Development of a Hybrid-III to Human Leg Transfer Function for Axial Loading

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Introduction

- Injury criteria exist for the human lower leg under axial loading, however ATDs are often tested
- Previous work has shown the stiffness of the Hybrid-III leg inaccurately approximates the forces predicted for higher rates of loading
- Few matched pair studies exist for the Hybrid-III and human lower leg under axial loading, so understanding the relative responses is important

Goal

- To use FE models to generate data for UBB loading rates in order to develop a transfer function for estimating force in the human lower leg from Hybrid-III leg forces, and then relate back to injury criteria for the human leg

Methods

- Validated Hybrid-III and human leg finite element (FE) models using PMHS and Hybrid-III experimental tests performed using a drop tower setup
- Parametric study of 15 loading conditions was performed using the FE models in LS Dyna (Livermore Software Technology Corporation, Livermore, CA)
- Isochronous Hybrid-III tibia force curves were generated from FE results and fitted using a polynomial equation
- Characteristic curves were created using methods by Lessley et al.
- Used Excel GRG nonlinear solver to determine a best fit for the characteristic curve
- Similar method was used to generate time-curves for a common force to compensate for rate differences between the human and Hybrid-III leg

Results

- FE models replicated experimental results
- Isochronous force-force curves generated a characteristic average curve that could be represented by a polynomial
- A time-force curve was used to account for rate differences

- Timing differences existed between the Hybrid-III and human force curves for a common input condition

Mathematical Formulation

Force Transfer Function

\[ F_{\text{Hybrid-III}} = A F_{\text{human}} + B F_{\text{human}} \]

Force Transfer Function Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>A</td>
<td>3.251</td>
</tr>
<tr>
<td>B</td>
<td>0.17676</td>
</tr>
</tbody>
</table>

Discussion

- Matched-pair Hybrid-III and PMHS whole body tests were used to validate the transfer function and showed good agreement at lower rates (Bir et al. 2008)

- Transfer function was used to determine injury risk using existing injury risk function (Henderson et al., 2013)

Conclusions

- Transfer function provided a good fit of FE results (R²>0.99)
- Valid for 4-20 kN lower tibia forces in the Hybrid-III
- Needs improvement to predict for a larger range of loading rates (verified for 200-600g with times to peak of 3-5 ms)
- A more sophisticated frequency-dependent transfer function approach is necessary to capture rate dependent effects

Future Research

1. Change approach to include a frequency-based transfer function
2. Validate for larger range of loading conditions
3. Further improve FE model for Hybrid-III lower leg

Limitations

1. Limited by validity of the FE models
2. Only valid for the loading rates tested

References


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