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Summary

This project explores the role and impact of the H-Point Machine (HPM) in vehicle design and crash safety assessment. Through a combination of expert focus group discussions and a targeted review of UN regulations, the project investigates how the use of the HPM -originally designed to represent a 50th percentile male - may influence occupant positioning, ergonomic design, and crash test outcomes. The focus group, comprising of experts from academia, industry, and government research, highlighted challenges in representing different body sizes, especially for smaller occupants such as 5th percentile females.

The discussions highlighted practical and methodological challenges related to body size variation, seat interaction, and positioning consistency across both physical and virtual testing. The regulatory review mapped the role of the HPM in various UN regulations, identifying areas where its use might contribute to differential effects between men and women. The project underscores the importance of robust methods that account for occupant diversity and supports future development of more inclusive safety assessments, including improved use of simulation tools and occupant variation in test protocols.

Analysis of the 3 D H-Point Machine in Relation to Diversity

1. Background

Today, the UN regulatory crash tests of both frontal and side impacts are carried out with dummies that represent a man who is 175cm tall and weighs 77kg, and in frontal crashed additionally with a 5th percentile female dummy who is 151cm tall weighing 48kg, which is a downscaled man. A UNECE ad hoc group on equitable occupant protection performed a review during 2021 and 2022 of relevant data and the result indicated that the injury risk is higher for women than for men regarding several types of injuries and regarding all types of crashes. The 3D H-point machine is a three-dimensional reference system, which represents an average male person, and is used to define and locate the standard seating reference point as well as the headroom, leg, shoe and pedal reference points to provide measurements for cabin dimensions and layout design. It has the adult male contours and simulate seat penetration of an average male (Secretariat, 2025).

2. Project set up

This section provides the project set up, describing the purpose, objectives, project period and partners of the pre-study.

2.3 Purpose

The 3D H-point machine, called HPM in the continuation of this pre-study, is frequently used in crash regulations. The need of more knowledge about how the HPM is used has been identified during work to develop occupant protection towards higher equity. The aim of this pre-study is to improve the understanding of the impact of the HPM on the variation of injury risk and its relation to occupant diversity.

2.4 Objectives

The objectives of this pre study are to (1) describe the use of the HPM and (2) explore the impact its usage has for interior vehicle design and crash safety.

2.5 Project period

2024.11.25 –2025-08-31

2.6 Partners

Autoliv

Chalmers Design & Human Factors

Transportstyrelsen

3. Method and activities

A focus group workshop was conducted with the aim to (1) describe the current usage of the HPM, and (2) explore the impact its application has on vehicle design and crash safety. The focus group included professionals with diverse expertise, representing fields such as vehicle design, crash safety engineering, and biomechanics. Several participants were affiliated with leading vehicle manufacturers and safety system suppliers. Considering that some manufacturers adopt distinct approaches to designing robust safety systems, approaches that may differ from those of other companies, this composition of the group may have influenced the perspectives highlighted in the discussion. The discussion topics included mapping how

the HPM is used throughout vehicle development and discussing its potential implication for occupant equity.

A brief overview of the topics was shared with participants in advance via email. The focus group session was conducted online and lasted two hours, including a 10-minute break. Throughout the session, one project member acted as moderator and led the discussions, while a second team member took structured notes, and a third provided technical support. The session was video recorded and transcribed afterward to ensure accurate documentation of the discussions.

The transcription of the focus group discussion was structured according to the predefined agenda topics. A deductive thematic analysis was conducted, in which the content was summarized and categorized based on these main discussion areas. This approach allowed for a systematic examination of how participants described the use of the HPM and its perceived impact on vehicle design and crash safety. The summary was developed through manual thematic grouping by the project members, based on topics discussed in the session. The initial summary was shared with all focus group participants, who were invited to provide feedback and clarifications. Their comments were incorporated to refine the final analysis and ensure it represented the diversity of expert input accurately. This step contributed to the validity of the analysis, helping to confirm that the interpretation remained aligned with the workshop objectives while accurately reflecting the expert perspectives shared during the discussion.

In addition to the focus group session, an exploratory review of the regulations related to the HPM was conducted to provide an overview of how the HPM is applied in UN regulations and how its use may influence vehicle design. The review aimed to identify whether the reliance on HPM could lead to different effects for male and female, and to explore whether certain regulations could be prioritised for further study or potential revision to support more equitable occupant protection.

4. Results and Deliverables

This chapter provides an overview on how the HPM influences crash safety outcomes across occupant sizes and shapes in 4.1 *Insights From Focus Group Session*, followed by the regulatory review in 4.2 *Overview of HPM Applications in UN regulations*. Lastly, the insights from the focus group session and the regulatory review are discussed in 4.3) *Potential implications for occupant equity*.

4.1 Insights from Focus Group Session

The findings from the focus group session resulted in an overview ranging from the history and development of the HPM to its potential impact on injury risk variation and its relationship to occupant diversity. This overview provides insights for improving the understanding of how the HPM influences crash safety outcomes across a range of occupant sizes and shapes.

History and Development of the HPM

The HPM was developed to provide a physical reference point in vehicles - a point from which vehicle design and safety testing are based. Below are milestones in the development of the HPM, including the first standards, revisions, the introduction of 5th percentile manikins, and initiatives to improve the machine's biofidelity through upgrades and research:

- 1962: The original H-point dummy was defined by SAE J826.
- 1995: Revision of the original standard.
- 1998: Introduction of 5th percentile dummy, a scaled-down version.
- 1999: Initiatives to upgrade HPMs were launched, led by UMTRI (University of Michigan Transportation Research Institute).

There are several variants of the HPM (see Table 1). Humanetics offers, among others, the following versions:

- 1. **50th Percentile Manikin:** Used to define the vehicle’s reference point. It is adjustable and can be supplemented with head and torso extensions. This is the most commonly used manikin and the one most often referred to in legal requirements and safety ratings. Also known as OSCAR.
- 2. **HPM-II:** This version is used for seat measurements and is designed to measure lumbar support, as the backplate is divided into several segments. It is defined by SAE J4002 and has undergone several upgrades to improve biofidelity and handling. It is intended for defining cushion angle in reclined seats. Currently, there are no official vehicle regulations or consumer ratings for the "reclined position," but ratings are planned to be introduced as early as 2027 on the Chinese market.
- 3. **5th Percentile Female Manikin:** Not used in regulation and rating but is an important part of testing and evaluation. It was introduced around 1998 as a scaled-down and weight-adjusted variant, i.e. it is designed to represent a smaller occupant in terms of overall size and leg length, but its gluteal (pelvic and buttock) form is fixed and corresponds to the 50th percentile male. According to the Humanetics website, there are currently no regulations linked to this model.

Table 1. The three H-Point Manikins and how they are used (Humanetics Group, 2025).

50-percentile HPM (TE-HPM)	HPM-II	5th percentile HPM (TE-HPM-05)
		

Applications	Provides the physical representation of the human H-Point reference for many testing and design functions.	No description.	Provides the physical representation of the human H-Point reference for many testing and design functions.
Regulations where used	Designation of Seating Procedures (Defining regulation: 49 CFR 571.10) Devices for Use in Defining and Measuring Vehicle Seating Accommodation (Defining regulation: SAE J826).	H-Point Manikin (Defining regulation: SAE J4002).	None.

Purpose of HPM Usage

The HPM is used to physically measure the vehicle's H-point - a defined reference point representing the hip location of a standardized occupant. It serves as a foundation for interior design, ergonomic analysis, and crash testing. This point is crucial for vehicle ergonomics, safety evaluations, and the design of interior components. The HPM is not only used to determine a standard position, such as the Seating Reference Point (SRP), but also to establish various reference points depending on the crash dummy and test scenario.

In vehicle design, a Seating Reference Point (SRP) is defined digitally in the CAD model as the intended H-point for a 50th percentile occupant. In the physical vehicle, the HPM is used to measure the actual H-point, which is then compared with the Seating Grid Reference Point (SgRP), a fixed coordinate in the vehicle's reference system. The SgRP anchors the interior layout and ensures consistency between design intent (SRP) and physical validation. It is also used to position crash test dummies consistently and to define fundamental interior dimensions such as belt routing and head restraint location.

Many fundamental interior dimensions are referenced to the H-point, such as the steering wheel location, pedal position, windshield height, seat belt anchorage, head restraint positioning, visibility reference lines, and general compartment dimensions. The HPM thereby provides the standardised foundation necessary for ensuring occupant accommodation, functional ergonomics, and compliance with regulatory safety requirements.

Even though crash test dummies vary in size and geometry, they are always positioned using a standardized method based on the H-point. For example, thigh and lower leg lengths are adjusted in tests with a 50th percentile dummy to match standardized anthropometric dimensions. Using the H-point as a reference ensures consistent and comparable dummy placement across vehicles and test cases.

An overview summarizing terms, definitions, applications, and purposes related to the tools discussed in this report is provided in Table 2.

Table 2. Definition of terms, applications, and purpose of the tools in this report.

Term	Definition	When Used	Purpose
SRP (Seating Reference Point)	Theoretical, digital H-point in the CAD model (design reference)	During early design and development phases when designing the vehicle interior and in ergonomic simulations, e.g., in RAMSIS	To guide the layout of interior components (steering wheel, seat belt, mirror, etc.)
H-point	Actual H-point measured with the HPM in a physical environment	During the prototype and verification phases	To verify that the physical seat matches the design
HPM (H-point machine)	Physical manikin used to measure the H-point	In real vehicles	To establish dummy positioning and ensure ergonomic correctness
SgRP (Seating Grid Reference Point)	Fixed reference point in the vehicle's global coordinate system	In CAD and geometry setup	To provide a consistent seat position reference across different models/versions

In vehicle safety development and assessment, the physical HPM is used as a tool to verify the vehicle's reference point for various purposes. Among others, the HPM is used to:

1. **Physically measure the actual H-point** when a physical vehicle is available. The design of the interior typically starts with a digital SRP, which defines the H-point and heel point. The HPM is then used to verify that the physical vehicle aligns with design targets (including the SRP) and to represent the human body's position within the vehicle.
2. **Position crash test dummies before crash testing.** The H-point measured with the HPM serves as a reference for placing dummies according to crash test protocols. This is crucial to ensure that test results are comparable across different vehicles.
3. **Prepare for regulatory tests**, such as visibility or seat belt geometry requirements.
4. **Compare seat adjustment ranges.** By measuring the H-point across different seat positions, information is obtained on how the adjustment range affects ergonomics and safety.
5. **Verify the H-point in various vehicle positions.** The passenger seat often shares geometry with the driver's seat but may offer fewer adjustment options (e.g., height, recline, fore-aft movement). The passenger side frequently shares the same SRP as the driver side, despite limited adjustability - particularly in height. The HPM is used in both front and rear seats. The method is nearly identical, but leg positioning differs between the seat rows. In the driver's seat, one foot is placed on the accelerator pedal, while in the rear seat, the feet are positioned horizontally on the floor. The femur angle is typically steeper in the

rear seat. However, this does not affect the H-point itself, as it is defined by the interaction between the seat and the manikin - not by the angle of the legs.

HPM Impact on Occupant Equity

Although the focus group acknowledged that the use of the HPM could contribute to differences in crash safety outcomes across sexes and body sizes, uncertainty remained regarding the specific mechanisms and extent of this impact. Yet, a significant issue noted by the focus group is that the gluteal form of the HPM always corresponds to a 50th percentile body, regardless of which occupant size is being represented. Even if the leg length and applied force are adjusted, the gluteal width remains unchanged. This affects how the seat cushion is loaded, resulting in a pressure distribution that does not accurately mimic a smaller body. Wider hips create a larger contact area and altered pressure pattern, which can influence the measured H-point. Leg geometry can also have a minor impact, despite being length-adjusted.

The focus group explained that an initial HPM measurement establishes the original H-point, and that crash test dummies must be positioned within a defined tolerance relative to this reference. Since the HPM does not accurately represent a variation of body sizes, transfer functions can be used to adjust the H-point for different body sizes. E.g. for a 50th percentile dummy, a rectangular tolerance area defines acceptable positioning, while for a 5th percentile dummy, the H-point is modified in height and fore-aft location to better reflect smaller occupant proportions.

Further, the focus group discussed regulatory impact on vehicle design. While vehicle design begins with defining the SRP and seat adjustment range, regulations then specify how dummies should be positioned using established procedures, which can pose challenges. For instance, focus group experts noted that if a prescribed seating position proves unfeasible, the manufacturer may need to adjust the allowable range of the seat, even when it was originally designed to accommodate a broader range of users.

Although the 5th percentile HPM is not required for regulatory testing, the focus group session discussed practical challenges that can arise when positioning a HPM with the shorter, 5th percentile legs in the front seat. Due to shorter stature, the seat must be moved forward to allow the feet to reach the pedals, which can result in the legs and knees being positioned close to the dashboard or steering wheel. This limited legroom not only affects comfort but may also increase injury risk in the event of a crash. Further, this creates limited space for positioning the HPM with attached 5th percentile legs. The focus group noted that for this reason, the lower legs can sometimes be omitted during measurements to represent a 5th percentile female occupant. However, whether this omission is allowed depends on the specific test protocol.

Finally, with increasing reliance on simulation and digital modelling, the focus group discussed emerging challenges regarding dummy positioning. In simulations, the dummy can be placed directly at the desired H-point, but at the simulation start time, the actual position may shift due to system force balancing. For example, firm seat foam may push the dummy upward (in the Z-direction), altering its intended position. One alternative is to let the dummy "settle" into the seat before the crash moment, allowing the system to reach dynamic equilibrium.

This differs from physical tests where the dummy is manually positioned and tested immediately. The focus group discussed that definitions for positioning may be easier to standardize in physical testing than in simulation, where variability and uncertainty in initial conditions remain a challenge.

4.2 Overview of HPM Applications in UN Regulations

The results of the regulatory review are presented in the table below. It provides an overview of UN regulations in which the HPM is applied, describing the HPM function and ATDs used in each regulation and potential implications occupant equity.

Table 3. An overview of relevant UN regulations where the H-point machine (HPM) is applied.

UN Regulation	Description - Uniform provisions concerning the approval of:	HPM function in relation to UN regulation	ATD used	Potential implications for occupant equity
14	Vehicles with regard to safety-belt anchorages	Establish the H-point, which is compared to the SgRP to verify anchorage locations. Ensures belt anchorage geometry aligns with occupant posture before static load tests.	No ATD used (static load tests on anchorages).	Anchors are positioned relative to a 50th percentile H-point, potentially misaligning with smaller occupants (e.g., belt fit for females, low-BMI users).
16	I. Safety-belts, restraint systems, child restraint systems and ISOFIX child restraint systems for occupants of power-driven vehicles II. Vehicles equipped with safety-belts, safety-belt reminders, restraint systems, child restraint systems and ISOFIX child restraint systems and i-Size child restraint systems	HPM defines H-point to set up belt routing relative to the SRP/SgRP. Used to confirm geometry before dynamic ATD testing.	Hybrid III 50th percentile male, Hybrid III 5th percentile female.	Smaller occupants may experience suboptimal belt fit (even when tested with a 5th female dummy), as belt routing geometry originates from the 50th male H-point.
17	Vehicles with regard to the seats, their anchorages and any head restraints	HPM establishes H-point and measures head restraint backset/height relative to the SgRP.	Static strength test (no ATD required); optional dynamic whiplash test with BioRID-II (50th male).	Head restraint geometry optimized for 50th male may leave females at higher whiplash risk due to smaller stature and different torso-pelvis geometry.
21	Vehicles with regard to their interior fittings	HPM defines H-point and seating posture for assessing head contact zones and visibility lines relative to SgRP.	No ATD required (geometry and headform impactor used).	Contact zones are determined around the 50th male posture, potentially overlooking smaller occupants' head trajectories.

94	Vehicles with regard to the protection of the occupants in the event of a frontal collision	Defines H-point and dummy positioning for frontal impact tests.	Hybrid III 50th percentile male, Hybrid III 5th percentile female.	Because the H-point geometry is male-based, the 5th female dummy sits in a male-referenced seat posture, which may not reflect real female seating.
95	Vehicles with regard to the protection of the occupants in the event of a lateral collision	Defines H-point and dummy positioning for side impact tests.	EuroSID-1, ES-2re, WorldSID 50th male.	Because the H-point geometry is male-based, lateral crash protection may not be optimised for females.
135	Vehicles with regard to their Pole Side Impact performance (PSI)	Defines H-point and dummy positioning for pole-side impact tests.	WorldSID 50th male.	Using only male-based references and ATDs risks underestimating injury risks for smaller females.
137	Passenger cars in the event of a frontal collision with focus on the restraint system.	Defines H-point and dummy positioning to set restraint system geometry.	Hybrid III 50th percentile male, Hybrid III 5th percentile female.	Since restraint geometry originates from a 50th male reference, fit and performance may not be optimised for females, even if tested.

4.3 Potential Implications for Occupant Equity

This section discusses potential implications for occupant equity based on insights from the focus group session and the regulatory review. While the HPM is not a crash tool, it serves as a geometric reference device to establish the H-point in the physical seat. Although the HPM does not directly determine injury outcomes in crashes, it anchors geometric baselines around a 50th percentile occupant model, which in turn influence dummy positioning and the design of restraint systems. This means that even when a 5th percentile female dummy is used in regulatory tests such as UN R94, it is positioned according to the H-point of the 50th percentile HPM, despite that occupant size, shape and sex influence injury outcomes. When it further comes to shape of the gluteal area, a study showed that approximately 29% of the variation in pelvis geometry can be attributed to anthropometric variables such as sex, age, stature, and body mass index (BMI) (Brynskog et al., 2021). Nevertheless, the gluteal proportions of the HPM are fixed. When applying the smaller female dummy, it compresses the seat differently, implying that the male-referenced geometry from the HPM cannot align optimally, potentially affecting belt fit, restraint engagement, and head restraint positioning. As a result, occupant protection is optimized for midsize males and therefore not for females, even when regulatory requirements are met. From a safety perspective, however, the goal should not be to optimize for a single body size, but rather to achieve robust protection that performs well across the diversity of occupants.

In practice, many OEMs, but not all, go further by testing with additional dummies (e.g., 95th percentile male, small female in varied postures) and by running out-of-position and sled tests that are not mandated by law. Beyond legal compliance, consumer rating programs such as Euro NCAP, IIHS, and NHTSA NCAP often have stricter protocols, broader dummy use, and performance-based scoring. Since these ratings strongly influence public perception and

vehicle sales, OEMs typically prioritize achieving strong performance in consumer safety assessments, often exceeding the minimum standards set by regulatory requirements. This incentive means that while the HPM anchors geometry to a male baseline, the addition of consumer tests and voluntary OEM practices may drive designs toward greater inclusivity across occupant sizes to some extent. Nevertheless, gaps still remain, especially for female and body shapes and sizes of other than the 50th male (Barry & Bergmann, 2019).

In summary, the HPM should not be viewed as a direct cause of male female injury differences, but rather as an indirect factor that may set boundary conditions for safety system design. While usage of the HPM ensures consistency with regulatory procedures, it also evaluates all dummies within the 50th percentile HPM geometry, rather than one that reflects the pelvis shape or seating posture of smaller occupants. Addressing inequities therefore requires not only diversification of crash test dummies and human body models but also a critical reassessment of how reference tools like the HPM anchor the entire occupant protection framework. Improved understanding of these effects is necessary to enhance equitable occupant protection.

5. Conclusions, Lessons Learnt and Next Steps

The aim of this pre-study was to identify whether the usage of the HPM could lead to different effects for male and female, and to explore whether certain regulations could be prioritised for further study or potential revision to support more equitable occupant protection. The findings suggest that while the HPM itself is not the single cause of sex-related injury differences, its role as a geometric reference tool indirectly shapes how dummies are positioned and how restraint systems are evaluated. This reliance on a 50th percentile male baseline means that variations in body size, shape, and sex may not always be adequately reflected in regulatory testing.

The findings from the focus group discussions and regulatory review, suggest that the challenge originates from how the HPM is applied across design and regulatory contexts. Standardised positioning ensures consistency, but it may also constrain the ability to represent diverse occupant geometries. OEM practices and consumer rating programmes often go beyond regulatory requirements, but gaps remain - especially for females and non-average male body types. This underscores the need to reassess how reference tools like the HPM set the boundary conditions for safety design.

The focus group acknowledged that the use of the HPM could contribute to differences in crash safety outcomes across sexes and body sizes, although uncertainty remained regarding the specific mechanisms and extent of this impact. Findings from the focus group session underscored that seating position, occupant size, and seat design influence crash outcomes, and that an exclusive reliance on standardized positioning may not fully reflect real-world variability. The regulatory review further identified several UN regulations in which the use of the HPM may contribute to unintended sex-related variations in safety performance, highlighting opportunities for improving occupant protection across sexes and body sizes. Policymakers should revisit these identified UN regulations to ensure that reference devices and positioning protocols support more equitable protection across occupant sexes, sizes, and shapes.

In upcoming studies, more targeted research is needed to clarify the extent to which HPM-based procedures contribute to systematic bias in occupant protection. To follow up this pre-study, the suggested next steps ahead include:

- Combining expertise from interior design and simulation to examine how HPM use influences safety outcomes across different sexes and body sizes.
- Conducting simulation studies with HBMs to quantify potential disparities
- Developing technical recommendations or best practices that help ensure more inclusive testing within existing regulatory frameworks.

6. Dissemination and Publications

This pre-studies result will be spread in the Safer community.

7. Acknowledgement

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8. References

- Humanetics Group. (2025). *H-Point manikin* [Product information]. Retrieved May 4, 2025, from <https://www.humaneticsgroup.com/products/testing-and-measurement-systems/seat-positioning-testing-devices/h-point-manikin/h-point>
- Barry, K., & Bergmann, A. (2019). The crash test bias: How male-focused testing puts female drivers at risk. *Consumer reports*, 23.
- Brynskog, E., Iraeus, J., Reed, M. P., & Davidsson, J. (2021). Predicting pelvis geometry using a morphometric model with overall anthropometric variables. *Journal of biomechanics*, 126, 110633.
- Secretariat, U. E. (2025). Consolidated Resolution on the Construction of Vehicles (re 3).