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A 3D Thermal Model to Analyze the Temperature Changes of Digits during Cold Stress and Predict the Danger of Frostbite in Human Fingers

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Abstract

The existed computational models of frostbite injury are limited to one and two dimensional schemes. In this study, a coupled thermo-fluid model is applied to simulate a finger exposed to cold weather. The spatial variability of finger-tip temperature is compared to experimental ones to validate the model. Semi-realistic 3D model for tissue and blood vessels is used to analyze the transient heat transfer through the finger. The effect of heat conduction, metabolic heat generation, heat transport by blood perfusion, heat exchange between tissues and large vessels are considered in energy balance equations. The current model was then tested in different temperatures and air speeds to predict the danger of frostbite in humans for different gloves. Two prevalent gloves which are commonly used in cold climate are considered for investigation. The endurance time and the fraction of necrotic tissues are two main factors suggested for obtaining the response of digit tissues to different environmental conditions.

Keywords: Frostbite, Finger, Thermo-fluid model, Endurance time, Cold injury, Necrotic tissue

1. Introduction

Freezing cold injury or frostbite, defined as the tissue damage and necrosis primarily in the extremities that occurs from acute cold exposure, is a major health issue in a large