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Review of average sized male and female occupant models in European regulatory safety assessment tests and European laws: Gaps and bridging suggestions

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ABSTRACT

There are two parts to the aim of this study. The first part comprised reviewing how men and women are represented in regulatory tests conducted to assess adult occupant safety in vehicles in Europe. This part also contains an overview of some differences between females and males that may influence dynamic responses in a crash. Based on the results of the review an outline for how to better represent the adult population in regulatory tests has been suggested.

The second part was to reflect on these issues from a specific critical legal perspective, that is from a Gender Legal Studies point of view, focusing on the European legal framework that governs the tests of adult occupant safety in vehicles in Europe. Since the beginning of the 1970s legal scholars have shown in several areas of law that there is a gap between superior legislation and practice, but also between gender equality as a superior legal principle and subordinate legal rules that govern safety requirements. The same pattern can be discerned in the area of Transportation Law.

The results of the review of the ECE regulations shows that the average sized male represents the adult population and that the average sized female has been excluded from regulations assessing the protection of adult vehicle occupants. The fundamental values, on which the Union is founded, including the overarching goals of the Union, seem to be rendered invisible in the laws and critically impact the safety of women in everyday life. According to the gender system theory, the interests and priorities of men are continuing to shape the law. Consequently, the law neglecting the safety of women on roads has implications on the development of society. The lack of legal provisions that demand female crash test dummies representing the female part of the population, means that there is no incentive for car manufacturers, authorities or other stakeholders to develop test methods and female crash test dummies in ways that promote political objectives expressed in legal form, i.e., the legal values expressed in general provisions and principles stated in the Treaty on European Union and the Treaty on the Functioning of the European Union, such as gender equality between women and men as well as non-discrimination

This study highlights the undeniable gap between the legal framework and legal requirements with regard to occupant safety for the whole adult population. It would be attainable to bridge this particular gender gap by providing equal representation for the female part of the population with regard to vehicle safety, as that males benefit from.

1. Introduction

Crash test dummies are used when developing and evaluating occupant protection performance of a vehicle in vehicle regulatory tests, such as ECE R16, R94, and R95 (UNECE 2017), and in consumer information tests, such as NCAP tests (Euro NCAP 2017). When comparing the risk of injury for males and females, higher injury risk for females has been shown for a range of crashes by Bose et al. (2011). Bose et al. (2011) analysed accident data from the National Automotive Sampling System Crashworthiness Data System (NASS CDS) 1998 – 2008 held by the US National Highway Traffic Safety Administration on fatally or severely injured belted occupants. The results showed that the

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odds of a belt-restrained female driver sustaining a Maximum Abbreviated Injury Scale (MAIS) 3 + and MAIS 2 + injury were 47% and 71% higher, respectively, than those of a belt-restrained male driver when controlled for the effects of age, mass, Body Mass Index (BMI) category, crash, change of velocity, vehicle body type, number of events, and crash direction. For the injuries studied to date, the largest difference between male and female injury risk is found for whiplash injuries. Injury statistics from the mid-1960s until today show that on average females are exposed to double the risk of sustaining whiplash injuries than males, ranging from 1.5 to 3 times higher (among others Kihlberg 1969; O'Neill et al. 1972; Otremski et al. 1989; Morris & Thomas 1996; Dolinis 1997; Temming & Zobel 1998; Richter et al. 2000; Chapline et al. 2000; Kullgren et al. 2003; Krafft et al. 2003; Jakobsson et al. 2004; Storvik et al., 2009; Carstensen et al., 2012). In fact, concepts for whiplash protection seats have proved to be more effective for males than females (Kullgren & Krafft 2010 and Kullgren et al. 2013) with concepts based on an reactive head restraint reducing the propotion of permanent medical impairment for male drivers by 70 % and increasing it for female drivers by 13 %. In addition to the differences in protection of females versus males of belt-restrained drivers in all types of crashes, these results show that the safety performance of different seat concepts vary when occupied by males and females.

Since the 1970s Gender Legal Studies in Scandinavia have shown in several legal areas that law has been, and still is, shaped by the dominant group's interests and priorities, i.e., the interests and priorities of men. In fact, gender inequality within the transportation system was first highlighted in 2001 by the Government Inquiry Gender Equality Council for Transport and IT (Official investigation by the Swedish Government, SOU 2001:44), and in 2003 in Jurisprudence through an article by Svensson (2003). This issue was then thoroughly and deeply analysed in a dissertation by Svedberg (2013). Due to Gender Legal Studies the law reflects the male norm and as such also preserves and reproduces gender inequality. In this sense, we can see that law itself, as a social institution, exercises power. At the same time, we have seen that gender equality is a prioritised issue, both in Scandinavia and in the EU. The legal principle of gender equality has been intensified and legislative reforms have been undertaken in different areas. This paper studies the gap between law and practice, and between the superior legal principle gender equality and subordinate legal rules, and how these gaps occur and persist.

Since the beginning of the 1970s legal scholars have shown in several areas of law that there is a gap between superior legislation and practice, but also between gender equality as a superior legal principle and subordinate legal rules that govern safety requirements. The same pattern can be discerned in the area of Transportation Law. The first gap, between superior legislation and practice, concerns how law is applied in practice by those who are obliged to comply with the law. The second gap, between superior legal principle and subordinate legal rules, concerns the lack of clear legal requirements that take into account the physical female body in the context of design and construction of dummies used in regulatory tests to assess adult occupant safety in vehicles in Europe. The superior principle of gender equality is legally binding, at all levels, and the gender equality perspective must be applied to any legislation in all areas and at all levels of the Union. Briefly, this means that the principle is supposed to be implemented in subordinate legislation. Another way of describing this aim is that there is an "emancipatory knowledge interest" where the purpose of the knowledge is to promote gender equality in every area of society, including the technical audience of this journal.

Of utmost importance, if not crucial, for implementing changes also in practice, is the need for a deeper understanding of the law, the legal requirements in EU law, as well as how the law is applied in society among professionals within different societal and scientific fields. The knowledge developed within the area of Gender Legal Studies explains how law can promote gender equality (legally defined as an issue of unequal power relations between men and women on a structural as well as an individual level in society), at the same time as it reproduces and maintains unequal power relations between women and men.

Due to the crash injury statistics and the results gained from this study, the most important issue at stake is why the law does not give priority to the protection of women's safety in the event of a collision. From a legal point of view, the above-mentioned gaps, i.e., the gap between law and practice, and between the superior legal principle gender equality and subordinate legal rules, exist because law is permeated by the male norm. Gender equality has been defined as an issue of equal distribution of power between women and men. This understanding of gender equality is based on the Genus System Theory developed by Yvonne Hirdman and presented as part of a public report (SOU 1990:44). How this process works is described as follows:

The theory explains gender inequality in society, or more particularly the relationship between men and women as the organizing pattern for society on symbolic, structural and individual levels. The theory sees the categories women and men as more than biology. The concept genus consists not only of the biological sex, but is also associated with what is considered to be feminine and masculine. According to the theory, the gender system is maintained by two principles. Firstly, the sexes are kept apart in all areas of life. Secondly, the male is the standard for a human being. At the same time, the male norm permeates every aspect of society, that is, from how the world is understood to which power relations that should be regulated legally. The Genus System Theory was adopted as the basis for the Swedish gender equality objectives in the bill, Shared Power – Shared Responsibility (Government Bill 1993/94:147) Svedberg 2013 pp. 485-486 [authors remark].

There were two parts to the aim of this study which focus on regulatory tests and the legal perspective in Europe. The first part comprised reviewing how adult men and women are represented in regulatory tests conducted to assess adult occupant safety in vehicles. Based on the results of this review an outline for how to better represent the adult population in regulatory tests has been suggested.

The second part was to reflect on these matters from a specific critical legal perspective, that is from a Gender Legal Studies point of view. The focus was on the European legal framework that governs the tests of adult occupant safety in vehicles in Europe.

2. Method

A review of regulatory tests for assessing occupant safety in the event of a crash was carried out. The review comprises tests performed in European regulatory vehicle assessments involving models of human occupants and presents the occupant model used in these tests. For some regulations, information had to be obtained directly from the dummy provider due to the regulatory text not fully describing what occupant the dummy is meant to represent.

By asking a legal question: whose traffic safety, women's or men's, is actually protected in the law, the results of the review of regulatory tests are reflected in the light of the values laid down in the Treaties and the knowledge emanating from Legal Gender Studies (Gender Jurisprudence). The approach aims at being critical and essentially highlighting any gaps between, on the one hand an offensive gender equality policy and the overarching legal values of the Union (including Sweden), and on the other hand minor offensive legislation within specific policy areas, i.e., legislative requirements regarding regulatory tests. This means that the approach will reveal if there are any gaps between law and reality, so-called 'the reality gap' in terms of women's rights and position in society (Svensson, 2001; Gunnarsson and Svensson, 2009). The methods used to interpret legal texts have been developed in the field of jurisprudence.

3. Results

3.1. Occupant model in vehicle approval regulation in Europe

For vehicles to be type approved in Europe, within the EU/EES area, the technical requirements for vehicles are applied under Directive 2007/46/EC (UNECE, 2017). The basis of Directive 2007/46/EC is the 1958 Agreement and its 135 addenda WP29 (UNECE, 2017). In Europe, there are five regulatory tests assessing adult occupant safety in the event of a crash, the ECE regulations No. 16 (R16) (safety belt), No. 94 (R94) and No. 137 (R137) (frontal collision) and No. 95 (R95) and No 135 (R135) (lateral collision). These regulations have been studied focusing on what occupant models, i.e., crash test dummies, the tests require.

3.1.1. ECE R16 (safety-belt approval)

The ECE R16 concerns the approval of safety-belts in power-driven vehicles. The ECE R16 is a dynamic test performed at the change of velocity of 51 km and with a crash pulse of maximum duration 80 ms and maximum mean acceleration of 32 g (ECE R16).

For ECE R16, a manikin (R16 Manikin) is used to represent an occupant that is the weight of an average sized male (75.5 kg, pp 68) as well as has the torso shape of a male. Which gender this manikin represents is not disclosed in the R16. However, the dummy manufacturer website (www.humaneticsatd.com) describes that the R16 manikin represents a 50th percentile male adult in general size and weight distribution. For reasons of simplicity the dummy has no lower arms and only one lower leg and is made from semi-translucent hard urethane. The manikin is specified as a test device for ECE-regulation No. 16; "Uniform provisions concerning the approval of safety belts and restraint systems for adult occupants of power driven vehicles" and for the EEC Directive 82/319 (UNECE 2017).

3.1.2. ECE R94 and R137 (frontal collision protection)

The ECE R94 and R137 concerns the approval of vehicles with regard to the protection of occupants in the event of a frontal collision. The ECE R94 is a dynamic test of a vehicle frontally impacting a barrier at the change of velocity of 56 km/h (pp. 26 in the regulation). The R137 concerns the approval of passenger cars in the event of a frontal collision with focus on the restraint system.

ECE R94 states that a dummy corresponding to the specifications of the Hybrid III should be used. The footnote to the Hybrid III (H III 50M) describes that "the Hybrid III corresponds to the principal dimensions of a 50th percentile male". In ECE R137, a dummy corresponding to the specifications of the Hybrid III 50th percentile male dummy shall be installed in the driver seat and a dummy corresponding to the specifications for the Hybrid III 5th percentile female dummy shall be installed in the passenger seat. The Hybrid III 5th percentile female dummy is described as follows "The dummy represents the smallest segment of the adult population and has been derived from scaled data from the Hybrid III 50th Dummy" (H III 5F).

3.1.3. ECE R95 and R135 (lateral collision protection)

The ECE R95 is a dynamic test of a vehicle laterally impacted by a deformable barrier at the change of velocity of 50 km/h (pp. 22 in the regulation). The ECE R135 addresses "Uniform provisions concerning the approval of vehicles with regard to their Pole Side Impact performance (PSI)" The side impact dummy in ECE R95 should have "the dimensions and masses of the side impact dummy representing a 50th percentile male, without lower arms." The footnote on page 48 states: The dummy is corresponding to the specifications of the ES-2 dummy (ES-2). The ECE R135 describes that "a WorldSID 50th percentile adult male dummy" should be used (WorldSID).

Table 1
The mass and height of the 5th and 50th percentile female and 50th and 95th percentile male (Schneider et al. 1983).

Percentile	Sex	Stature (cm)	Mass (kg)
5th	Female	151.1	47.3
50th	Female	161.8	62.3
50th	Male	175.3	77.3
95th	Male	186.9	102.3

3.2. Differences between females and males that could influence the dynamic responses in a crash

The anthropometry of females and males is different, as shown by Schneider et al. (1983). Table 1 shows the difference in mass and height of the 5th and 50th percentile female and 50th and 95th percentile male from Schneider et al. (1983)

A detailed description of certain differences between males and females has been compiled by Young et al. (1983) and Schneider et al. (1983). These differences have been visualised in Fig. 1 by the numerical models of the rear impact dummy, the BioRID and the average female equivalent, the EvaRID (Linder et al. 2013).

The mass distribution of the different body parts has been found to vary according to gender (McConville et al. 1980; Young et al. 1983). Furthermore, there are inherent differences between each sex in terms of geometry, such as shape and form of the torso, for example. The dynamic response in the event of a crash may also differ due to muscle and ligament strength differences in males and females. Some examples are found in Table 2.

It has also been reported that the dynamic response of females in rear impact volunteer tests is somewhat different than in males, such as greater head forward acceleration, greater (or similar) T1 forward acceleration, more pronounced rebound and larger angular displacements between adjacent vertebrae in females (Szabo et al. 1994; Siegmund et al. 1997; Hell et al. 1999; Welcher & Szabo 2001; Croft et al. 2002; Mordaka & Gentle 2003; Viano 2003; Ono et al. 2006; Linder et al. 2008; Schick et al. 2008, Carlsson et al. 2011; Carlsson et al. 2012; Sato et al. 2014; Sato et al. 2015).

A further issue that may be of importance in a dynamic event is the difference in spinal alignment in males and females (Sato et al. 2016), with males displaying a more pronounced curvature of the neck in seated positions. A rear impact simulation study of Sato et al. (2017) showed larger intervertebral angular displacements in the cervical spine in female spinal alignment compared to in male. Hence, thresholds for injury criteria are expected to differ for average male and female models. In a simulation study, Yao et al. (2016), reproducing potentially injurious pressure transients in the neck vertebral canal during whiplash trauma, showed a trend toward increased pressure magnitudes with female properties, compared to male properties.

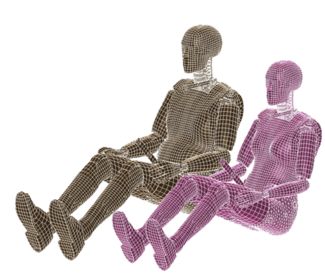

Fig. 1. The low severity rear impact average sized virtual male dummy BioRID (left) and the average sized female EvaRID (right) (Linder et al. 2013).

Table 2
Example of differences between male and female responses and strengths that could influence the response of the human body in the event of a crash.

Aspects	Difference male/female	Reference
The maximum isometric strength during flexion and extension of the head in seated position	20% to 25% greater in males	Jordan et al. 1999
Maximum moments of the neck	40% to 50% lower in females	Vasavada et al. 2001
Flexion strength and stiffness of the upper cervical spine	Greater in male human specimens	Nightengale et al., 2007
Axial stiffness of the lumbar spine	Greater in males	Brown et al. 2002
Neck strength	Female-to-male ratios ranging from 0.4 to 0.8	Kumar et al. 2001; Peolsson et al. 2001; Chiu et al. 2002; Garcés et al., 2002; Vasavada et al. 2001

3.3. The legal value of gender equality and non-discrimination, and obligations according to Article 2 and 3 of the Treaty of European Union

According to Article 2 of the Treaty on European Union, the Union is founded on the values of respect for human dignity, freedom, democracy, equality, the rule of law and respect for human rights, including the rights of persons belonging to minorities (Consolidated version of the Treaty on European Union, 2016). These values are common to the Member States in a society in which pluralism, *non-discrimination*, tolerance, justice, solidarity and *equality between women and men* prevail. Article 3 of the above-mentioned Treaty declares that the Union shall combat social exclusion and discrimination, and shall promote social justice and protection, equality between women and men, solidarity between generations and protection of the rights of the child.

Effectively, the Union shall in all its activities aim to eliminate inequalities, and promote equality, between men and women, according to Article 8 of the Treaty on the Functioning of the European Union (Consolidated version of the Treaty on the Functioning of the European Union, 2016). The article is addressed to all the institutions of the Union and therefore legally binding at all levels. Moreover, the article expresses the concept of gender mainstreaming which is the main strategy of the Union for achieving gender equality meaning that a gender equality perspective shall be applied to any planned policy actions, including legislation and political programmes in all areas and at all levels of the Union.

4. Discussion

Five European regulatory tests assess adult occupant safety in the event of a crash. Although regulatory tests worldwide display several local differences all tests, in similarity to the European tests, exclusively use the 50th percentile male to represent the whole adult population. To study the effect on the smallest and largest parts of the population, the 50th percentile male has been scaled down to represent the height and weight of a 5th percentile female and scaled up to a 95th percentile male.

Despite the need and ambition for developing a 50th percentile female it has never been included in the family of available dummy models. In their work in the early 1980s, Schneider et al. (1983) who defined anthropometric design specifications for crash test dummies, argued that providing both 50th percentile male and female dummies would be optimal; even so, the 50th percentile female was still omitted. For decades, crash injury statistics has shown that certain crash configurations impose a larger risk of injury on females than males. The risk of females sustaining Whiplash Associated Disorder symptoms is, on average, double that of males, and even higher in similar crash conditions. Furthermore, studies have shown that females are at higher risk than males of sustaining severe injuries and fatalities in comparable crashes (Bose et al. 2011). Bose et al. (2011) analysed US road accident data from 1998-2008 showing that the odds of a belt-restrained female driver sustaining a MAIS 3+ and MAIS 2+ injury were 47% and 71% higher, respectively, than of a belt-restrained male driver when controlled for the effects of both individual factors and crash configuration. The crashes in Bose et al. (2011) are those that the regulatory tests ECE R16, ECE R94 and R137, ECE R95 and R135 address. If models representing the female part of the population were available, it seems likely that this discrepancy in protection would be eliminated.

The review of the ECE regulations shows that the adult population is represented by the average sized male and that the average sized female is not represented in regulations assessing the protection of adult vehicle occupants. The study shows that relatively detailed technical requirements within the law concerning safety-belts and body dimensions of manikins used in regulatory tests, hide the fact that the law primarily assess the traffic safety of men in the event of a crash. Although the structure of male and female bodies is similar, certain inherent differences prevail producing differences in the average of males and females which has the potential to, and in a range of crash scenarios already been shown (among others Bose et al. 2011 and Kullgren et al. 2013) to influence the protective performance of a vehicle. Furthermore, in Kullgren et al. (2013) certain seat designs were shown to provide increased protection for both women and men, while others did not offer similar protection. The proportion of drivers suffering permanent medical impairment was reduced by 52 % for females and 47 % for males when seated in a WIL or a Whips seat, whereas being seated in a seat with a reactive head restraint (RHR) the propotion of permanent medical impairment was increased by 13 % for females and reduced by 70 % for males, compared to the equivalent proportions in a standard seat, Fig. 2.

In order to identify the best performing occupant safety systems, it would be advantageous to use dummy models representing both parts of the adult population. To introduce such testing methods, an average sized female prototype dummy, the BioRID 50F (Linder et al. 2013), and a scaled down version of the BioRID 50M, was developed. To illustrate some of the geometrical differences between males and females, both models can be seen seated in the same seat, Fig. 3.

A dummy representing the female part of the population would require Injury Assessment Reference Values (IARVs) and thresholds representing females, similar to those established for the average male dummy. Recently, Schmitt et al. (2012) has initiated such work. Based on a synthesis of literature data, Schmitt et al. (2012) suggested reducing the Neck Injury Criterion (NIC) threshold by 20% for the average female, compared to the average male.

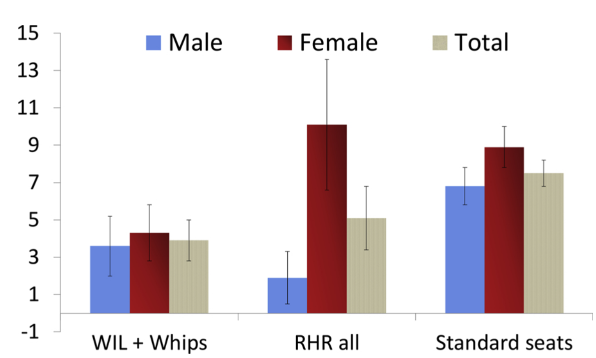

Fig. 2. The proportion of female and male drivers sustaining permanent medical impairment in three different seat categories: WIL and Whips, seats with reactive head restraint (RHR) and standard seat from Kullgren et al. (2013).

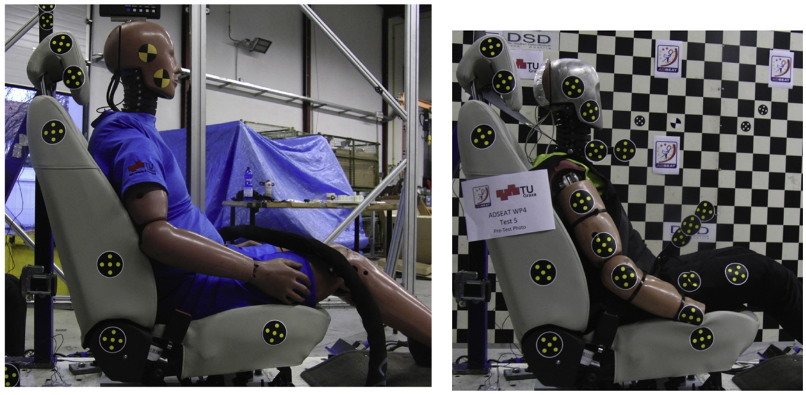

Fig. 3. The low severity rear impact average sized male dummy BioRID 50M (left) and the average sized female prototype BioRID 50F (right) (Linder et al. 2013).

According to the perspective on law developed within the field of Sociology of Law, where law is seen as a result of the power people exert over one another in society, means that law in general reflects these power relations. Furthermore, the dominant group of people determines the content, form and function of law, and the law reflects the dominant group's interests and priorities. How law is constructed can impact on social life. The law can even be discriminatory by ignoring the inequalities hidden beneath the formally neutral system. Although this is not the purpose, law can indirectly produce discriminatory effects according to Gender Legal Studies. The current study shows that fundamental values of the Treaties, on which the Union is founded, as well as the superior principles and rules of the Union, seem to be rendered invisible within the laws that have impact on the traffic safety of women in everyday life. Certain conclusions have been drawn based on this study:

a) According to the gender system theory, the interests and priorities of men are continuing to shape the law. The same pattern has been observed in this study.
b) As the law is neglecting the safety of women on roads, it can be concluded that the lack of subordinate legal provisions that require a manikin to actually represent the female part of the population, leaves car manufacturers, authorities and other stakeholders without an incentive to develop test methods or a manikin accounting for the physical female body, in ways that promote political objectives expressed in superior principles and rules in the Treaties.
c) Using the contemporary manikin, supposed to represent the female part of the population, is indeed violating the law as the manikin is scaled down, designed and constructed based on the male norm (a physical male body).
d) In this context, it would not be controversial to add that men have historically been over-represented in the research and engineering fields that contributed the data and tools for the development of motor vehicle crash safety. Improving gender diversity in these scientific fields, as well as among lawmakers specialising in traffic safety, may be one of several measures required to bring traffic safety for females to the same level as males enjoy. As the Gender System Theory shows, equal gender representation is not the only solution for enhancing gender equality in the content of future law. In addition to the legislators behind lawmaking, the law itself exercises power in different ways and at different levels to create hidden premises, basic assumptions, concept principles, as well as beliefs related to gender.
e) To demonstrate that the Union itself genuinely takes the superior legal principle of gender equality seriously, it must impose clear subordinate rules regarding the design and construction of female manikins, that in fact, represents the female population.

The first gap, between superior legislation and practice, concerns how law is applied in practice by those who are obliged to comply with the law. The second gap, between superior legal principle and subordinate legal rules, concerns the lack of clear legal requirements, that takes into account the physical female body with regard to design and construction of manikins used in regulatory tests to assess adult occupant safety, in vehicles in Europe. Essentially, this means that the principle is supposed to be implemented in subordinate legislation, as the superior principle of gender equality is legally binding at all levels and that the gender equality perspective shall be applied to any legislation in all areas, and at all levels, within the European Union. A different way of describing this aim is that the purpose of the knowledge is to promote gender equality in every area of society, including the technical audience of this journal.

A deeper understanding of the law and the legal requirements, as well as how the law is interpreted by professionals within different societal and scientific fields is of significant importance, if not crucial, for achieving change also in practice. The knowledge developed within the Gender Legal Studies explains how it is possible to promote gender equality by law (where gender equality is legally defined as an issue of unequal power relations between men and women on a structural as well as an individual level in society), at the same time as the law reproduces and maintains unequal power relations between women and men.

Regulations tell the provider of a product what is demanded to introduce a product, in this case vehicles, in a country. In Europe, fulfilling the UNECE requirements grant a vehicle to be sold in all countries within the European Union. If regulations require that the protection performances for half the population be shown, the message received by manufacturers is that they are expected to consider the protection of half the population. If, on the other hand, regulations demand that protection performances must be demonstrated for the whole population, the message would be that the whole population must be considered. If the regulatory tests require manufacturers to include the whole population in the assessment of occupant safety, it is feasible to expect that voluntary tests, such as the Euro NCAP, would follow suit.

In the last few decades, finite element human body models (HBMs) for the assessment of human responses in crashes have been developed with detailed representation of the geometries and mechanical properties of human body structures. These models typically started out as average sized male models, for example the Total HUman Model for Safety (THUMS) (Iwamoto et al. 2002; Iwamoto & Nakahira 2015) and the Global Human Model Consortium (GHBMC) (Gayzik et al. 2011; Vavalle 2012). These models have recently been further developed into a small female and a large male version to represent a more extensive occupant height and weight range. Although these additional sizes are important, they are not sufficient or comparable, in representing the female part of the population, similar to the average sized male manikin representing the male part of the population. Thus, developing an average sized female human model similar to the average male model, still remains. The first step has been taken by developing the open source HBM ViVA model (ViVA, 2016), representing an average female adapted for low severity rear impact testing (Östh et al. 2016).

To study the effect on the smallest and largest parts of the population in general, the 50th percentile male dummy has been scaled down to represent the height and weight of a 5th percentile female and scaled up to a 95th percentile male. However, according to growth curves of the Swedish population, the 5th percentile adult female is equivalent to an average sized 12-13-year-old girl (PCPAL, 2018), reinforcing that the female part of the population is yet to be represented by crash test dummy models. This study highlights the undeniable gap between the legal framework and legal requirements with regard to occupant safety for the whole adult population. It would be attainable to bridge this particular gender gap by providing equal representation for the female part of the population with regard to vehicle safety, as that males benefit from.

5. Conclusions

Although governments in European countries and other parts of the world aim at creating inclusive societies for all individuals through gender equality, there is a gap that needs bridging between this aim and how vehicle occupant safety is actually assessed. Despite injury statistics showing that protection in the event of a crash is not equal for women and men, the average male represents the adult population in vehicle safety assessments. Development and usage of occupant models representing the female part of the population, i.e. crash test dummies representing the average female, for use in regulatory tests together with the male equivalent would narrow this gap.

This study shows the gap between law and practice as well as the gap between the superior legal principle gender equality and subordinate legal rules, and how these gaps occur and persist. Moreover, the study highlights the (urgent) need for questioning the law: Why the law does not give priority to the protection of women's traffic safety in a similar manner it does with regard to the traffic safety of men.

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