taken	121	30.8	105	30.9	21	34.4	283	31.9
Rear brake only	73	18.6	72	21.2	8	13.1	164	18.5
Front brake only	3	0.8	1	0.3	1	1.6	7	0.8
Both brakes	79	20.1	48	14.1	13	21.3	151	17.0
Swerve only	28	7.1	31	9.1	6	9.8	74	8.4
Lay down & slide	2	0.5	4	1.2	1	1.6	8	0.9
Accelerate	3	0.8	4	1.2	-	-	8	0.9
Rear brake + swerve	44	11.2	39	11.5	8	13.1	104	11.7
Front brake + swerve	3	0.8	1	0.3	-	-	4	0.5
Both brakes + swerve	35	8.9	32	9.4	3	4.9	77	8.7
Other	2	0.5	2	0.6	-	-	5	0.6

Total	393	100.0	340	100.0	61	100.0	886	100.0

In both studies, the rider's evasive action was evaluated to determine whether the rider had made the proper choice of evasive action for the situation and whether the rider had executed his chosen evasive action properly (whether the action was the proper choice or not). Table 4 summarizes the data for riders who did take evasive action and for whom investigators rendered a "proper / improper" judgment on both choice and execution of the evasive action. In both Thailand and Los Angeles, riders who took evasive action were much more likely to choose the proper action than they were to execute their chosen evasive action correctly: about 50-60% chose a proper evasive action. In Los Angeles only 20-25% executed properly whatever evasive action they chose, compared to about 40% in Thailand. Only about 10-20% of those who took evasive action both chose the proper action and then executed it properly. It should be noted that this evaluation is a subjective judgment and that the standard for what was "proper" judgment or action was higher in Thailand than in Los Angeles.

Table 4. Evaluation of proper choice and proper execution among riders who took evasive action. Cell percentages are total for each group, so each cluster of four cells totals 100%.

Evasive action choice	Execution of evasive action							
	Los Angeles						Thailand	
	Self –taught (N=266)		Family, friends (N=219)		Formal training (N=38)		No formal training (N=528)	
	Improper	Proper	Improper	Proper	Improper	Proper	Improper	Proper
Improper	45.1%	4.5%	55.7%	5.0%	47.4%	5.3%	35.8%	27.3%
Proper	29.3%	21.1%	23.7%	15.5%	28.9%	18.4%	24.1%	12.9%

Figure 2. Evasive action performance in Los Angeles as a function of rider training

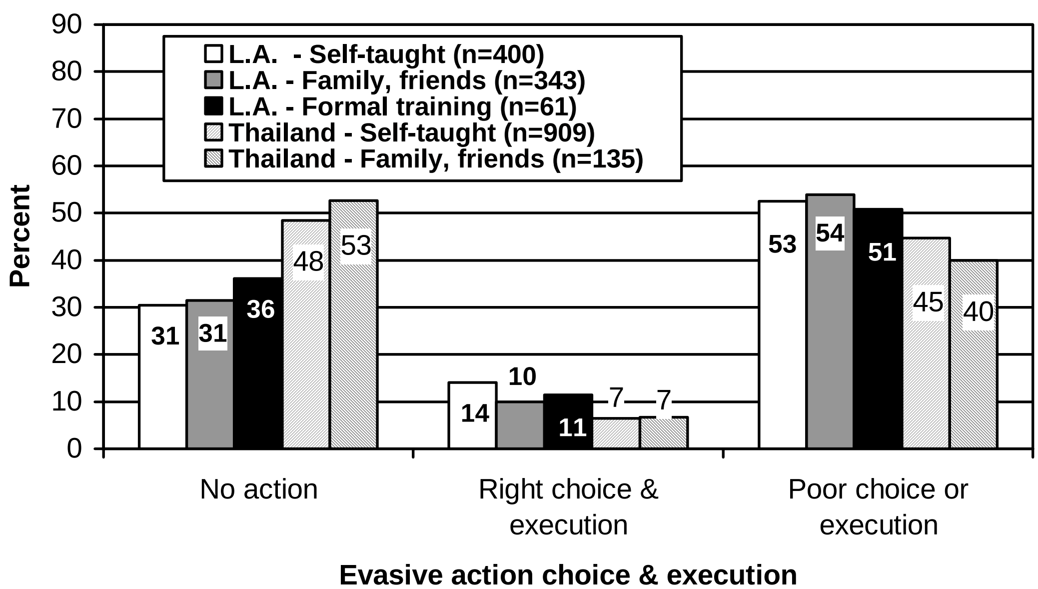


Figure 2 compares the type of rider training to those investigator judgments about rider collision avoidance performance. It shows the minimal differences between riders who were self-taught, those who learned from family or friends and those who had formal training. Roughly half the riders in Thailand and one-third of each group in Los Angeles took no evasive action (often because there was insufficient time to act). Roughly half the riders in both study areas made errors of choice or execution or both. Only about 10% chose a good evasive action and then executed it properly, regardless of training.

Of course, some motorcyclists lost control of the motorcycle as a result of poorly executed evasive action. Some intentionally slid out in an attempt to avoid colliding with a car, but most lost control despite efforts to maintain control. (For example, a "high-side" slide-out usually occurs when the rider tries to avoid a low-side slide-out by releasing the rear brake but does so a moment too late.) Table 5 compares the loss-of-control mode for those riders in Thailand and Los Angeles who took some kind of collision avoidance action just before they crashed. Riders in Los Angeles with formal training were no more likely to maintain control of the motorcycle during emergency evasive maneuvers than riders without formal training. A similar lack of difference occurred in Thailand: self-taught riders were no better or worse those who learned informally from family and friends. The two Thai groups did not differ significantly (χ^2 = .348, $p > .05$, df =1); nor did the three groups in Los Angeles (χ^2 = 4.87, $.05 < p < .10$, df = 2.)

However, Thai riders who took evasive action were significantly more likely than those in Los Angeles to maintain control of the motorcycle (approximately 80% vs.60%). For all Thai riders compared to all riders in Los Angeles, χ^2 = 45.58, $p < .001$, df =1.) That is, 40% of Los Angeles riders who took evasive action lost control of the motorcycle compared to only 21% in Thailand. The most common loss of control mode in both study areas among those riders who took evasive action was a braking slide-out, either low-side or high-side, which accounted for about 65% of the loss-of-control cases in Thailand and nearly 75% in Los Angeles.

Table 5: Loss of control among riders who took evasive action, as a function of rider training

Loss of control mode, (Percent distribution)	Thailand rider training		Los Angeles rider training		
	Self-taught (n=471)	Family, friends (n=65)	Self-taught (n=272)	Family, friends (n=235)	Formal (n=40)
No loss of control	78.3	81.5	55.9	65.1	55.0
Capsize, fall over	2.1	-	2.2	3.0	2.5
Braking slide-out, low side	12.5	13.8	31.3	22.6	30.0
Braking slide-out, high side	0.8	3.1	2.2	1.3	7.5
Ran off road	5.5	1.5	8.1	6.8	2.5
Other	0.6	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

3.3 Loss of control

How are collision avoidance actions related to loss of control? In Thailand, the evasive action most likely to lead to loss of control was the combination of swerving and braking, which had a loss-of-control rate of nearly 40%, three-quarters of which were slide-outs.

Combined braking-and-swerving was much more likely to precede slide-out or capsize loss of control than was braking-only (34% vs. 18%), and the difference was significant ($\chi^2 = 11.3$, $p < .001$, df = 1). Swerving without braking was the least likely to result in loss of control. Riders who lost control despite taking no evasive action were most likely to run off the roadway; 39 of those 51 cases (76%) were riders who had been drinking alcohol before they crashed. The Thailand data are shown in Table 6, which excludes the 43 riders whose avoidance action or loss of control was coded as “other” or “unknown.”

Table 6. Thailand loss of control mode by type of precrash evasive action

Loss of control mode	Cell datum	Motorcycle evasive action				Total
		No action	Braking only	Swerve only	Brake & swerve	
No loss of control	Frequency	430	188	147	75	840
	Row %	51.2%	22.4%	17.5%	8.9%	100.0%
	Column %	**83.3%**	**76.7%**	**93.6%**	**62.0%**	**80.8%**
Capsize, fall over	Frequency	31	1	4	5	41
	Row %	75.6%	2.4%	9.8%	12.2%	100.0%
	Column %	**6.0%**	**.4%**	**2.5%**	**4.1%**	**3.9%**
Braking slide-out	Frequency	4	40	2	34	80
	Row %	5.4	50.0	2.7	42.5	100.0
	Column %	**0.8**	**16.3**	**1.3**	**28.1**	**7.1**
Ran off road	Frequency	51	16	4	7	78
	Row %	65.4%	20.5%	5.1%	9.0%	100.0%
	Column %	**9.9%**	**6.5%**	**2.5%**	**5.8%**	**7.5%**
Total	Frequency	516	245	157	121	1039
	Row %	49.7%	23.6%	15.1%	11.6%	100.0%
	Column %	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Similar patterns emerged in the Los Angeles data. Once again, swerve-only was the evasive action least likely to be associated with a loss of control. In Los Angeles, 209 riders (23% of the 900 crashes) either slid out or high-sided; nearly 80% of those occurred during collision avoidance braking. (Some of the slide-out and high-side crashes that occurred in the absence of any avoidance action were the result of hitting contaminated pavement.) Running off the road without taking any avoidance action was significantly less common in Los Angeles than in Thailand (χ^2 = 12.7, p < .001, df = 1). In Los Angeles, braking-only was slightly more likely to precede a loss of control than combined braking and swerving (45% vs. 37%), but the difference was not statistically significant (χ^2 = 2.74, p < .10, df = 1). The data are shown in Table 7.

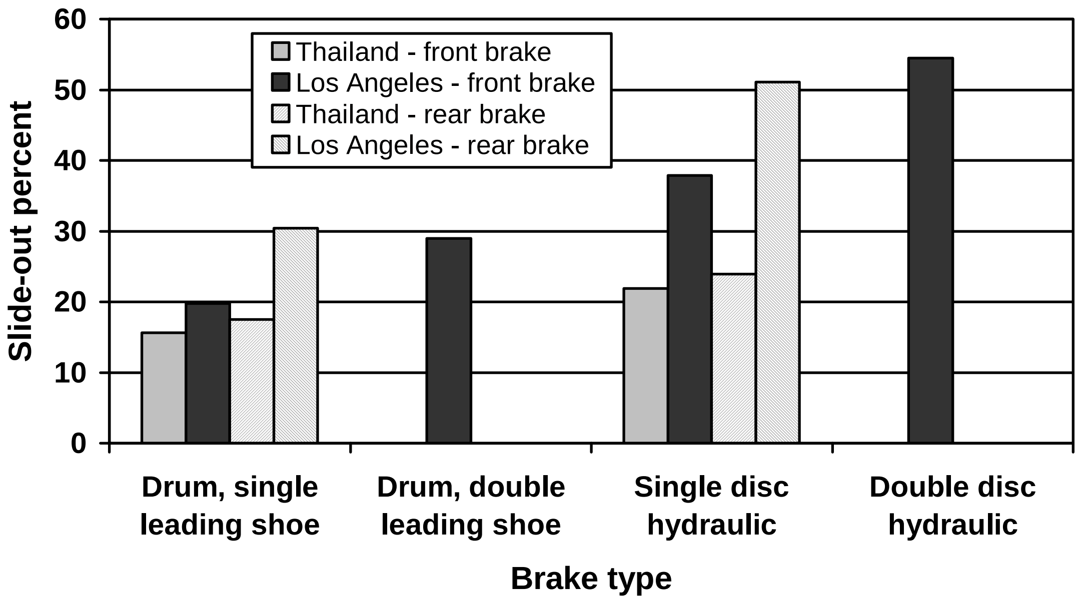
Table 7: Los Angeles, evasive action by loss-of-control type

Loss of control mode	Motorcycle evasive action									Total
	Cell datum	None	Rear brake	Front brake	Both brakes	Swerve only	Rear brake & swerve	Front brake & swerve	Both brakes & swerve	
No loss	Count	173	95	3	78	56	60	1	56	522
	Row %	33.1	18.2	.6	14.9	10.7	11.5	.2	10.7	100.0
	Column %	**63.8**	**58.6**	**42.9**	**53.1**	**75.7**	**57.7**	**25.0**	**72.7**	**61.7**
Capsize	Count	26	6		3	4	2		1	42
	Row %	61.9	14.3		7.1	9.5	4.8		2.4	100.0
	Column %	**9.6**	**3.7**		**2.0%**	**5.4**	**1.9**		**1.3**	**5.0**
Slide-out, Low-side	Count	37	43	3	54	1	33	3	17	191
	Row %	19.4	22.5	1.6	28.3	.5	17.3	1.6	8.9	100.0
	Column %	**13.7**	**26.5**	**42.9**	**36.7**	**1.4**	**31.7**	**75.0**	**22.1**	**22.6**
Slide-out, High-side	Count	5	6		3	1	3			18
	Row %	27.8	33.3		16.7	5.6	16.7			100.0
	Column %	**1.8**	**3.7**		**2.0**	**1.4**	**2.9**			**2.1**
Ran off road	Count	30	12	1	9	12	6		3	73
	Row %	41.1	16.4	1.4	12.3	16.4	8.2		4.1	100.0
	Column %	**11.1**	**7.4**	**14.3**	**6.1**	**16.2**	**5.8**		**3.9**	**8.6**
Total	Count	271	162	7	147	74	104	4	77	846
	Row %	32.0	19.1	.8	17.4	8.7	12.3	.5	9.1	100.0
	Column %	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Los Angeles riders who braked to avoid a collision were significantly more likely to slide out than their Thai counterparts. Nearly one-third in Los Angeles slid out, compared to 20% of those in Thailand (χ^2 = 15.6, p < .001, df = 1).

Perhaps the type of brake with which the motorcycle is equipped affects the probability of slide-out loss of control (either low-side or high-side). Figure 4 shows the frequency of slide-out as a function of brake type only for those riders who braked to try to avoid a crash. Generally speaking, brake torque capabilities increase among the different brake types going from left to right (although there is considerable overlap, and all brake types are capable of exerting enough torque to lock the brake.) And generally speaking, the frequency of slide-outs goes up going from left to right in Figure 4, suggesting that increasing brake torque capabilities may act to increase the frequency of slide-out loss of control during emergency braking. Some caution is needed regarding dual-disc hydraulic front brakes, because only 22 motorcycles in Los Angeles were equipped with such brakes, which were just being introduced in the mid-1970s when the Hurt study took place.

Figure 4: Frequency of slide-out as a function of brake type among riders who braked to avoid a collision.



4. Discussion

The most striking finding reported here is the absence of any apparent benefit of formal rider training on collision avoidance actions in Los Angeles. The minority of riders with formal training were mostly police motorcycle officers with extensive training and experience with on-duty street riding. However, they were no more likely to take evasive action than riders without formal training (66% vs. 69%) or to use the front brake (28% vs. 27%). Formally trained riders were no more likely to choose the proper evasive action than other riders (46% vs. 45%) or to execute it properly (24% vs. 24%) and no more likely to do both properly (11% vs. 12%). Forty percent of riders without formal training who took evasive action lost control of the motorcycle, compared to 45% of riders who had formal training. The reasons for the lack of difference between riders with and without formal training in Los Angeles may be due to one or both of two reasons: 1) the very short amount of time available for evasive action in most crashes, or 2) the deterioration of rider skills in the face of a sudden life-threatening situation. Whatever the reason, it appears that if riders with formal training are less likely to be involved in a crash, it must be due to something other than highly skilled emergency collision avoidance.

Certainly training cannot explain why riders in Thailand who took evasive action were significantly less likely to lose control of the motorcycle than riders in Los Angeles (21% vs. 40%). In particular, Thai riders were much less likely to slide out during emergency braking maneuvers (20% vs. 33%). Why would riders in Thailand do a better job of maintaining control during emergency braking?

The answer cannot be differences in the frequency of different brake types. Generally, hydraulic disc brakes were more likely to be associated with low-side or high-side slide-outs, but hydraulic discs were more common in Thailand than in Los Angeles (68% vs. 50% for front brake and 43% vs. 9% for rear brake). A tempting hypothesis to explain why Thai riders lost control less often is that they simply have nearly constant practice at swerving or heavy braking due to frequent, sudden speed changes in heavy traffic and because serious right-of-way challenges are so common in Thailand. Thailand traffic, particularly in Bangkok, can appear chaotic. So little land area is devoted to roads (about 6% in Bangkok, according to United Nations estimates, compared to 20-25% in American cities) that vehicles try to squeeze through every available bit of space, which leads to frequent speed and lane changes.

In addition, the ironclad right-of-way rules in the U.S. appear to be much more flexible in Thailand. American riders can safely assume that a car that could potentially violate their right-of-way will in fact yield as required by law – if the car driver sees them. As a result, American motorcyclists are astounded and furious when a car driver “looks right at them” and then violates the motorcycle right of way. Riders in Thailand don’t have the luxury of assuming an opposing vehicle will yield the right-of-way, and it is common to see car drivers edge into a motorcycle’s path, challenging the motorcyclist to yield his right-of-way. Car drivers in Los Angeles who collided with a motorcycle almost always said they hadn’t seen the motorcycle in the critical seconds just before the collision. Car drivers in Thailand rarely said they hadn’t seen the motorcycle (unless there was a view obstruction), perhaps because motorcycles are so very common in Thailand traffic (29% in Bangkok, 42% upcountry, compared to 0.5% in Los Angeles.) Instead, Thai drivers often thought that the motorcycle should have yielded to their car, regardless of right-of-way rules. Or perhaps the explanation why Thai riders are better at maintaining control during evasive action is more Darwinian: perhaps riders who don’t develop effective braking skills are quickly eliminated from the traffic mix.

Unfortunately, these explanations for differences in braking slide-outs in Los Angeles and Thailand arise from informal observation and cannot be verified with the available accident data, so the reader is well advised to reserve judgment. The differences between Los Angeles and Thailand are real and important, but the explanations offered here are only tentative and hypothetical.

Why does rider training seem to have so little benefit for collision avoidance skills? The fact is that riders face a number of problems whenever they undertake emergency evasive action to avoid a collision and those problems may overwhelm any benefit of training.

First, a rider's ability to process information may become overloaded with the avalanche of critical information from a variety of sources pouring in during the few seconds before a crash. Faced with a dire threat, a rider may need to monitor simultaneously the speed and path of the opposing vehicle, his rate of intercepting that vehicle, decide which possible avoidance maneuver would be best, monitor whether his tire traction is approaching its limits (if he's braking) and decide whether and how to modify brake lever pressure and monitor motorcycle yaw, roll and pitch (if he swerves). All these things have to occur even while the rider may be gripped by fear or even panic as an impending disaster rapidly fills his field of view in what might be (or feel like) the last few seconds of the rider's life. An established principle of psychology is that well-practiced skills can be improved by a moderate increase in stress, but too much increase in stress can cause performance to deteriorate markedly. The last seconds before a crash or near-crash would seem to qualify as extremely stressful moments that are unlikely to bring out the best performance in most riders.

In addition, riders who brake before a collision face the problem that speed loss over distance is non-linear. For example, during constant deceleration to a stop, a vehicle uses the first three-fourths of its stopping distance to lose half its speed; the remaining half of speed is lost in the last one-fourth of the stopping distance. To a rider who has been doing a skillful job of braking hard for a couple seconds, it may feel like the motorcycle cannot stop in time, so he may apply the brakes even harder and thereby cause one or both brakes to lock up and perhaps lose control. This kind of error is pretty common and, in fact, one can now find videos on the Internet of riders making exactly that mistake, when they overbrake for a problem that occurs while doing a "stoppie" (applying the front brake so hard the rear wheel comes up off the pavement).

Braking itself simply acts to delay the rider's arrival at the point of impact. One hopes the delay is long enough for the opposing vehicle to clear out of the motorcycle's path. But how much can a rider delay his arrival in most situations?   As an example, consider a rider going down the street at 35 mph (57 km/hr). If he's lucky to have the as much as 30 feet (9 m) of braking distance, simple rear-only braking might delay his arrival at the conflict point by .05 seconds (compared to no braking at all). Skilled front-and-rear braking could delay his arrival by .13 seconds. In that brief time period, a car moving the median speed of 12 mph (20 km/hr) would move about 1 –2¼ feet (26-70 cm.) Compared to unskilled rear-only braking, skilled braking can delay the rider's arrival at the conflict point in this situation an extra .08 seconds, or enough for a car going 12 mph (the median speed of vehicles that collided with motorcycles in Los Angeles) to move forward an additional 1.4 feet. In some situations, this might be enough delay and distance to avoid a collision. In most cases, it would not.

It is by now well known that motorcycles change directions by first countersteering. For example, an initial steering movement to the right causes the motorcycle to lean (or begin falling) to the left, then a quick steering movement to the left arrests the fall and directs the motorcycle onto a curving path to the left.   However the initial countersteer-and-lean motion consumes about one half second, during which time the motorcycle does not change its path [Watanabe & Yoshida, 1973]. In ordinary riding, this half-second time lag is inconsequential. However, in a critical crash threat situation, where two to three seconds are available and half of that time is taken up by the mental processes of perception and decision making, the added half-second for countersteering is critical.

A problem arises when riders try to combine braking and swerving because of the longer reaction time for swerving. In effect, the brakes often come on before the motorcycle begins to change direction. If the rider applies the rear brake hard enough to lock the rear wheel, the rear tire cannot generate the side-forces necessary to lean into a turn. The result is often a slide-out or high-side loss of control, which is still a crash, even if the rider manages to avoid colliding with the object he hoped to evade.

When one can examine only crashes (and no successfully avoided near-collisions), swerving to avoid a collision can appear ineffective. Many riders who try to swerve seem to "freeze up" and lean the motorcycle far less than its cornering limits. Occasionally, one sees a rider who successfully avoids the collision he hoped to avoid, only to strike some other vehicle or obstacle. It appears in these cases that instead of aiming for a particularly target path at the end of his swerve maneuver, the rider swerved, then waited to make sure that he had cleared the threat before trying to correct his path. For example, a rider might swerve right to avoid a vehicle in his path but wait too long before steering back to the left too late to avoid going off the road or into opposing lanes. Unfortunately, head-on crashes into oncoming traffic and run-off-road crashes are the two most lethal types of collisions [Kasantikul, 2002a, 2002b].

In the end, the most important determinant of accident involvement may be the amount of time available between the precipitating event (PE) and impact. Roughly 80-90% of riders had than three seconds or less in which to detect a threat, then choose and execute an evasive action before they reached the point of impact. Riders with more than four seconds from PE to impact were 1% of the Los Angeles data and 5% of the Thailand data. Perhaps riders with less than three seconds are rarely able to avoid a crash while those with more than three or four seconds usually escape disaster.

This suggests that the best time for a rider to take action to prevent a crash is five to ten seconds before it might happen and that waiting until the last few seconds and relying on skill and nerve to somehow save the day is a recipe for disaster. That is, perhaps more would be gained by focusing on preventing the precipitating event instead trying to react effectively after it has already occurred.

5. References

Anderson S, Picking up the pieces, *Cycle World,* January, 2005; *44* (1) 64-70.

Hurt, HH, Jr., Ouellet, JV, Thom, DR, *Motorcycle Accident Cause Factors and Identification of Countermeasures, Final Report*, 1981; DOT-HS-F-01160.

Kasantikul, V, *Motorcycle Accident Cause Factors and Identification of Countermeasures in Thailand: Volume I: Bangkok,* KP Printing, Bangkok, 322 pages, 2002a.

Kasantikul, V., Motorcycle Accident Cause Factors and Identification of Countermeasures in Thailand: Volume II: Upcountry. KP Printing, Bangkok, 309 pages, 2002b.

Kasantikul V, Ouellet JV, Smith TA, Sirathranont J & Panichabhongse V; The role of alcohol in Thailand motorcycle crashes; *Accident Analysis & Prevention; 2*005; *37,* (2): 357-366.

OECD - Technical Expert Group of the Co-ordinating Group for Motorcycle Accident Investigations; of the Road Transport Research Programme; of the Directorate for Science Technology and Industry; of the Organization for Economic Cooperation and Development, OECD/DSTI/RTR/RS9/TEG: Motorcycles: common international methodology for on-scene, in-depth accident investigation; 1999.

Watanabe Y & Yoshida K, Motorcycle handling for collision avoidance, *Second International Congress on Automotive Safety*, SAE Paper 73018, San Francisco, 1973.

6. Appendix I

Accident investigation methodology probably cannot be used to determine whether a rider's skill in taking evasive action to avoid a crash was the single critical element that prevented a crash. First, investigators would have to find out about a near-miss, which is a huge (and probably insurmountable) obstacle. It is difficult enough trying to get accident notifications from public agencies such as police and emergency medical services, but how would one get notified of a non-accident? There would be almost no other means of notification except for a rider to call investigators and wait for their arrival at the scene (because riding even 100 yards can degrade or destroy braking scuff marks on a tire.)

The second reason is that the lack of physical evidence from a near-miss may preclude any kind of scientific reconstruction of events. An actual crash usually generates a fair amount of physical evidence in the form of skid and scrape marks, damage to the motorcycle and other vehicles, injuries to the rider and so on. This physical evidence allows a reconstruction of immediate precrash evidence.

In a near-miss situation, especially one involving skilled collision avoidance by the rider, almost no physical evidence would be generated. For example, how could an investigator determine how close the motorcycle actually came to the car? Missing a car by five meters and two seconds leaves exactly the same physical evidence (or lack of it) as missing it by one centimeter.

Even if skilled braking can be verified, it is likely to be impossible to tell if it was the critical element in crash avoidance. Figure 4 illustrates why this is so for a typical situation in which a car turns across the path of a motorcycle coming from the opposite direction.

Figure 4 illustrates three critical moments in a non-stop car turn: 1) the precipitating event, when the car begins its turn; 2) the moment the car enters the motorcycle path; and 3) the moment the car clears the motorcycle path. In great part, whether a collision occurs depends on where the motorcycle is at the time of the precipitating event. If the motorcycle is very close to the car (segment A), it will clear the conflict point (where the vehicle paths cross) before the car arrives. Similarly, if the motorcycle is far enough away (segment F), the car will move past the conflict point before the motorcycle arrives. In between those two points, the motorcycle is at risk of colliding with the car. In segment C, motorcycle cannot brake hard enough to avoid a collision; a crash is inevitable. In segment D, the motorcycle can avoid a collision, but only if the rider uses both front and rear brakes. In segment E, rear-only braking would be sufficient to avoid a crash. (It should be noted that Segments D and E represent a continuous gradient of deceleration rates needed to avoid a crash; the closer the motorcycle is to the car (and the darker the band in the segment), the greater the deceleration required. At the most distant end of Segment E, simply letting off the throttle would be enough to avoid contact with the car.) Segment B is a paradoxical region in which the rider would avoid a crash if he does nothing, but could crash if he hits his brakes and delays passing the conflict point long enough for the car to collide with his motorcycle.

The reason reconstruction cannot be used to determine whether skilled braking actually prevented a collision is that there is simply no reliable way for an investigator to determine whether the motorcycle was in segment D or segment E, in the absence of any physical evidence about the location and speed of motorcycle and car at any given moment.

Perhaps video observation of high-risk locations, combined with photogrammetry can resolve the issue of how often skilled collision avoidance prevents crashes, but it seems unlikely that accident investigation methods can do so.

Figure 4: Diagram of typical opposing-turn collision.