SKIERS, TREES AND AVALANCHES: A MURDEROUS TRIAD

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ABSTRACT: Many skiers and snowboarders perceive treed slopes as less dangerous during periods of unstable snow. In recent years a growing number of accidents have involved enthusiasts with—and in some cases with significant—avalanche awareness training riding steep, treed slopes during periods of unstable snow. Contrary to perceptions, in such conditions treed slopes mean more danger and greater risk. To be swept into a tree is similar to a pedestrian struck by a car. Observations from the highway-safety domain show vehicle speed predicts severity of pedestrian injuries. When vehicle speeds are below 20 mph the probability of serious or fatal injury is less than 20%. When speeds rise above 35 mph, most injuries are lethal or incapacitating. These noted speeds are well less than the speeds of typical dry snow avalanches. This paper explores the misperception of trees and safety, and addresses how current avalanche education may be contributing to this problem. Also presented are suggestions to better inform riders about the dangers of avalanches and trees.

KEYWORDS: avalanche, accident, fatalities, trees, skier, pedestrian, collisions, motor vehicles

1. INTRODUCTION

Information from motor vehicle accidents involving pedestrians can be used as a metaphor to better understand and anticipate the problems of skiers and snowboarders caught on tree-covered slopes. The catastrophic forces experienced even in the low-speed collision of a skier versus tree (or rock) are likely not understood and therefore under appreciated. Evidence of this ignorance is propagated in avalanche education in two axioms. One, is the relatively new, general advice to ski and ride in tightly-spaced trees during periods of unstable snow. The other is the simple rule to grab a tree if caught in an avalanche. If followed, either axiom (and usually applied sequentially) will result in a bad outcome. Motor vehicle accidents give insight as to why.

In the past five winters (2007/08 to 2011/12) avalanche deaths in the United States have averaged 32 victims per winter. Skiers and snowboarders accounted for 43% of these deaths. Of the 68 skiers and snowboarders killed, 22 (32%) died from collisions with trees. This one-in-three ratio is comparable with results from a Canadian study by Boyd and colleagues (2009) that found a similar percentage of skiers caught in avalanches died from trauma.

The focus of this paper is not to address patterns or severity of injuries suffered by skiers and snow-boarders caught in avalanches. Asphyxiation is the leading cause of death of buried avalanche victims (Grissom, Radwin, Macintosh, and Atkins, 2010); however, terrain and vegetation where the avalanche occurred can greatly increase the likelihood of traumatic injuries. While the focus of this paper is about skiers and snowboarders the conclusions apply to any avalanche victim who might encounter a collision.

2. AVALANCHE ACCIDENTS IN TREES

The general forces experienced by an avalanche victim entrained in the flow of the typical human-triggered avalanche are not sufficient to cause life-threatening injuries. In the absence of a collision extremity fractures and dislocations are suspected to result from the twisting movements experienced by the victim. In the cases of injured skiers, Hohlrieder and Brugger (2007), also suggest skis and poles exert additional mechanical leverage leading to these injuries.

Obviously, a collision during the avalanche causes significant bodily injuries, and for skiers and snowboarders (henceforth referred to as "riders") trees likely pose the greatest collision threat. This study reviewed the 20 fatal accidents that involved collisions with trees. Not considered were at least four other accidents where riders died from collisions with rocks in alpine terrain. One in three rider deaths (22 of 68) due to trauma, and all 22 involved tree collisions, is much greater than the often stated statistic that less than 25% of all avalanche victims die from trauma (Grissom, et al., 2010).

Of these 20 accidents three remarkable attributes stand out. While it is not surprising that every victim could be described as an avid riding

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enthusiast, what is surprising is that nearly all had avalanche awareness training and many had significant training and experience in avalanche terrain. Second, at least 70% of the accidents occurred on days when the avalanche danger was rated “considerable” or “high” (table 1). And third is the nastiness and obviousness of the injuries. Seldom were victims unmarked. Most victims suffered obvious, large wounds: lacerations, deformities and fractures across their bodies. Several victims straddled trees, and one victim’s leg was severed and not found.

danger rating	N (%)
No rating / Not reported	4 (20%)
Low	0
Moderate	2 (10%)
Considerable	7 (35%)
High	7 (35%)
Extreme	0

Table. 1 Avalanche danger ratings in effect at the time of skier–avalanche–tree accidents.

3. GENERAL AVALANCHE DATA

Dry snow avalanches are fast moving and can result in high impact pressures. The reason is that impact pressures are proportional to the avalanche speed squared, v^2, and the density of the moving snow (McClung and Schaerer, 2006). The same simple physics can be applied to a person caught up in the flow of an avalanche who slams into a tree, rock or other obstacle.

Avalanches travel quickly and Mears (1992) summarizes the range of maximum velocities for typical dry-snow avalanches (table 2). For purposes of this paper the three ranges may be thought of as short, medium and long running avalanches.

vertical fall (m)	velocity range (m/s)
100–200	20–35 (45–78 mph)
200–500	35–55 (78–123 mph)
500–1000	55–70 (123–157 mph)

Table. 2 Typical dry-snow avalanche maximum velocity estimates from Mears (1992).

In 2008 this author related avalanche dimensions to the extent of injuries—injured or not-injured—and found vertical fall and fracture-line depth as the two most important factors. Collisions were not considered. Size matters and a sample of human triggered avalanches during the past five winters (table 3) shows that many avalanches are likely traveling as fast as a speeding car.

N	73
mean (m)	220
SD (m)	± 205
median (m)	105

Table. 3 Vertical fall of reported avalanches triggered by skiers and snowboarders, 2007/08–2011/12.

4. SKIER AND SNOWBOARDER SPEEDS

There are no known studies of the speeds at which backcountry riders travel. However, Shealy at al. (2005) evaluated the speeds of alpine skiers and snowboarders on groomed intermediate slopes at ski areas. He and his team found the average speed for all riders to be 43 km/h (26.7 mph). Skiers were a bit faster than snowboarders. Shealy also reported that the observed speeds were well above ASTM standard (22.6 km/h, or 14.0 mph) for recreational snow sports helmets.

5. MOTOR VEHICLE ACCIDENTS

Unlike avalanche accidents which are rare, motor vehicle collisions involving pedestrians are common. In 2010 the National Highway Traffic Safety Administration reported 4,280 pedestrians killed and 70,000 injured. In transportation safety it is well known that vehicle speed plays a major role and is a predictor of the severity of pedestrians injuries (Leaf and Preusser, 199, Rodegerdts, et al. 2004). Even at relatively low speeds, <32 km/h (20mph), the probability of serious or fatal injury is notable and real. However, at speeds above 35 mph (56 km/h) most injuries are incapacitating or fatal (Leaf and Preusser, 1999). When a pedestrian is struck the likelihood of death increases in a nonlinear fashion relative to the increase in vehicle speed (figure 1). The same can be surmised for a person caught in an avalanche.

Similar to the report of Leaf and Preusser a more recent report by the UK Department of the Environment, Transport and Regions (DETR, 2000) stated that 90% of pedestrians hit by a car traveling just 30 mph will be seriously injured and nearly half of them will be killed. In terms of avalanches 30 mph is very slow.

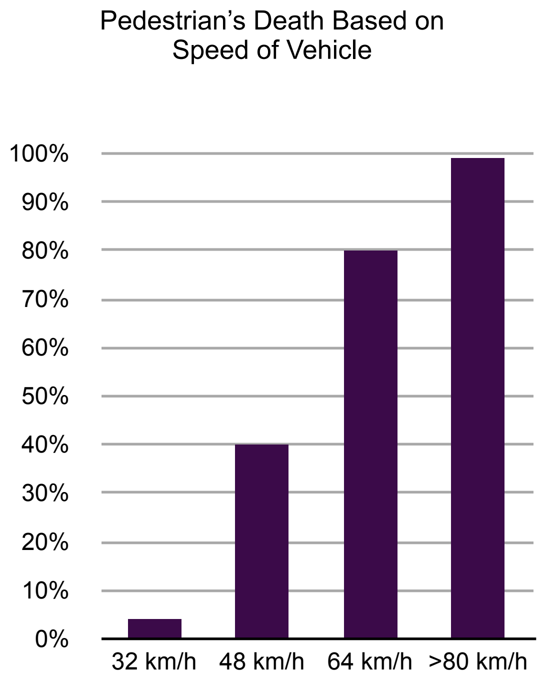

Figure 1. A pedestrian's chances of death if hit by a moving vehicle. UK Department of Transportation, *Killing Speed and Saving Lives*, London 1987.

In 2004 the World Health Organization cited similar values from work done by Pasanen in 1991. Ninety percent (90%) of pedestrians struck by a moving car traveling at or less 30 km/h will survive. However, for impacts at or greater than 45 km/h less than half will survive.

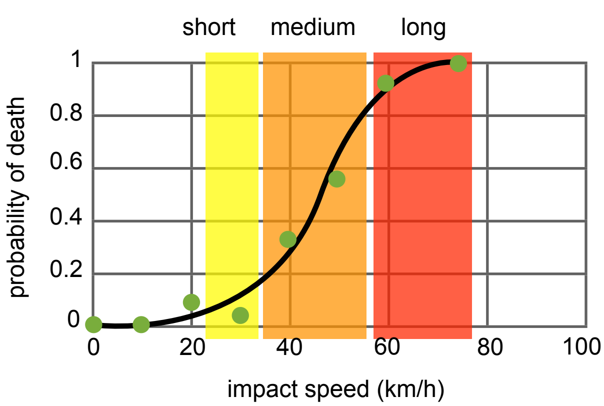

Figure 2. Pedestrian fatality risk as a function of vehicle speed (WHO, 2004). Overlaid are velocity ranges of avalanches by Mears, 1992 (table 2).

6. CONCLUSIONS

Speed matters and avalanches generally carry riders at speeds far greater than one typically skis or snowboards. From the domain of motor vehicle collisions involving pedestrians it is well understood that even low-speed collisions result in serious injuries and sometimes deaths. It is also well known that small increases in speed (over 32 km/h, 20 mph) result in relatively large increases in risk. Serious injuries and death become certain at speeds of only 48 km/h (50 mph). These speeds are typical of smaller avalanches. The bottom line is that being caught in an avalanche and colliding with a tree results in the same consequences as being struck by a speeding car: serious injuries or death.

It is this author's opinion that the old rule "avoid steep slopes when snow is unstable" has in recent years morphed into a rule of "it's alright to venture onto steep slopes during periods of unstable snow as along as one stays in tight trees." This new practice is misguided and results in greater risks. If there is room to ski and link turns, there is room to release an avalanche.

Another axiom, as stated earlier, is the long taught advice for the rider to "grab" a tree if caught. This strategy has also morphed over time from one of simply "holding on" which only works when one is already standing next to a tree, to a strategy of reaching out and grabbing a tree as one skis or is swept by. This strategy should not be counted on to work with satisfactory results. A simple test will demonstrate, though painfully, the futility of "grabbing" a tree. Back away about 30–40 m and then sprint at full speed toward a tree, then try to "grab" the tree as you run by. Even at our pedestrian-like (slow) sprint speeds, compared to an avalanche, the forces will be too great. Caution: before attempting this test, be advised that it may be hazardous to your health. Even at this relatively slow speed nearly 1 in 20 pedestrians die when struck by a car.

Riding steep slopes during periods of unstable snow is always dangerous. Riding these slopes with trees compounds the danger. Unfortunately, many riders likely dismiss this greater danger thinking that trees provide some degree of safety.

Lastly, protecting one's head is always important; however, recreational snow sports helmets are not designed for the speeds and impact forces encountered in avalanches. A helmet might help hold together one's head but will not offer protection to the catastrophic forces of a collision encountered in an avalanche.

Skiers, trees and avalanches result in a murderous triad. The bottom line is painfully simple. For a skier caught even in a small avalanche a collision with a tree will likely be fatal.

7. RECOMMENDATIONS

- Skiing and snowboarding in trees should not be thought of as a defensive or protective strategy.
- During periods of instability tree-covered slopes should be given extra respect and caution.
- Dense trees on steep slopes are likely protective if they cannot be enjoyably skied.
- Do not expect trees to comfortably arrest a person caught in an avalanche.
- If one does not fancy to be struck by a car, then one should not venture onto steep, tree-covered slopes during periods of instability. Whether one is struck by a car or hits a tree, the consequences will be similar.

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9. POTENTIAL CONFLICT OF INTEREST DISCLOSURE

I, Dale Atkins, provide services to and receive compensation from RECCO AB.