Criteria for Head Injury and Helmet Standards

Jim Newman
NBEC Inc.

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On the Use of the Head Injury Criterion (HIC) in Protective Headgear Evaluation

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PROCEEDINGS OF
NINETEENTH STAPP CAR CRASH CONFERENCE

November 17-19, 1975
San Diego, California
Head Injury Assessment Functions.

A head injury assessment function (HIAF) is a functional relationship between the probability/severity of brain injury and some measurable response of the head to impact.
Premises

- Head injury caused by head impact.
- Head impact causes head motion.
- Head motion characterized by rigid body kinematics.
- Kinematics usually expressed as linear acceleration.
- Most head injury assessment functions are based upon acceleration.
Exceptions

- High speed (ballistic) impact
- Low speed (crushing) loading
- Brain injury secondary to impact (e.g. swelling).
- Facial impact.
- Localized skull deformation.
Linear Kinematic Head Injury Assessment Functions

- **Maximum translational acceleration.**
- **Average acceleration plus time duration.**
- **Gadd Severity Index - GSI.**
- **Versace “Correction”.**
- **“Head Injury Criterion” - HIC.**
Helmet Impact Test Setup
Headform Acceleration Response
Maximum translational acceleration.

\[ a_m < N \]

where \( a_m \) is the maximum value of the resultant head (c of g) linear accl’n.

Snell standards
Linear Kinematic Head Injury Assessment Functions

- Maximum translational acceleration.
- Average acceleration plus time duration.
Wayne State Concussion Tolerance Curve

Relationship of Front Flat Plate Fracture Acceleration Results to WSU Cerebral Concussion Tolerance Curve

<table>
<thead>
<tr>
<th>TEST NO</th>
<th>SEV. INDEX</th>
<th>EDI-IN</th>
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<tr>
<td></td>
<td>$A_{CG}$</td>
<td>$A_{A-P}$</td>
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<tr>
<td>30</td>
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</table>
Average acceleration and time duration.

\[
\bar{a}^{2.5} T < 1,000
\]

Never ever used to assess head impact severity or head protection systems.
Linear Kinematic Head Injury Assessment Functions

- Maximum translational acceleration.
- Average acceleration plus time duration.
- Gadd Severity Index.
Gadd Severity Index (1966).

\[
\frac{a^{2.5}}{T} < 1,000
\]

\[
\int_T^T a^{2.5} \, dt < 1,000
\]

NOCSAE football helmet standard.
Linear Kinematic Head Injury Assessment Functions

- Maximum Translational Acceleration.
- Average acceleration plus time duration.
- Gadd Severity Index - GSI.
- Versace “Correction”.

Versace “Correction”. (1971)

\[ \sqrt[2.5]{\alpha^2} T < 1,000 \]

\[ \left[ \frac{1}{T} \int_{T} a(t) dt \right]^{2.5} T < 1,000 \]

If he’d only left it alone…………
Linear Kinematic Head Injury Assessment Functions

- Maximum translational acceleration.
- Maximum acceleration plus dwell times.
- Gadd Severity Index – GSI.
- Versace Correction.
- “Head Injury Criterion” - HIC.
“Head Injury Criterion” - HIC.

\[ \left[ \frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a(t) dt \right]^{2.5} (t_2 - t_1) < 1,000 \]

FMVSS 208 - occupant protection
What’s wrong with HIC?

1. Introduced by NHTSA without peer review.
2. Assigns attributes to $a(t)$ based on $a_{ave}$
3. Provides “unsafe pulse” within a “safe” pulse.
4. Has nonsensical units.
5. Takes no consideration of
   1. Injury type.
   2. Rotation.
   3. Direction.
What’s right with HIC?

1. It contains $a_{\text{max}}$.
2. It correlates better than $a_{\text{max}}$ because it introduces part of the “time duration” factor.
3. Risk curves have been developed.
HIC Brain Injury Risk Curve (Mertz)

\[ \mu = 1434, \sigma = 430 \]
Linear Headform Response
Rotational Headform Response

![Rotational Headform Response Graph](image)

- Rotational Acceleration (rad/s/s)
- Time (s)
- X, Y, Z components