What causes injuries?
What exposure is relevant to measure?

Johan Ullman M.D.

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Minimising
Exposure and Injury risks
when using
High Speed Boats

Johan Ullman M.D.

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Working with the users
on
constant development

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Vetenskap och beprövad erfarenhet

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Vetenskap och beprövad erfarenhet

=

Science and Proven Experience

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Science and Proven Experience

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What is the

Science and Proven Experience

in injury risk reduction on

High Speed Boats?

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What is established by Evidence Based Science

- Repeated impact exposure causes physical fatigue
- Standing up can amplify human impact levels > 3 times
- Bottoming out can amplify human impact levels > 3 times
- The spine is stronger when S-shaped than C-shaped
- Structural failure in the body normally causes pain
- Lateral impacts are more dangerous than pure vertical
- Neck is more vulnerable – Symptoms come late

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What is the established
Proven Experience

- Slamming induced impacts cause severe injuries
- Harder slamming increases injury risks
- Lateral/Oblique impacts are more dangerous
- People can get ejected by lateral slamming
- Slouching postures cause more pain
- Users normally never adjust boat seats

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02:17:14
232.7 DT
3237N2218
DIS10.13.2
044.6 KN
11714W6696

In Slow motion
Look at the head jolt

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02:17:36
271.1 DT
946.6 KN
3237N13466 11714W8786


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What is the primary object ?

- for the employers?

1. Keeping personnel unharmed and fit
2. Complying with the EU directive

- for the operators?

1. Mission Success
2. Reduce Fatigue
3. Extend the mission span
4. Avoid injuries

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What is the difference in actions needed to

Comply with the old directive?

vs to

Prevent injuries?

NONE

There is no difference

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Which actions are needed for
Preventing injuries
vs needed for
"Complying" with the EU-directive?

It is **NOT** possible to comply!

It is **NOT** possible to meet the exposure limits at sea.

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What is needed to
"Comply" by Preventing injuries ?

Duty of Care: Prevent injuries
Legal Obligation: Best Practice
=>
Apply the Best Available Solution
based on Evidence Based Science
& Proven Experience

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What level of impact exposure measured in lab test is acceptable by the EU directive?

NONE

The directive states levels for human occupational exposure - not for lab values

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Will injuries occur in the future?

Can YOU guarantee
that Human impact exposure at Sea
will not exceed the limits
in the EU directive?

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Will injuries occur in the future?

Is your Duty of Care based on Evidence Based Science and Proven Experience?

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WHY DOES
The EU directive states levels for human occupational exposure?

To reduce the risks of occupational injuries

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Where is the Scientific support
for the connection
Exposure levels - Risk of acute Injury?

There is NO Evidence Based Science
supporting any of the exposure
levels stated in the EU directive.

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Can the exposure limits in the EU-directive be used to determine what suspension seat is most effective to prevent injury?

The units in the EU directive are not related to impact exposure

No scientific evidence supports any relation to injury risks.

The limits are set in non-proven units, which will change again.

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Purpose of drop testing suspension seats

Compare performance of mechanisms in pure vertical impacts

NOT to compare the protective performance of seats with live humans

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What relevant data can not be acquired in lab drop testing

REAL EXPOSURE		**LAB TEST**
Multidirectional	-	Unidirectional
Stochastic impacts	-	Standard impacts
Human response	-	Passive loads

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Drop testing vs. Real exposure

REAL IMPACT EXPOSURE

- Is stochastic
- Come from multiple directions
- Differ in amplitudes
- Differ in rise times
- Differ in durations
- Differ in periodicity

Drop testing vs. Real exposure

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Drop testing vs. Real exposure

REAL IMPACT EXPOSURE

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Limitations of drop testing suspension mechanisms

Seats built to synergise with the human body's muscular reflex response - can not be tested in laboratory drop tests

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Limitations of drop testing suspension mechanisms

Impacts, anywhere near
the relevant risk levels,
would be even more dangerous
in the lab - with human subjects

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Limitations of drop testing suspension mechanisms

Lateral impacts

Oblique Impacts

Multidirectional

- Can not be tested

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Lateral impacts are more dangerous

They are harder slamming on the side of the hull

The spine is weaker to lateral forces (shear forces)

They cause ejections

Most seats have no lateral mitigation

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Who is responsible?

The coxswain?

Only if he has disobeyed direct orders

The platoon commander ?

Only if he has given orders directly causing an accident or injury

The seat manufacturer ?

Only if he has stated untruthful claims about protective capacity

The boat builder ?

Only if he has lied about protective capacity or withheld information regarding risks

The employer ?

YES – even when having been ”in good faith”

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Claims based on faked science?

“Our seats make you comply with the EU directive.”

“Our seats will reduce 49g impacts at sea to 11g.”

“Our seats reduce risks of injury.”

“Our seats increase physical performance by 30%.”

“Our seats will always protect the user from harmful exposure.”

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FAKED scientific evidence

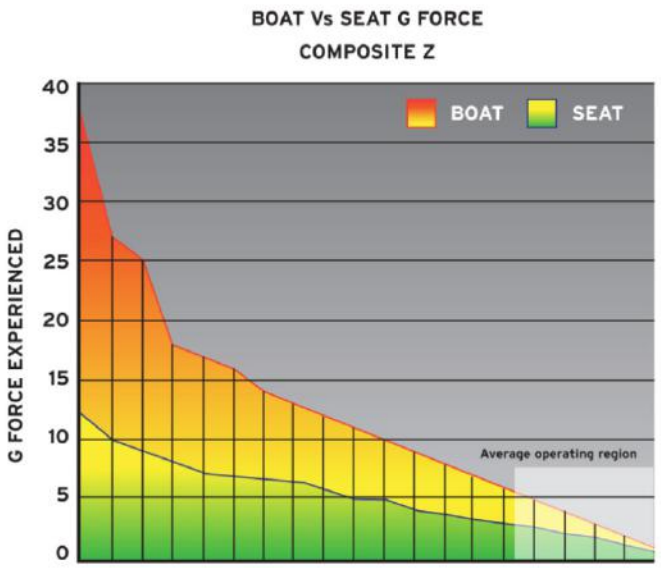
Typical Test session parameters

		Boat	Seat
Sea state: **1 – 6**	Max G	**49G**	**11.5G**
Speed: **0 - 50Knts**	Min G	**1.25G**	**0.45G**
Test time: **7 hours**	Averg	**2.09G**	**1.1G**
Wave events: **45,064**			

Detailed data available upon request

49g is **lethal** – Would require a plane crash - on land.
45 000 wave events in 7 hrs = (25 000 sec) is **impossible!**
Going **full speed** upwind give max ≈ 1 wave slam/sec.
(Speeds below 15 kts do not give impacts)

Graphs & charts showing results from testing carried out



FAKED scientific evidence

This graph shows only that the results are faked.
Reducing 49 or even 38 g to 11 g is Impossible!
This testing can never have been “carried out”.
It has never been published.

Professional Boat Builder

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MEASURING IMPACT EXPOSURE

Practical Impact-Exposure Testing

Taking measures required under the European Union's 2002 Vibration Directive, Boomeranger Boats, a builder of specialized high-speed RIBs in Finland, tests two models of shock-mitigating seats to determine which will best reduce whole-body impacts on boat operators.

Text by Jussi Mannerberg
Photographs and illustrations courtesy Boomeranger Boats

Above—Built in Finland, the 31.2' (9.5m), 6,614-lb (3,000-kg) Boomeranger Special Ops C-3500 open RIB, powered by twin 300-hp Mercury Verado outboards, is designed for high-speed commercial or government service. As such, the boat is subject to the European Union's directive limiting worker exposure to impacts and vibrations. It requires adoption of the best available shock-mitigating technology to protect crews working in extreme marine environments.

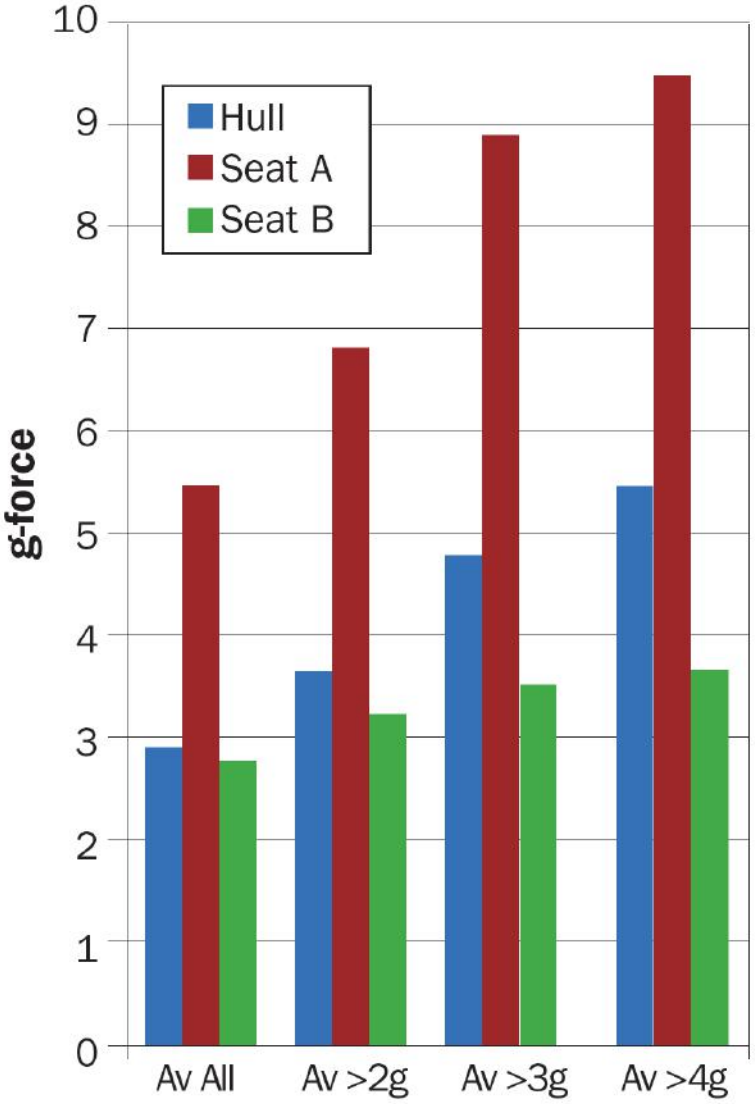
Editor's Note: *Professional BoatBuilder has devoted significant editorial space in recent issues to exploring the efforts of naval architects and engineers to model and understand the slamming and impact accelerations that fast planing boats and their crews are exposed to. "Analyzing Accelerations" Parts 1 and 2 appeared in PBB Nos. 140 and 141, respectively. Those articles detailed what we know about the specifics of seakeeping in high-speed craft, what we should be able to model during the design phase, and what tests and data would help designers better predict vertical accelerations over a range of speeds and sea states.*

The following article is a practical account of how a designer and builder of high-speed professional-grade RIBs addresses vertical accelerations in its existing models. Its author, boatbuilder Jussi Mannerberg, tells how the company he manages, Boomeranger Boats (Loviisa, Finland), measures slamming loads on hulls and assesses impact exposure of professional boat crews to meet the requirements of the European Union's Vibration Directive. This article is based on a similar paper Mannerberg presented at the 2012 High Speed Boat Operations Forum in Göteborg, Sweden.

—Aaron Porter

Boomeranger Boats Oy has built professional high-speed rigid inflatable boats (RIBs) since 1991. In the last two years, we've seen an increasing number of potential buyers inquiring whether the boats comply

Figure 4. Mean Peak Values for Impacts Above 2g, 3g, and 4g



What claims are fake
- By Proven Experience?

“Our seats are equivalent to those in your spec ”

“Our seats are adjustable for height and weight”

“Our seats have lateral suspension”

“The negative g-forces are the most dangerous”

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Jules Morgan racing in V24

FAKED
Proven
Experience

This boat has no space for any suspension at all
- the seats sit on the deck.


True confidence
Is when you know
the cheapest bidder
supplied the gear
and
Still trust it with your life
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Duty of Care

Duty of Care for personnel, subject to high risks of injury, includes:
Collecting data about each injury and
accident and the circumstances

Analysing such data to find common factors.
Trying to understand which factors can have caused injuries.

Trying to find ways to eliminate risk factors
by applying alternative means and measures

In aviation every accident is followed up
with an investigation and a report.

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Scientific evaluation of suspension seats

Only controlled studies qualify as scientific.
Controlled means: Comparison against a relevant control item, with known properties.

Exposure and test conditions must be relevant

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How can test and evaluation of suspension seats be scientific?

Performance test must be done side-by-side
- at sea - in real or realistic conditions,
- with sufficient amount of exposure,
- In sufficient sea conditions*

= *(high enough to not allow full speed)

Measuring needs to be done side-by-side
- so the that same impacts and the same vibrations
- can be recorded simultaneously
- on test item and reference/control item
- with the same timestamp

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How can test and evaluation of suspension seats be scientific ?

Testing two unknown entities side-by-side,
can only show their relative performance,
- not if they are good or bad.

Side-by-side testing must be done against
a reference with known properties

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What is relevant to measure

Vibration is known to

- cause fatigue over time and
- speed up aging of cartilage in hips on tractor drivers, sitting twisted to see how they are ploughing.
- temporarily reduce fluid content in intervertebral discs, making the spine more rigid

Vibration should also be measured

- but

Vibration Does NOT cause Acute Injury

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What is the problem with the different standards?

They are all based on vibrations

- instead of on impacts.

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What is vibration?
and
What is impact?

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This is vibration

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This is Impact

We can not estimate the effects of this impact by analysing mean values of the continuous vibration.

We can not predict the effects of the impacts by analysing mean values of the continuous vibration.

What Causes Injuries?

Acute injury = structural
failure in anatomic structures

Is caused buy impacts

Not by

mean values of vibration

This is regardless of which algorithms are used to boil down
a number of impacts, of varying amplitude and character,
and hours of vibration, to a single figure.

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What is relevant to measure

The only parameter proven to be related to risk of acute injury is Impact Exposure.

Impacts data should be collected, reported, analysed and compared by numbers of impacts and peak values .

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Basis for scientific analysis

There is no way in which the injury risks caused by an impact can be predicted by analysing the mean values of the preceding vibrations.

There is no way in which the exposure to impacts during a day can be relevantly expressed in a single figure

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Basis for scientific analysis

NO scientific evidence exists that can justify or even support any of the methods created to express

Impact Exposure

as

Mean values of Vibration

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Basis for scientific analysis

Higher impact levels (g-levels)

⇒ Higher compression forces

- or bending forces

- or tearing forces

- or shear forces

When any of these forces exceed the structural strength - structural failure occurs.

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What is relevant to measure

Impact exposure must be measured
- by measuring impacts

Measured impacts must be shown, reported and compared as impacts

Measured impacts must be reported in numbers and amplitudes

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What is relevant to measure

A scientific study, sponsored by the UK MoD, doing exactly this,
proved that very extreme differences in impact exposure DO NOT SHOW when the data are processed through the suggested algorithms.

Ref

The effectiveness of shock mitigating technology in reducing motion induced fatigue in small high speed craft.; Myers, S. et al

HSC Motion Analysis -ICI, Impact Count Index; Dobbins, Meyrs et al.

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UK MoD's Sea Trial Seat Testing

The real impact data showed
4 X the number of impacts > 2.0g
3 X higher impact levels

Shuttle run test showed
26% decline in performance!

The data processed for standards
and directives showed
NO significant difference

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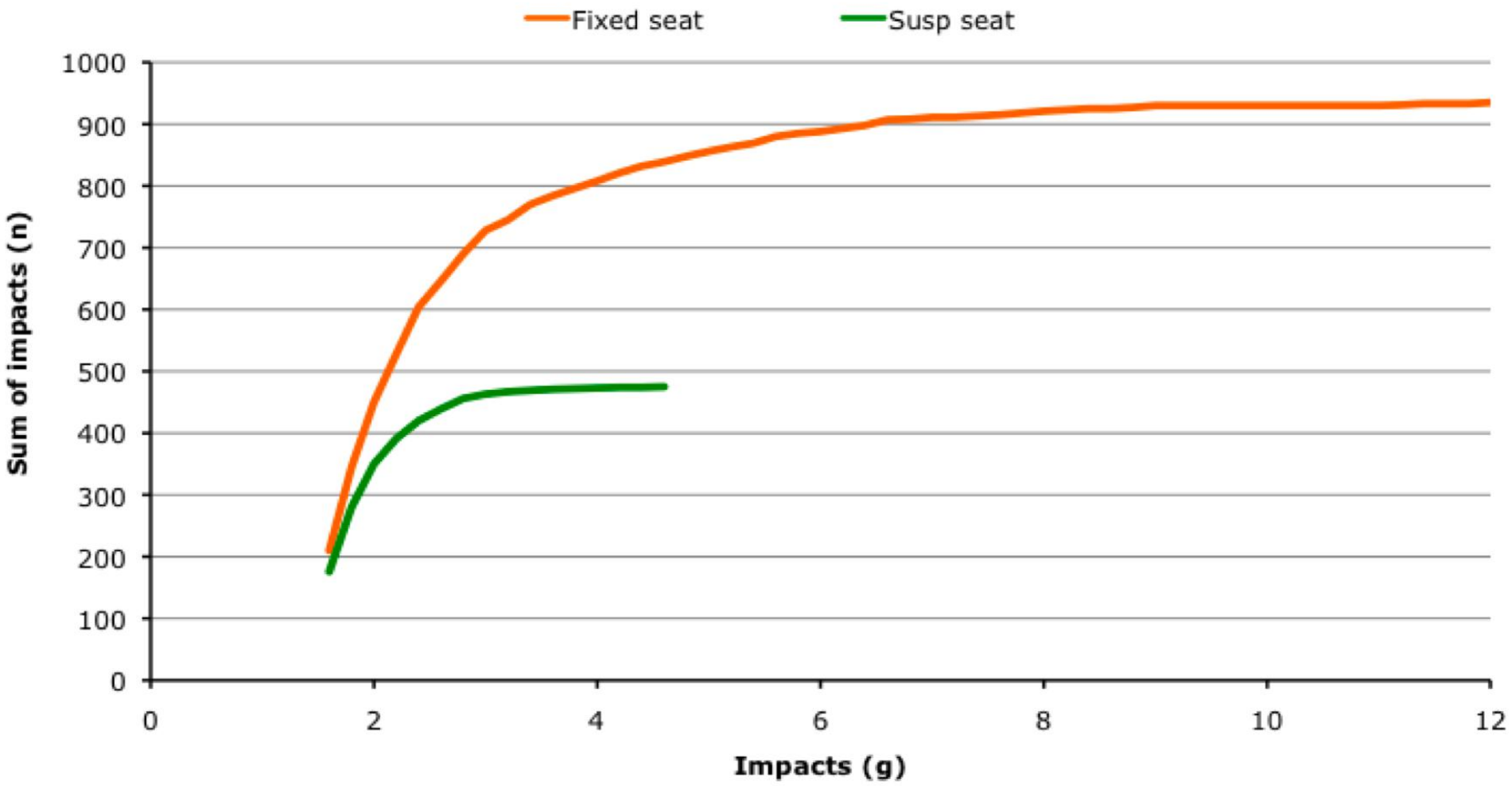
CUMULATIVE IMPACT COUNT (IC)



TRADITIONAL WBV MEASURES

Fixed seat vs. suspension seat trial

Measures **DO NOT** reflect what occupants feel / report

		WBV		
		wRMS ($m.s^{-2}$)	**Crest Factor**	**VDV** ($m.s^{-1.75}$)
HSC: Fixed Seat	**Deck:**	2.00	24.0	39.9
	Fixed seat	1.93	25.1	36.8
HSC: Susp. Seat	**Deck:**	1.98	31.8	41.7
	Susp. seat	1.99	15.8	33.8

EU PAD WBV:

RMS – EAV = 0.5 $m.s^{-2}$, ELV = **1.15 $m.s^{-2}$**.

VDV – EAV = 9.1 $m.s^{1.75}$, ELV = **21 $m.s^{1.75}$.**

18M HSC AT ~40KTS FOR 4 HOURS

		EU PAD WBV Values	
	Trial Exposure	**EAV**	**ELV**
wRMS	2.43 $m.s^{-2}$	0.5 $m.s^{-2}$	1.15 $m.s^{-2}$
Crest factor	28		
VDV	58.3 $m.s^{1.75}$	9.1 $m.s^{1.75}$	21 $m.s^{1.75}$

RMS & VDV generally **NOT** considered to be helpful when discussing HSC exposure related to EU prescribed limits

What should be measured?

The only scientifically valid method to predict the risk of injury, is to measure real impact exposure on the human body, in real exposure conditions.

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Why is HSBO Forum organised?

HighSpeedBoat OperationsForum

To present and scrutinize scientific work in the field
- to find out what is **Evidence based Science**

To compare experiences
- to find out what is the **Proven Experience**

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THERE IS ALWAYS SOMEONE...

... WHO WILL DO IT CHEAPER!