# AVALANCHE ACCIDENT RISK REDUCTION TOOLS IN A NORTH AMERICAN CONTEXT

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ABSTRACT: Over the last decade, a number of avalanche risk reduction tools have been developed to assist recreational winter backcountry users avoid avalanche accidents, including the Avaluator Avalanche Accident Prevention Card (Haegeli & McCammon, 2006), Avaluator V2.0 (Haegeli, 2010), the Nivo Test (Bolognesi, 2001, 2007), and Munter's Reduction Method (Munter, 1997, 2003). These tools are based on different sets of assumptions and data, focus on widely varied pieces of information, and use different processes to arrive at their respective recommendations for safe travel. McCammon and Haegeli (2005) evaluated some of these methods using North American avalanche accident records but unfortunately they inappropriately deleted all accidents with missing data from their data set (e.g., if an accident record did not state whether or not there was any new snow, they simply deleted it) (see Uttl et al., 2008, 2009, 2010). We reviewed and evaluated these and other avalanche risk reduction tools in a North American context using over 1,000 Canadian and US avalanche accident records as well as computer simulations and modeling. We discuss the implications of our findings for avalanche safety training programs.

KEYWORDS: Accident Prevention, Risk reduction tools, Risk, Decision Making

## 1. INTRODUCTION

Over the last decade a number of avalanche risk reduction tools have been developed to assist recreational winter backcountry users to avoid avalanche accidents. Most of them have been developed in Europe with the exception of McCammon's Obvious Clues method developed based on the historical analysis of US avalanche accidents (McCammon, 2002, 2004). McCammon and Haegeli (2004, 2005) reviewed several of the most common European tools as well as McCammon's Obvious Clues method and concluded that McCammon's Obvious Clues method was the best of them all in a North American context. Shortly thereafter, the Obvious Clues method was incorporated into a brand new "made in Canada" decision-making tool designed to prevent avalanche accidents and called the Avaluator Avalanche Accident Prevention Card (Haegeli and McCammon, 2006).

However, McCammon and Haegeli's (2005) analysis suffers from several critical problems that render their conclusions invalid. First, McCammon and Haegeli evaluated the tools based on so-called "prevention values" or the percentage of historical accidents prevented if historical users limited their travel to the go/no go recommendations of the individual tools. However, the use of prevention values to evaluate tools' utility has been severely criticized. To illustrate, Uttl, Taylor, and Uttl (2010) showed that their new 7CF (seven coin flips) avalanche accident prevention tool prevented as many accidents as Heageli an McCammon's (2006) Avaluator's Obvious Clues method. The user takes seven coins, tosses them in the air, counts the number of coins that land heads showing, and if the number of heads is greater than four, the user is advised not to proceed to travel across the avalanche slope. Thus, Uttl, Taylor, and Uttl (2010) demonstrated effectively that the prevention values themselves are not sufficient for evaluating the effectiveness of the avalanche accident risk reduction tools.

Second, Haegeli and McCammon (2006) inappropriately deleted from their data set all accidents with missing values (i.e., accidents where accident records did not include necessary information to determine whether or not specific accident characteristic, for example, an obvious clue, was present or absent) and failed to consider what effect such wholesale data deletion may have on interpretation of their analyses. Specifically, they started with 751 avalanche accidents from USA but because the accident records often did not include relevant information they simply deleted all accidents with missing information from their analyses and their evaluations of various tools were based on only small non-representative fractions of accidents. As a result of these accident deletions, different tools were evaluated against different sets of accidents,

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depending on the pattern of missing data. Table 1 shows that McCammon and Haegeli (2005) based their analyses on as few as 15% of all available accidents (i.e, NivoTest analyses). In general, it is well known that such massive data deletions with no consideration of consequences on data interpretation are grossly inappropriate (Little & Rubin, 1987; Schaffer & Graham, 2002). More specifically, using multiple methods, Uttl and his colleagues (Uttl, Henry, & Uttl, 2008; Uttl Uttl, & Henry, 2008; Uttl & Kisinger, 2009, 2010) demonstrated that, in case of the Obvious Clues, missing data mean primarily the absence of the Obvious Clues. Accordingly, the McCammon and Haegeli (2004, 2005) analyses comparing various avalanche risk reduction tools, as well as their conclusions, are invalid for the Obvious Clues as well as other tools.

Table 1. Number of Accidents Remaining in McCammon and Haegeli (2005) Analyses after Deletion of Accidents with Missing Values.

| Tool | Remaining Accidents |
|---|---|
| Beginner Reduction Method | 280 (37%) |
| Reduction Method | 229 (30%) |
| SnowCard | 257 (34%) |
| NivoTest | 115 (15%) |
| Obvious Clues | 252 (34%) |

In this paper, we review and re-evaluate several avalanche risk reduction tools in a North American context: the original Avalanche Accident Prevention Card's Obvious Clues (Haegeli & McCammon, 2006), the Avalanche Accident Prevention Card's v2.0 Slope Evaluation (Haegeli, 2010), Nivo Test (Bolognesi, 2007), and Munter's Beginner Risk Reduction Method (Munter, 2002; Kurzeder & Feist, 2003). These tools are based on different sets of assumptions and data, focus on widely varied pieces of information, and use different processes to arrive at their respective recommendations for safe travel. We examine their prevention values but more importantly we examine whether or not their assessments of avalanche accident danger or risk correlate and whether or not they would make the same or similar travel recommendations.

In essence, each of these tools can be reduced to a simple checklist where a user determines the presence or absence of various avalanche conditions, terrain characteristics, and human factors; adds up all the points; and uses recommended cut-offs to determine whether or not travel across a particular slope is not recommended or allowed with various degrees of caution.

Table 2 illustrates the Avaluator's v1.0 Obvious Clues method. A user adds up the number of the Obvious Clues and if the sum is greater than 4, the Avaluator indicates that the travel across the slope is not recommended (Haegeli & McCammon, 2006).

Table 2. Avaluator's v1.0 Obvious Clues.

| Obvious Clue | Pts |
|---|---|
| AVALANCHES Are there signs of slab avalanche activity in the area within the last 48 hours? | 1 |
| LOADING Was there significant loading by snow, wind, or rain in the area within the last 48 hours? | 1 |
| PATH Are you in an obvious avalanche path or starting zone? | 1 |
| TERRAIN TRAP Are there gullies, trees or cliffs that would increase the consequences of being caught? | 1 |
| RATING Is the danger rating considerable or higher? | 1 |
| UNSTABLE SNOW Are there signs of unstable snow, such as whumpfing, cracking or hollow sounds? | 1 |
| THAW INSTABILITY Has there been recent significant melting of the snow surface by sun, rain or warm air? | 1 |

Table 3 summarizes the Avaluator's v2.0 Slope Evaluation “Warning Signs” (Haegeli, 2010). The Warning Signs include the seven Obvious Clues plus three new clues/warning signs: Slope Steepness, Slope Shape, and Persistent Avalanche Problem. Similar to the Avaluator v1.0 Obvious Clues, the user adds up the number of points and if the sum is greater than 6, then travel across a particular slope is not recommended. The Avaluator v2.0 actually includes two checklists but, as shown by Uttl, McDouall, & Mitchell (2012) these two checklists reduce to a single checklist for purposes of “Not recommended” decisions.

Table 4 shows Nivo Test's Risk Factors (Bolognesi, 2007). The user adds up the number of points and if the sum exceeds 22, then travel across the slope is considered “hazardous”, that is, not recommended.

Table 3. Avaluator v2.0 Slope Evaluation Warning Signs.

| Warning Sign | Pts |
|---|---|
| REGIONAL DANGER RATING Is the avalanche danger rating "Considerable" or higher? | +1 |
| PERSISTENT AVALANCHE PROBLEM Is there a persistent or deep persistent slab problem in the snowpack? | +1 |
| SLAB AVALANCHES Are there signs of slab avalanches in the area from today or yesterday? | +1 |
| SIGNS OF INSTABILITY Are there signs of snowpack instability including whumpfs, shooting cracks or drum-like sounds? | +1 |
| RECENT LOADING Has there been loading withing the past 48 hours including roughly 30 cm of new snow or more, significant wind transport or rain? | +1 |
| CRITICAL WARMING Has there been a recent rapid rise in temperature to near 0 C, or is the upper snowpack wet due to strong sun, above-freezing air temperatures or rain? | +1 |
| SLOPE STEEPNESS Is the slope steepness between 30 and 35 degrees?<br>Or<br>Is the slope steeper than 35 degrees? | +1<br><br>+2 |
| TERRAIN TRAPS Are there gullies, trees or cliffs, that increase the consequences of being caught in an avalanche? | |
| SLOPE SHAPE Is the slope convex or unsupported? | +1 |
| FORREST DENSITY Is the slope in the alpine, in a sparsely treed area or in open forest (cut-block, burn, wide-spread glades)? | +1 |

Finally, Table 5 shows Munter's Beginner Reduction Method. If any of the rules apply, travel is not recommended.

## 2. METHOD

We examined over 1,000 recreational avalanche accidents published in *The Snowy Torrents* (Williams, 1975; Williams & Armstrong, 1984; Logan & Atkins, 1996), *Avalanche Accidents in Canada* (Stethem & Schaerer, 1979, 1980, 1987; Jamieson & Geldsetzer, 1996), and

Table 4. Nivo Test Risk Factors.

| Risk Factor | Pts |
|---|---|
| Rain in past 2 days? | +3 |
| Snowfall more than 20cm in past 3 days? | +3 |
| Snow drift in past 5 days? | +3 |
| Air temperature above 0 C? | +1 |
| Poor visibility (darkness, thick mist)? | +3 |
| Deep snow (20-40 cm foot penetration)? | +3 |
| Very deep snow (40 cm or more foot penetration)? | +5 |
| Wet snow? | +2 |
| Irregular snow pack (depth or structure)? | +1 |
| Snow pillows or cornices? | +5 |
| Internal weak layer? | +3 |
| Avalanche today? | +4 |
| Avalanche yesterday or the day before? | +2 |
| Cracks in the snowpack? | +1 |
| Route with no islands of safety? | +4 |
| Dangerous runout (rock pitches, cliffs, crevasses)? | +1 |
| Unfrequented route? | +1 |
| Route with steep slopes (30 or more)? | +4 |
| Steep slopes (30 or more) above the route? | +2 |
| Steep convex slope? | +1 |
| Group member with poor technical ability? | +1 |
| Unfit group member? | +1 |
| Group member without transceiver, probe and shovel? | +1 |
| Group of more than 5 or less then 3 members? | +1 |
| Group not trained in rescue? | +1 |

Table 5. Munter's Beginner Reduction Method.

| Rules | Pts |
|---|---|
| Danger Rating = 2 AND Slope ≥ 40 | +1 |
| Danger Rating = 3 AND Slope ≥ 35 | +1 |
| Danger Rating = 4 AND Slope ≥ 30 | +1 |
| Danger Rating = 5 | +1 |

Avalanche Center database (www.avalanche-center.org).

Each avalanche accident record was coded for the presence or absence of various avalanche accident factors/characteristics (e.g., the presence vs. absence of the Obvious Clues) using a 5-point scale: Yes (factor is present), Weak Yes (factor is probably present), Unknown (presence or absence cannot be established), Weak No (Factor is probably absent), No (factor is absent) (see Uttl, Henry, & Uttl, 2008).

## 3. RESULTS

Table 6 shows the prevention values for various methods under the assumption that missing values mean the absence of characteristics (Uttl, Henry, & Uttl, 2008; Uttl & Kisinger, 2009, 2010). The prevention values calculated using this assumption are the most conservative and, in case of the obvious clues, the most appropriate (Uttl, Henry, Uttl, 2008; Uttl, Uttl, & Henry, 2008; Uttl & Kisinger, 2009, 2010). However, when the tool (e.g., Avaluator v2.0, Nivo Test, Beginner's Reduction) relies on non-obvious clues (e.g., exact slope angle), the assumption that missing values mean absence is not appropriate (Uttl & Kisinger, 2009, 2010). In this case, it may be more appropriate to fill in the missing values randomly using the distribution of the actually observed values in accidents with the reported data. While this approach seems reasonable for Avaluator's v2.0 Slope Steepness and Slope Shape as well as for the Beginner's Reduction's Slope Angle, it is problematic for many of the Nivo's 25 risk factors. Accordingly, for the Avaluator v2.0 and Beginner's Reduction only, Table 6 shows the prevention values calculated after the missing values were filled in randomly using the distribution of observed values in accidents with the reported data.

Table 6. Prevention Values of Various Tools.

| Tool | Prevention Value |
|---|---|
| Avaluator v1.0 | 14% |
| Avaluator v2.0 | 17% |
| Avaluator v2.0/MVF | 35% |
| Nivo Test | 17% |
| Beginner's Reduction/MVF | 75% |

Note. MVF = Missing values for non-obvious clues filled in (see text).

As expected, the prevention values are uniformly much smaller than those reported by McCammon and Haegeli (2005) based on their non-representative samples. Only Beginner's Reduction with Missing Values Filled in comes close to the prevention value reported by McCammon and Haegeli (2005). Considering the prevalence of danger ratings (Uttl, Uttl, & Henry, 2008) and slope angles in Canada, the Beginner Reduction method would, however, advise users not to ski any avalanche terrain through most of the winter. Moreover, the prevention values do not favor the Avaluator's Obvious Clues method, as claimed by McCammon and Haegeli (2005) based on their non-representative data sets after deletion of accidents with missing values.

Table 7 show the correlations between the danger level determined by the various tools whereas Table 8 shows the correlation between go/no-go recommendations of the tools. As expected, the Avaluator's v1.0 Obvious Clues assessment correlates highly with the Avaluator's v2.0 Slope Evaluation and both correlate fairly highly with the Nivo Test's assessment. In contrast, Munter's Beginner Reduction correlates only weakly with the Avaluator's Obvious Clues, Slope Evaluation, and Nivo Test; it is based on only two of the clues/signs/factors included in the other tools so low correlation is expected.

Table 7. Correlations Among Danger Levels Determined by Various Tools.

| Tool | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| 1. Avaluator v1.0 | | | | | |
| 2. Avaluator v2.0 | .80 | | | | |
| 3. Avaluator v2.0/MVF | .85 | .85 | | | |
| 4. Nivo | .64 | .70 | .63 | | |
| 5. Beginner Reduction/MVF | .28 | .37 | .36 | .42 | |

Note. MVF = Missing values for non-obvious clues filled in (see text).

Moreover, as expected from psychometric theory, the dichotomized go/no-go behavioral recommendations correlate only moderately between the Avaluator's v1.0 Obvious Clues, the Avaluator 's v2.0 Slope Evaluation, and the Nivo Test, and only minimally between Munter's Beginner Reduction and the Avaluator v1.0, v2.0, and Nivo Test (see Table 8).

Table 8. Correlations Among Go/No-Go Travel Recommendations Made by Various Tools.

| Tool | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| 1. Avaluator v1.0 | | | | | |
| 2. Avaluator v2.0 | .48 | | | | |
| 3. Avaluator v2.0/MVF | .51 | .62 | | | |
| 4. Nivo | .35 | .40 | .44 | | |
| 5. Beginner Reduction/MVF | .14 | .22 | .21 | .10 | |

Note. MVF = Missing values for non-obvious clues filled in (see text).

## 4. DISCUSSION

The prevention values of various avalanche accident reduction tools are much lower than the prevention values reported by McCammon and Haegeli (2004, 2005). In calculating the prevention values, McCammon and Haegeli (2004, 2005) inappropriately deleted most of the accidents in their sample which did not provide sufficient information to determine whether various clues/signs/factors were present or absent. They failed to consider how such widespread data deletion may influence their findings and they did not consider what might be the mechanism behind missing values. McCammon and Haegeli's (2004, 2005) conclusion that McCammon's Obvious Clues method was the best and would prevent 77% of accidents was incorrect (Uttl, Henry, & Uttl, 2008; Uttl, Kibreab, Kisinger, & Uttl, 2009; Uttl, Kisinger, Kibreab, & Uttl, 2009; Floyer, 2008; Gauthier, 2010). In fact, the Obvious Clues method, associated prevention values, as well as McCammon himself were recently removed from the new Avaluator v2.0 and replaced by the Slope Evaluation tool with Haegeli appearing as the sole author of the new Avaluator (Haegeli, 2010). Although the Slope Evaluation tool includes the same (somewhat renamed) seven obvious clues as McCammon's Obvious Clues method, it also includes the most important terrain clue – slope angle – in addition to slope shape and persistent weak layer (Uttl, McDouall, & Mitchell, 2012).

Our results also indicate that the correlations between behavioral recommendations provided by the reviewed tools are minimal to moderate. Users of these tools are likely to make different travel decisions depending on which tool they decide to use. Although there is no “gold standard” against which to evaluate these tools, Bolognesi's NivoTest (Bolognesi, 2000, 2007) is the most comprehensive and, from psychometric perspective, the most reliable decision making tool developed to date.

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