PREDICTING SURVIVAL TIME DURING AIR EXPOSURE AND WATER IMMERSION

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INTRODUCTION

Estimates of survival time are required to optimize planning and execution of search and rescue operations and to improve the likelihood of a successful outcome. For accidental immersion, survival times are often represented in tables or curves as a function of water temperature, e.g. Molnar survival curve (2). Such one-dimensional representations can be misleading as tables and plots are often over simplified. Using tables to estimate survival time in different situations often requires interpolation between discrete values to fit a given set of conditions. Curves provide a continuous analog representation of survival information, but require a graphic interpretation. A better alternative is to use a mathematical model of human thermoregulation. Mathematical models allow input of more specific information relative to a given incident and thus predict survival times that more accurately reflect the physiological state of victims. The purpose of this research effort was to develop a Probability of Survival Decision Aid (PSDA) that predicts survival time for hypothermia and dehydration during prolonged exposure to a wide range of air and water conditions at sea.

METHOD

Many factors combine to determine the survival time of victims in the water or on the water surface. The present modeling effort focuses on the contributions of hypothermia and dehydration to survival. Other risk factors, e.g., cold shock, swim failure, injury, and starvation, cannot be ascertained without in-situ observers or reports and may be unique to a specific event, and are thus beyond the scope of the present modeling effort.

PSDA consists of (a) a Six Cylinder Thermoregulatory Model (SCTM), (b) an empirical water loss equation developed from physiological data, and (c) a windows desktop application that that manages inputs, runs the model, and displays the outputs (5). SCTM combines first principles of the biophysics of heat exchange with a realistic approximation of human physiology, and is applicable to exposure to both air and water immersion under warm and cold conditions. The empirical water loss model is based on the measured water loss of test volunteers in rafts (1) and serves as a secondary or supplemental prediction of water loss.

A critical concern in developing a modeling application is the translation of a mathematical formulation into a useful tool. The design of the desktop application is thus a critical element in the development of a search and rescue application. Our desktop application allows users to easily access the PSDA model by selecting or entering inputs for ten basic parameters. These ten parameters are: air temperature, water temperature, relative humidity, wind speed, gender, height, weight, percent body fat, immersion state, and clothing type. Real time unit conversions are also available for all parameters. When anthropometric factors are unknown, pull down menus allow users to select different descriptive categories such as medium, tall, light and lean etc. Based on this information, the SCTM calculates the size and layer thickness of each cylinder (6). As the desktop application runs SCTM and the empirical dehydration model, it is then updated to display predictions for the cold functional time (i.e., when core temperature reaches 34°C), cold survival time (i.e., when the core temperature reaches 30°C), dehydration survival time (i.e., when water loss reaches 20% of body weight), and the empirical dehydration survival time.

RESULT AND DISCUSSION

PSDA was validated using historical survival data, reported cases for accidental water immersions, and limited data for channel swimmers (2-4). For ten immersion victims whose height and weight are known, the predicted survival time for each victim was either very close to or greater than the observed survival time. PSDA predicts survival times out to 120 hours. An experienced diver wore a wetsuit and survived 75 hours of immersion in 16°C water; PSDA predicted his cold functional time of 72.3 hours and cold survival time of 81.3 hours.

To account for human variability, anthropomorphic data from US Army was used to generate sample populations of 100 individuals. PSDA was run with these 100 sets of inputs. In

0°C water, survival times ranged from 1.2 to 3.8 hours, which appeared to be consistent with events during the Titanic shipwreck, as there were virtually no survivors after ~2 hours. Survival times ranged from 1.7 to 12.4 hr in 5°C water, from 2.1 to 19.0 hr in10°C water, and from 2.6 to 33 hr in 15°C water. This demonstrates an advantage of PSDA over commonly used tables or curves that do not provide information based on individual differences.

The predictive capability of PSDA is limited, however, by the supporting data. To expand the applications of PSDA, more detailed physiological data from case histories and controlled studies are needed.

CONCLUSION

PSDA calculates the survival time of a victim in the water or floating in an emergency craft with reasonable accuracy and can be used for mission planning and organization. The desktop application provides access to the model, enabling search and rescue personnel to determine estimates of survival time which assists the search and rescue planning process.

DISCLAIMER

Approved for public release; distribution is unlimited. The opinions or assertions contained herein are the private views of the author(s) and are not to be construed as official or reflecting the views of the Army or the Department of Defense.

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