6.8 CLINICAL TRIALS FOR A NEW CANADIAN WIND CHILL PROGRAM

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1. INTRODUCTION

A new way to calculate and communicate wind chill was implemented in October 2001 in Canada, following standardization of the wind chill index between Canada and the United States. The Meteorological Service of Canada's (MSC) new wind chill index based on a model of facial heat loss due to the wind and cold. Crucial to the development of this new index were clinical trials, to test and validate this model. Twelve volunteers, including the first author, participated in the trials, held in May and June 2001, at the Defence and Civil Institute of Environmental Medicine (DCIEM)—part of Defence R&D Canada, the research agency of the Canadian Department of National Defence—located in Toronto, Canada.

2. DEVELOPMENT OF MSC'S NEW PROGRAM

In January 1999, a cold wave over southern Ontario made headlines across Canada, but not so much due to the cold. Rather, it was because the frequent mention, in forecasts, of the wind chill factor in W/m^2—the way by which wind chill was expressed in most of Canada at the time (e.g. "Windchill near 1800")—triggered many complaints. This episode made the MSC question its way of reporting and forecasting wind chill.

The following spring MSC commissioned a public opinion study on wind chill, comprised of focus group sessions followed by a national survey. These revealed that the equivalent temperature method was by far Canadians' preferred way to hear information on wind chill. The also revealed a fair amount of confusion with respect to the notion of wind chill with about 4 in 10 survey respondents agreeing with the (wrong) statement that they would feel colder than the actual temperature even when sheltered from the wind.

At the same time, MSC conducted a literature review of the science of wind chill (Maarouf and Mitzos, 2000). This review showed considerable debate among scientists on the value of various wind chill indices and models used to derive them. In response to this, the MSC held an Internet Workshop on Wind Chill in April 2000. Papers presented at this workshop revealed that controversy existed in the scientific community regarding wind chill, and highlighted the need for more research, particularly research involving human subjects.

At the same time, interest to review the wind chill index arose in the USA, and in the fall of 2000, the (US) Office of the Federal Coordinator for Meteorological Service and Supporting Research (OFCM) formed the Joint Action Group on Temperature Indices (JAG/TI), with participation from academia and Canadian and American federal agencies. Session P1.9 of the Interactive Information and Processing System (IIPS) for Meteorology describes in greater detail this process and the features of the new index.

In early 2001 the JAG/TI recommended that a new wind chill index be developed jointly by Maurice Bluestein, of Purdue University, and Randall Osczevski, of DCIEM, based on their recently developed models, using commonly used environmental parameters (wind speed, temperature and solar radiation). The JAG/TI further recommended that the human face be used for evaluating wind chill since it is the body part most often exposed to cold, and that human studies (clinical trials) be conducted at DCIEM to validate the new index.

3. THE CLINICAL TRIALS

The initial model used to develop the wind chill index had been developed by measuring, in different wind and temperature conditions, temperature changes and heat losses from a mannequin head that had a "skin" made of thermoconducting material. The model factored in body and skin temperatures, as well as skin resistance to heat loss.

As per instructions from the JAG/TI, clinical trials to validate this model were held at DCIEM in May and June 2001. The research protocol requested 12 volunteers (six men and six women) between 18 and 50 years old, subject to medical screening and a physical, with no history of frostbite in their faces. In the end, subjects ranged from 22 to 42 years of age. We (subjects) were also asked to refrain from alcohol or pain killers (e.g. aspirin, acetaminophen, etc.) for 24 hours and caffeine for 12 hours prior to each test. Two subjects at a time could take a test.

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The trials consisted, for each subject, of four 90-minute tests at different temperatures and wind speeds inside a refrigerated wind tunnel. In each test we were dressed with clothing appropriate for the weather (e.g. heavy or lighter overcoats, mitts or gloves, etc.), but with our faces exposed. We walked on a treadmill at 4.8 km/h for three 30-minute periods, facing a wind of 2, 5 and 8 m/s, respectively. The tests were conducted at -10°C, 0°C and +10°C. The fourth test was a "wet" test at +10°, during which our faces received a one-second spray of water every 15 seconds; this test was to determine the impact of water of facial cooling.

Although test tests per se lasted 90 minutes, the whole procedure would last about four hours due to preparation, necessary preliminary measurements, and de-instrumentation afterwards. After arriving at the facility, we needed first to change into the military clothes that were standard for that particular test, and to be instrumented. In addition to a rectal probe used to measure core temperature during the tests, each subject needed to have heat flow sensors and/or thermocouples attached to his or her forehead, chin, nose, and cheeks. There was also a device to measure heart rate, and a temperature sensor inside the right cheek that meant that we could only breathe through our noses: breathing through the mouth would have corrupted the data.

Prior to entering the wind tunnel, baseline data were measured for 10 minutes, at normal room temperature, without heavy clothing, while we were explained the procedure and given instructions for the test, particularly to wipe out any liquid that might flow from an eye or the nose (these could influence skin temperature and cause bad data), and to avoid getting warm while walking by opening up our overcoats if necessary. Just before entering the wind tunnel, we were given balaclavas and a hood to wear for two minutes in the tunnel, before the treadmill would start. This was to ensure our faces would stay warm while the first set of measurements in the tunnel were taken.

Data from each sensor was collected continually during the test. In addition, every 15 minutes, we were asked to rate how cold our faces and the rest of our bodies felt (e.g. warm, comfortable, cool but comfortable, cold, etc.), and to rate how the environment felt; we did so by pointing on a sheet since we could not open our mouths. It became quite evident during the test that our bodies did adapt to the cold. Most participants, including this author, reported that although they felt quite cold when the wind speed was increased, that feeling would subside after several minutes. However, significant differences were noted in facial skin temperature and heat loss among subjects. One such difference was that seven of the 12 subjects exhibited a physiological response known as cold-induced vaso dilation. When the surface temperature of their skin fell to a certain level, the blood vessels that were previously constricted to conserve core body heat suddenly opened up and sent, for a short period, warm blood to the exposed skin to keep it from freezing. The process would then repeat when their skin temperature fell again.

Physiological differences made some people feel cold faster than others, even at the same wind-temperature combination. It was demonstrated that people with greater skin insulation (generally people who are heavier) lose core body heat more slowly and are therefore less susceptible to hypothermia. However, this also means that less heat flows through their skin, with the result that their skins cools faster. These same people are therefore more at risk of frostbite.

The wet tests confirmed that wind makes people feel colder by evaporating any water on the skin. Data collected showed the wind chill to be 5 to 10 degrees colder in wet conditions than in dry ones also carried out at +10°C. As a result, the development of a marine wind chill chart is now being contemplated. Such an index would be of use to mariners during heavy spray conditions, for instance.

4. MSC'S WIND CHILL PROGRAM

The Osczevski-Bluestein wind chill model was somewhat modified after the clinical trials to take results into account. Cheeks were found to be generally the coldest area of the face, so they were used to determine the worst-case scenario for frostbite. The model was then calibrated to the 95th percentile of skin resistance, i.e. for the 5% of the population that has a skin resistance greater than 95% of the observed values of the subjects in the trials: these are the 5% most at risk of frostbite as the risk increases with skin resistance. The researchers then developed a non-iterative equation based on their model, as follows (SI units):

$$\mathbf{C = 13.12 + 0.6215T - 11.37V^{0.16} + 0.3965TV^{0.16}}$$

where C is the wind chill index (based on °C but reported as a unitless number), T is the temperature in C and V is the wind speed at 10 meters (standard anemometer height), in km/h, correlated to the speed at 1.5 m via the constants in the equation.

Implemented on October 3, 2001, MSC's new wind chill index is based on the Osczevski-Bluestein model, and, apart from the use of SI units, is the same as that of the USA. In the fall of 2000, the MSC put in place an intensive campaign of public information and education to ensure Canadians' awareness of the new index. As researchers have also given preliminary indications of time to frostbite, to be refined in the future, MSC's information campaign also includes approximate thresholds for risk of frostbite, as per the table below. It has been found that for many people such values add meaning to the numbers and help understanding by putting the numbers in context. In addition, a Web site was developed to improve Canadians' access to wind chill information (http://windchill.ec.gc.ca) and ease their transition to the new index. The program will continue to improve in future years as science continues to improve (e.g. better estimates of time to freeze, inclusion of solar radiation) and feedback on its utility is received from users.

5. REFERENCES

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Table 1: Wind Chill Calculation Chart, where Tair = Air temperature in °C and V_{10} = Observed wind speed at 10m elevation, in km/h.

T air / V_{10}	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
5	4	-2	-7	-13	-19	-24	-30	-36	-41	-47	-53	**-58**
10	3	-3	-9	-15	-21	-27	-33	-39	-45	-51	-57	**-63**
15	2	-4	-11	-17	-23	-29	-35	-41	-48	-54	**-60**	**-66**
20	1	-5	-12	-18	-24	-31	-37	-43	-49	-56	**-62**	**-68**
25	1	-6	-12	-19	-25	-32	-38	-45	-51	-57	**-64**	**-70**
30	0	-7	-13	-20	-26	-33	-39	-46	-52	-59	**-65**	**-72**
35	0	-7	-14	-20	-27	-33	-40	-47	-53	**-60**	**-66**	**-73**
40	-1	-7	-14	-21	-27	-34	-41	-48	-54	**-61**	**-68**	**-74**
45	-1	-8	-15	-21	-28	-35	-42	-48	-55	**-62**	**-69**	**-75**
50	-1	-8	-15	-22	-29	-35	-42	-49	-56	**-63**	**-70**	**-76**
55	-2	-9	-15	-22	-29	-36	-43	-50	-57	**-63**	**-70**	**-77**
60	-2	-9	-16	-23	-30	-37	-43	-50	-57	**-64**	**-71**	**-78**
65	-2	-9	-16	-23	-30	-37	-44	-51	-58	**-65**	**-72**	**-79**
70	-2	-9	-16	-23	-30	-37	-44	-51	-59	**-66**	**-73**	**-80**
75	-3	-10	-17	-24	-31	-38	-45	-52	-59	**-66**	**-73**	**-80**
80	-3	-10	-17	-24	-31	-38	-45	-52	-60	**-67**	**-74**	**-81**

Approximate Thresholds:

Risk of frostbite in prolonged exposure: windchill below	**-25**	
Frostbite possible in 10 minutes at	**-35**	Warm skin, suddenly exposed. Shorter time if skin is cool at the start.
Frostbite possible in less than 2 minutes at	**-60**	Warm skin, suddenly exposed. Shorter time if skin is cool at the start.