

A PORCINE FORELEG FINITE ELEMENT MODEL FOR SURFACE WAVE CHARACTERIZATION

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ABSTRACT

Injuries from BB shots are responsible for thousands of injuries each year, with many resulting in contusions or superficial embedments to the extremities. To help better understand the injury biomechanics of BB shots, a porcine foreleg finite element model was selected for comparison with some documented porcine ballistic experiments. The model was created by segmenting a porcine leg computerized tomography (CT) scan into the major bones, skin, and soft tissues, and then generating a mesh from the resulting geometries. A previously published hyperelastic material model was incorporated to represent the skin's non-linear mechanical behavior. The pig leg model was used to simulate the skin response to 87.1 and 114.6 m/s stainless steel BB shots. The simulation matched the non-penetrative behavior from the experiments, predicting peak dynamic deformations of 12.6 and 25.4 mm respectively. MatLab was used to collect the movement of surface nodes and reconstruct continuous surfaces every 0.5 ms. The position and speed of the impact-induced wave was non-linear and did not depend on the BB initial velocity. Future work is needed to compare the simulation results against experimental digital image correlation (DIC) data, increase the time and spatial resolution of simulated sampling surface, and eventually include dynamic material data to account for skin damage with increasing BB initial velocity.

Keywords: finite element, porcine, ballistics, digital image correlation (DIC), biomechanics, impact

INTRODUCTION

BB-related injuries account for about 6,000 emergency room admissions each year [1]. These injuries skew heavily toward young males (6-18 years old) and 51.3% of injuries are to the upper or lower extremities. Due to the low mass and inertia, the most common outcomes of BB shots are bruising (10.4%) and superficial embedment (50.6%). While these types of injuries are predominantly minor in severity (93.2% do not require hospital admission), it is still desirable to reduce the frequency at which they occur. A better understanding of the biomechanical interactions between the skin and BB can help to further reduce these injuries. This study focuses on the development of a finite element (FE) model that can evaluate the skin biomechanical response on the extremities to BB shots.

FE modeling of the skin can be challenging because the skin is not a uniform material, but rather a complex, irregular layered structure containing hair follicles, nerves, and blood vessels [2]. The layers from the inside out are the hypodermis, dermis, and epidermis. These layers contain significant quantities of collagen and elastin fibers, and interior layers also contain blood vessels, all of which impart both non-linear and anisotropic behavior to the tissue. The fiber elastic modulus is a major component of the skin's mechanical strength, and their transition from a loose and crimped state at rest to straight and extended state under strain drives a significant part of the non-linear skin response [3].

The skin as a biomaterial has received increasing interest, so much so that the data have been collected into review articles [2][3]. Multiple mathematical material models, many of which are compatible with the FE method, have been developed to capture the complex behavior of the skin.