Validation of a MADYMO Hybrid III Lower Limb Model Using MLLI Experimental Data

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I. INTRODUCTION

Anti-vehicular (AV) blast landmines and improvised explosive devices (IEDs) remain a major threat to military ground vehicles and their occupants. When an armoured vehicle is subjected to an underbody blast event, the resulting high-rate loading is transmitted to the occupant primarily through the vehicle floor and seat, creating a serious risk of lower extremity and axial skeletal injury [1].

Experimental testing provides important insight into these loading mechanisms, but it is often costly, complex, and limited in the range of conditions that can be investigated. Numerical simulation offers a complementary approach by enabling controlled analysis of impact conditions and occupant response. In this study, the purpose was to compare the MAthematical DYnamic MOdels (MADYMO) simulation results with experimental measurements obtained from Modified Lower Leg Impactor (MLLI) tests. The study aimed to evaluate how well the MADYMO model could reproduce the lower and upper tibia axial force responses observed experimentally, thereby assessing its suitability for representing lower limb loading under blast-related impact conditions.

II. METHODS

MADYMO is a computational multibody dynamics platform developed by TNO Automotive Safety Solutions and widely used in vehicle safety, biomechanics, and defence research [2,3]. In this study, a Hybrid III 50th percentile dummy model was modified by removing the boot so that the lower tibia response under MLLI loading could be investigated. Because the exposed feet were represented as rigid multibody components without finite elements, new master–slave contacts were defined between the impactor and the right foot. The simulation used the measured MLLI displacement as input after establishing an equilibrium posture. The MADYMO simulation setup for the Hybrid III ATD without a boot is shown fig 1a

The MLLI was used to conduct a series of tests on the anthropomorphic test devices (ATD) instrumented HII leg (Fig.1b). The impact conditions, targeted an impacting plate velocity of 3.4 m/s. This is the highest test condition that the HIII leg lower tibia loadcell can withstand before clipping, without a boot.

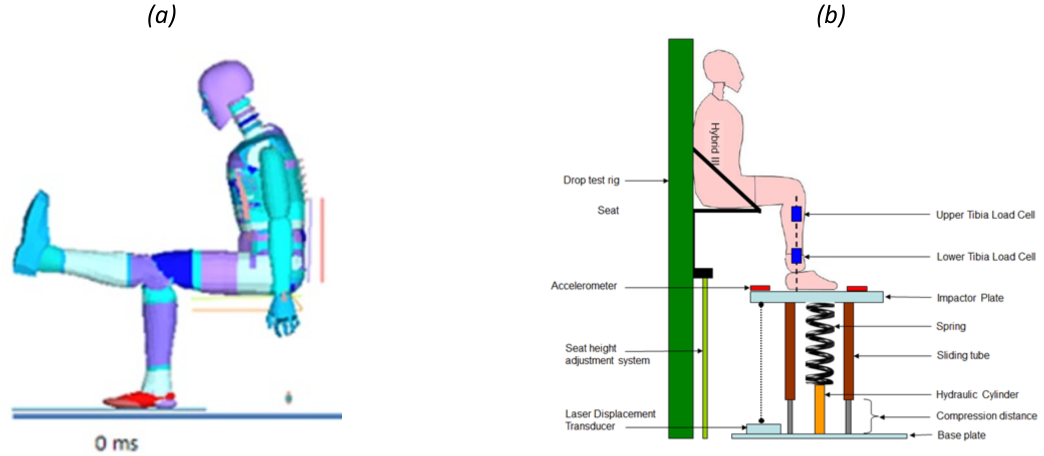

Fig1: (a) MADYMO simulation setup and (b) Experimenta setup [4]

III. INITIAL FINDINGS

Figure 2(a) and (b) present the comparison between the simulation and experimental results for the lower and upper tibia force responses. The lower and upper tibia force–time histories exhibited a parabolic trend. The

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simulation peak lower tibia force and peak upper tibia force were 10.2 kN and 6.6 kN, respectively. Across the experimental tests, the mean ± standard deviation of the peak lower and upper tibia forces were 9.4 ± 0.54kN and 6.5 ± 0.73 kN, respectively.

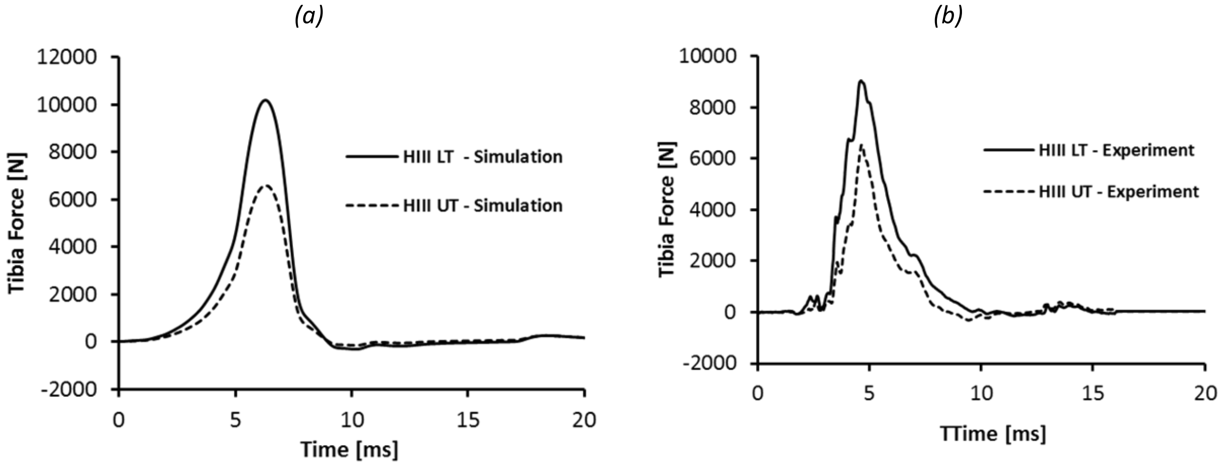

Fig 2 Lower and Upper Tibia Axial Force Recorded During (a) MADYMO Simulation with HIII Leg and (b) MLLI tests

Fig 3 shows a bar chart comparison of the experimental results with the simulation results. The simulation peak lower tibia force of 10.2 kN was 8.5% higher than the experimental mean of 9.4 kN. Similarly, the siumaltion peak upper tibia force of 6.6 kN was 1.5% higher than the experimental mean of 6.5 kN. These small percentage differences indicate good agreement between the simulation and experimental results.

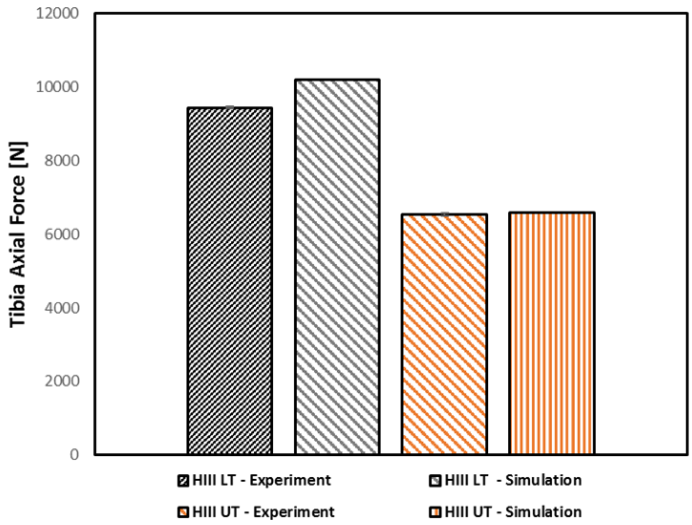

Fig3: Comparison of MADYMO Simulations and MLLI Experiment

IV. DISCUSSION

The experimental results compare very well with the simulation results, with both showing similar trends in the force–time response and close agreement in the peak lower and upper tibia forces. This good correlation indicates that the MADYMO model was able to reproduce the essential loading behaviour observed during the physical tests. The agreement between the numerical and experimental results demonstrates that MADYMO has strong capability in predicting the dynamic response of the Hybrid III (HIII) leg under the tested impact conditions. It therefore provides confidence in the use of the model as a reliable tool for investigating lower limb loading and for supporting further studies where experimental testing alone may be limited or costly.

V. REFERENCES

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