Criteria for Head Injury and Helmet Standards

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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

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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

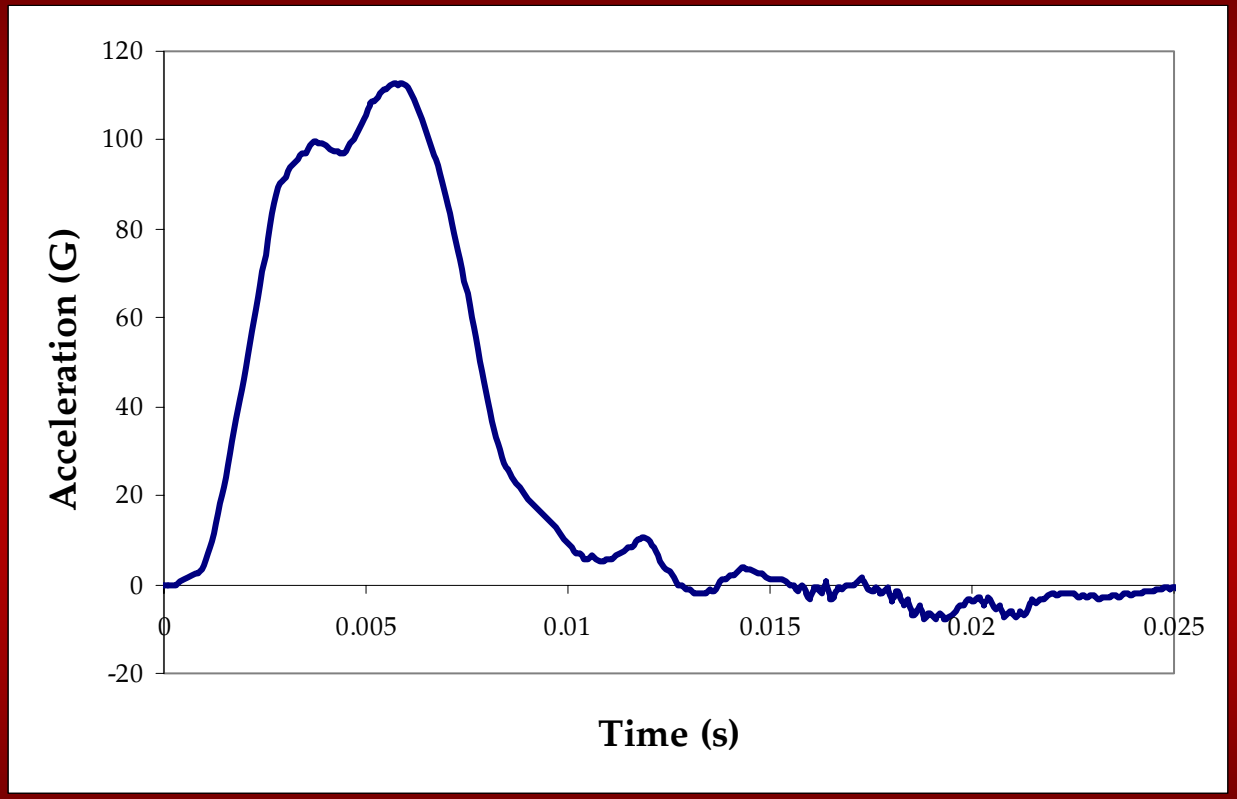
- High speed (ballistic) impact
- Low speed (crushing) loading
- Brain injury secondary to impact (e.g. swelling).
- Facial impact.
- Localized skull deformation.

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.

$$a_m < N$$

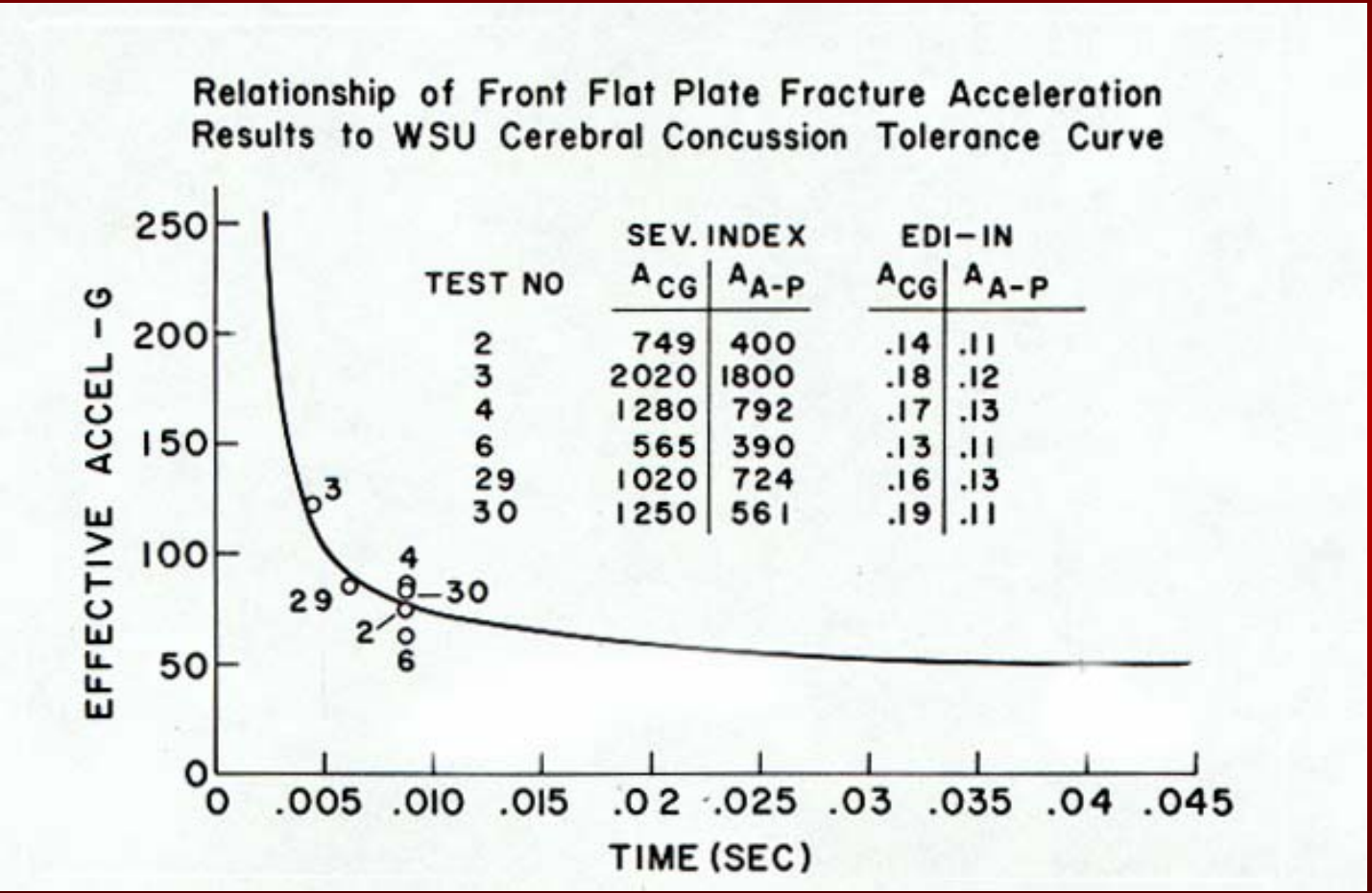
where a_m is the maximum value of the **resultant** head (c of g) linear accl'n.

- Snell standards

Linear Kinematic Head Injury Assessment Functions

- Maximum translational acceleration.
- **Average acceleration plus time duration**.

Wayne State Concussion Tolerance Curve



TEST NO	SEV. INDEX A_{CG}	SEV. INDEX A_{A-P}	EDI-IN A_{CG}	EDI-IN A_{A-P}
2	749	400	.14	.11
3	2020	1800	.18	.12
4	1280	792	.17	.13
6	565	390	.13	.11
29	1020	724	.16	.13
30	1250	561	.19	.11

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).

$$\overline{a}^{2.5} T < 1{,}000$$

$$\int_T a^{2.5} dt < 1{,}000$$

- 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)

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

$$[1/T \int_{T} a(t)dt]^{2.5} T < 1{,}000$$

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.

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

FMVSS 208 - occupant protection

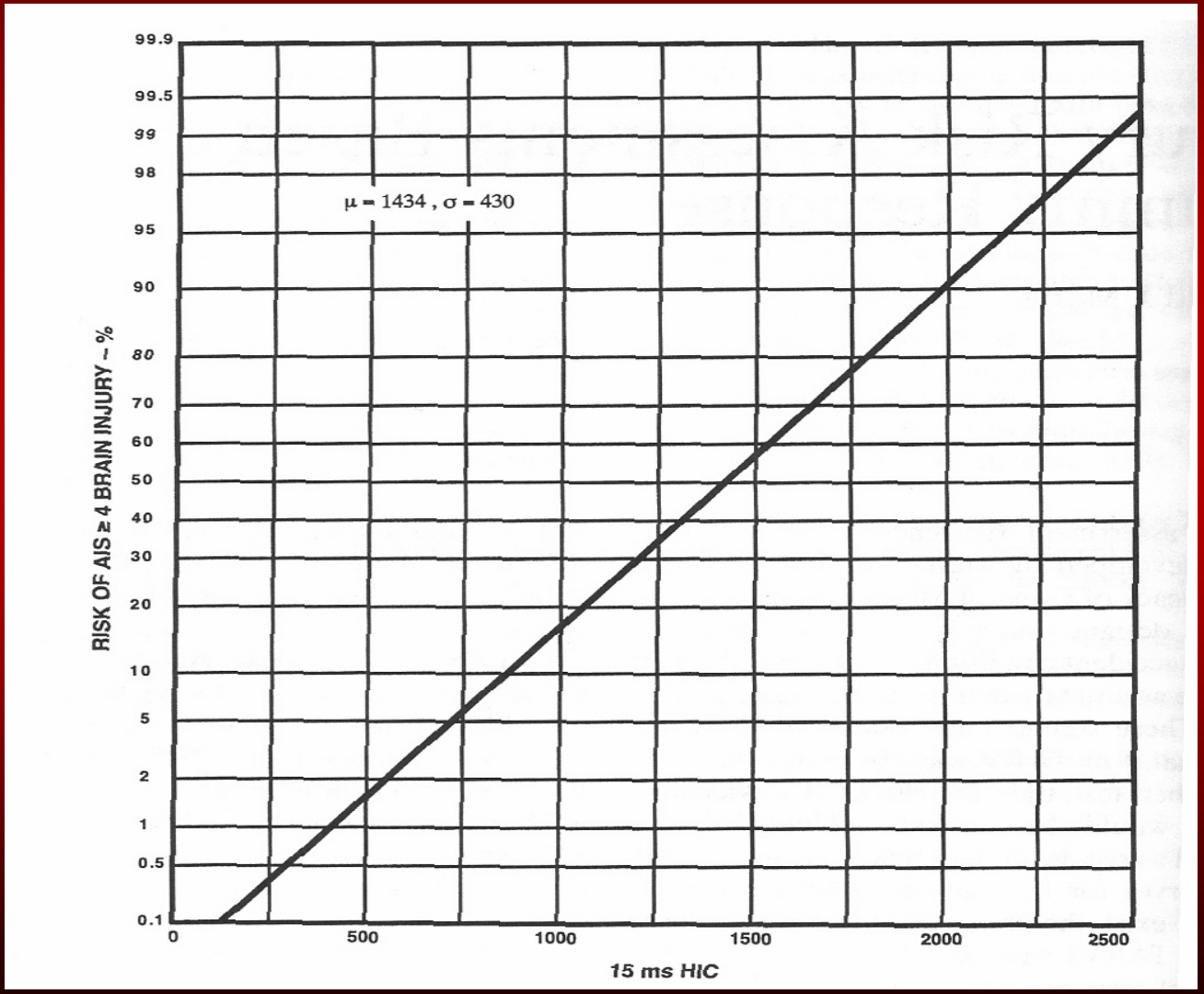
What's wrong with HIC?

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.*
    4. *Mass.*

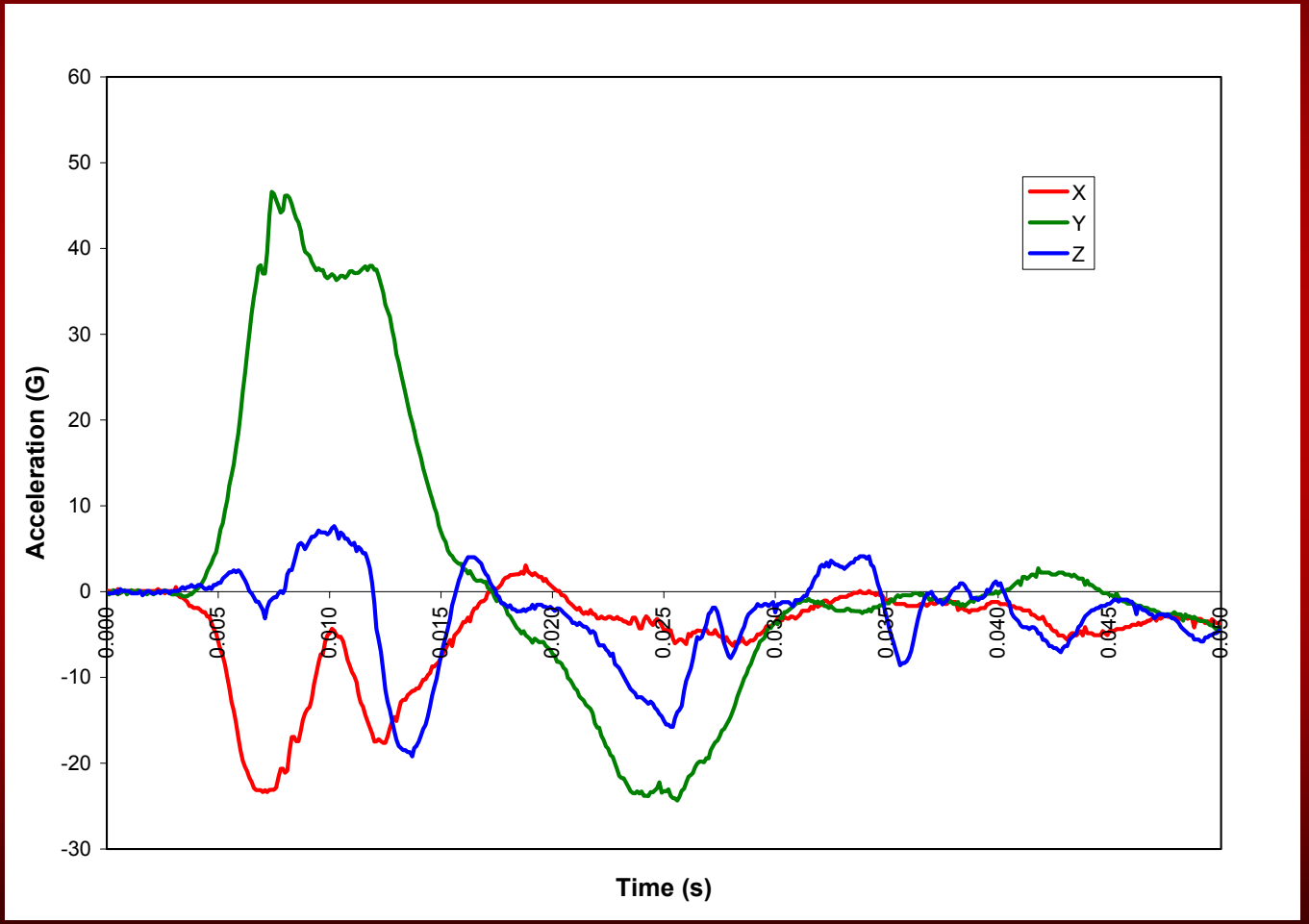
What's right with HIC?

1. It contains a_{max}.
2. It correlates better than a_{max} because it introduces part of the "time duration" factor.
3. Risk curves have been developed.

HIC Brain Injury Risk Curve (Mertz)



Linear Headform Response



Rotational Headform Response