#SelfieForSafety

A crowd sourced study addressing the importance of shoulder belt position

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Abstract

Introduced already in 1959, the three-point safety belt is still the single most important protection system in vehicles. Over the 60 years since, significant improvements have been made adding safety belt functions and enhancing safety belt geometry. To improve even further, striving towards making it even more effective, comfortable and attractive to use, the understanding of the usage and the belt fit for the diverse population is essential.

A crowd sourced study through Instagram was performed in September 2019, investigating the shoulder belt position of car occupants. By inviting people to contribute with selfies through social media, a wide variation of occupants and car models in a global context could be studied. During three weeks of data collection, in total 740 people showed active interest in contributing to the study by tagging #SelfieForSafety and @volvocars. 394 participants fulfilled all the inclusion criteria and are included in the analysis.

Studies on real-world safety belt usage form an important contribution to knowledge on factors that influence shoulder belt fit. However, few studies of occupants' shoulder belt position in cars are available, and they mostly cover small occupant samples in narrow contexts. This study, incorporating data from a diverse and global population, is therefore both unique and a valuable contribution to the research area. The findings of this study will help improve the usability and thereby also the acceptance, of the safety belt in future cars, having impact on overall occupant protection.

Shoulder belt position was categorized for each participant based on the selfies. For optimal protection, the shoulder belt should be placed, and remain, on the shoulder during a crash. In this study, half of the occupants had their shoulder belt in an optimal mid-shoulder position. Approximately 60% of the occupants had a safe shoulder belt position; either mid-shoulder position or towards the neck, providing good protection in a crash. The remaining, almost 4 in 10, had their safety belt positioned on the edge of the shoulder or off the shoulder. For those occupants, depending on the crash and influenced by the safety belt geometry and technology (e.g. pretensioner), the shoulder belt might slip off the shoulder in a crash, potentially resulting in injuries to internal organs and/or head impacts.

Keywords: Safety belt, shoulder belt, belt fit, passenger cars, user study

Introduction

The three-point safety belt was introduced and put in production 1959, based on the basic principles of protection, also called Volvo's basic restraint philosophy, as defined by the Volvo safety engineer Nils Bohlin (Bohlin, 1977). The safety belt has been refined over the years, including retractors and different types of pretensioners and load limiters, resulting in improved protection and comfort (Bohlin, 1981, Jakobsson et al. 2007 and 2015). Nevertheless, Bohlin's basic principles of protection remain; a) easy fastening – one hand operation and one common adjustment unit for both lap and diagonal belt, b) effective protection keeping upper torso and lower body effectively restrained, and c) load the strongest parts of the body - over the pelvic bone and across the chest and shoulder.

60 years later, the safety belt is still the primary restraint in a passenger car (NHTSA 2019). By keeping the occupant restrained to the car in case of a crash, it provides access to a host of safety technologies, such as the advanced car body design and auto brake systems, in addition to all restraint technologies, including airbags and advanced safety belt retractors.

The safety belt provides protection in all crash situations. Especially in frontal impacts, it is fundamental in its interaction with the human body. To be effective in a crash, it is essential to ensure that the safety belt restrains the strong parts of the body; the pelvic bones and across the chest and over the shoulder (Adomeit 1975 and 1977, Bohlin, 1977). The lap belt position is crucial in helping avoid lap belt interaction with the abdomen. In addition, restraining the pelvis is fundamental for the upper body to "pitch forward" as described by Adomeit (1975 and 1977). Information on the lap belt routing is not included in this study, although it is an important area and a prerequisite for full efficiency of the shoulder belt performance. Prior studies emphasize the challenges of providing optimal lap belt interaction for different types of occupant shapes and is of increasing importance in the growing population of ageing and obesity (Reed et al. 2012 and 2013, Bohman et al. 2019, Osvalder et al. 2019).

This study focuses on the shoulder belt position. An optimal shoulder belt position is on mid-shoulder, ensuring good interaction with the strong parts; across the chest and over the shoulder (Adomeit 1975 and 1977, Bohlin 1977). Non-optimal shoulder belt position is when the shoulder is not engaged, such as when positioned on the arm or even under the arm. "*Placing the shoulder belt under the arm is a means of relieving neck irritation and other complaints from shoulder belts but may result in serious or fatal injuries*", as reported by States et al. (1987). There are several influencing factors for shoulder belt routings off the shoulder; e.g. belt design in the car in relation to height, depth and width of the shoulder, sitting posture away from the most direct routing of the shoulder belt, or even adjusted shoulder belt more outboard due to comfort or other reasons.

Wearing the safety belt is the foundation of occupant protection, hence it is essential to understand occupants' perception and usage of the safety belt. Studies of people in everyday life provide important information that can inform safety belt design, especially from a comfort and usability point of view. This work is in line with the statement by Nils Bohlin (1981) based on the first decades of experience with the three-point safety belt: "*Volvo safety belt development gives priority to comfort and aims to turn a possible negative and neglecting attitude of the occupant into a positive attitude. And this comfort line has meant much to the overall effectiveness of the Volvo belt installation and to increased belt use*."

Several studies have been conducted investigating factors behind safety belt usage (belt yes/no; Cunill et al. 2004, Nambisan & Vasudevan 2007, Bao et al. 2015), and usability (take on / off; Ebert & Reed 2002), in addition to studies of safety belt position over the body. Shoulder belt fit studies have been conducted in the laboratory, to understand how shoulder belt position may vary due to age and BMI (Reed et al. 2012 and 2013). Other studies focusing on safety belt fit and elderly in their own vehicles, showed that about 47% had poor belt fit, and one fifth would reposition the safety belt due to discomfort (Fong et al. 2016, Brown et al. 2017). Other studies of safety belt fit for elderly showed a high portion of mid-shoulder belt fit. However, in cases with non-optimal belt fit there was low awareness, with few participants recognizing the non-optimal belt fit (Bohman et al. 2019, Osvalder et al. 2019).

Unfortunately, there are few studies monitoring adults' belt fit during driving or riding. Driving studies with children show that shoulder belt position varies over time during the ride, due to activities and discomfort (Andersson et al. 2011, Jakobsson et al. 2011, Osvalder et al. 2013 and Cross et al. 2019), in addition to evasive vehicle movements (Bohman et al. 2011, Stockman et al. 2013 and Baker et al. 2017 and 2018). Graci et al. (2018) studied nine adults and six children in a vehicle subjected to a constant radius manoeuvre, designed to produce lateral acceleration, providing insight into bracing strategies and kinematics in this type of evasive event potentially preceding a crash. It is obvious from these studies that individual occupant aspects (such as age, size and shape) as well as study set-up influence the outcome. Hence, there is need for further studies, using a variety of methods on collecting and analysing data on safety belt fit, especially in real world like situations.

The objective of this study is to gather safety belt usage information from everyday situations, by analysing a large number of photos of people sitting in a car wearing the safety belt. Specifically, the shoulder belt position is studied and categorized into different positions. The finding of the study will help to improve the usability and thereby the acceptance of the safety belt in future cars, having impact on overall occupant protection.

Methods

This study was made as a second step of the E.V.A. (Equal Vehicles for All) Initiative, launched in March 2019 (Volvo Cars, 2019). With the purpose of using crowd sourcing via social media (Instagram) to collect information from every day safety belt usage, the current study was launched in September 2019. The study is named after the hashtag used when contributing: #SelfieForSafety. The information provided on Volvo Cars' international website on the purpose of the study is shown in Figure 1.

> #SelfieForSafety
>
> ***Next step for the E.V.A. Initiative:*** *Your next selfie could help save lives. Simply showing us wearing your safety belt could help give us valuable insights into individual road safety. We want to create a crowdsourced study of car safety and share it with the world — so we can continue to help make all cars safer.*
>
> ***Turning selfies into safety research:*** *This study aims to gather valuable safety belt usage information from everyday situations. This initiative was created together with Dr. Lotta Jakobsson and Volvo Cars Safety Centre, with a view to help improve the usability and acceptance of safety belts in future cars. If successful, the findings could help to enhance overall driver and passenger protection. This would help to improve the usability and thereby the acceptance of the safety belt in future cars, having impact on overall occupant protection.*
>
> *Volvo Cars will review and contact the participants for their approval to use their selfie. Those who agree will be marked as "responder". Each "responder" photo will then be used to learn about human behavior through real-world scenarios, and even highlight areas of further studies for Volvo Cars Safety Centre to pursue. By the end of 2019, the report will be made available for anyone to download. Just like The E.V.A. Initiative, we hope it will lead to safer cars for all*

Figure 1. The information of the study

Recruitment

Data collection took place 2-23 September 2019. Information was published globally through social media channels, mainly; Instagram, Facebook, Twitter, LinkedIn and YouTube. Special efforts, including engaging with influencers on a global as well as market specific level, were executed to spread the message. The information at Instagram, providing details on how to contribute, is displayed in Figure 2. It was posted at the site throughout the time of collection.

Figure 2. The information on Instagram on how to contribute to the study

For each photo/selfie fulfilling the inclusion criteria listed in Figure 2, an acceptance of terms and conditions was sent out. Those who accepted the terms and conditions, and who were not excluded for other reasons (see lists below) were included in the dataset for analysis.

The following list summarizes the inclusion criteria:

- Tagged correctly: #SelfieForSafety and @volvocars
- Public Instagram profile
- Relevant photo: restrained occupant in passenger car
- Adult (aged 18 or more)
- Acceptance of terms

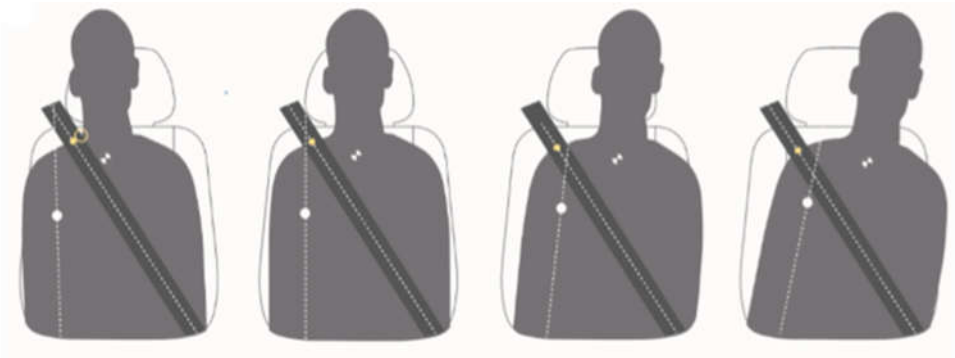
The reasons for exclusion and their corresponding frequency (in brackets) were the following:

- Pending (137) or declined (19) terms
- Deleted content (42)
- Underage (41)
- Copies (25)
- Poor view (40)
- Unrestrained (11) or holding the seatbelt (7)
- More than 2 people in the photo (3)
- Not relevant in other way (23), e.g. teddy bear, dog, outside car, helicopter, driving or video

In total 740 people showed active interest in contributing to the study by tagging #SelfieForSafety and @volvocars. A total of 394 individuals fulfilled all the inclusion criteria and are included in the analysis. The participants represent a wide international distribution as well as a large variety of cars.

Shoulder belt position categories and analysis

By analysing the selfies, every participant was categorized according to five shoulder belt position categories; ‘on neck’, ‘mid-shoulder’, ‘edge position’, ‘off the shoulder’ and ‘other’, as illustrated in Figure 3. A two-step process was applied. An initial categorization was made for each selfie as soon as it was clear that all participation criteria were fulfilled. At the start of the aggregate analysis, a review of the selfies in each shoulder belt position category was made to ensure consistent categorization. Inconsistencies were corrected by readjusting the categorization for some participants.



‘on neck’ ‘mid-shoulder’ ‘edge position’ ‘off the shoulder’ ‘other’

Figure 3. Shoulder belt position categories

As part of the analysis, each selfie was reviewed, and information was added on sex (male, female or unknown) and seat position (left or right front occupant, rear seat occupant, or unknown). When visible, an estimation of height of shoulder in relation to the top of the seat backrest was made (lower, approximately same height, higher). In addition, those who were changing their posture to take the selfie were identified.

Results

When categorizing the 394 occupants according to the above shoulder belt position categories, it can be seen that half of the occupants have their shoulder belt in an optimal 'mid-shoulder' position, Figure 4. The majority of the occupants (61%) have a safe shoulder belt position; either 'mid-shoulder' position or towards the neck ('on neck' position); 193 (49%) and 49 (12%), respectively. 131 (33%) of the occupants have their shoulder belt on the 'edge position', while 21 (5%) have their shoulder belt 'off the shoulder'.

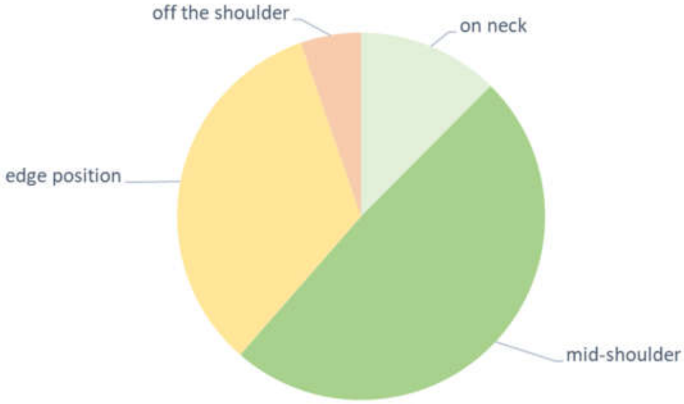
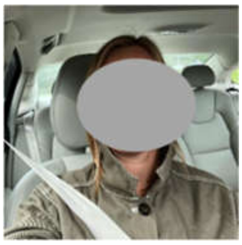


Figure 4. Shoulder belt position distribution for the 394 occupants included in the study

Examples from the four categories are shown in Figure 5. Generally, the 'mid-shoulder' (b) or 'on neck' (a) positions are considered a safe shoulder belt fit, while on the 'edge position' (c) or 'off the shoulder' (d) are non-optimal.

a.'on neck'

b.'mid-shoulder'



c.'edge position'

d.'off the shoulder'

Figure 5. Examples of the four shoulder belt categories

The participant data is evenly distributed between women and men; 196 versus 198. When comparing shoulder belt position distribution for women and men, some differences are seen, see Figures 6a and 6b. No major difference with respect to a safe shoulder belt position ('on neck' or 'mid-shoulder') is seen; women 63% as compared to men 60%. More women are categorized into the two extreme positions; 30 women as compared to 19 men have 'on neck' shoulder belt position and twice as many women (14 as compared to 7) wear their shoulder belt in an 'off the shoulder' position.

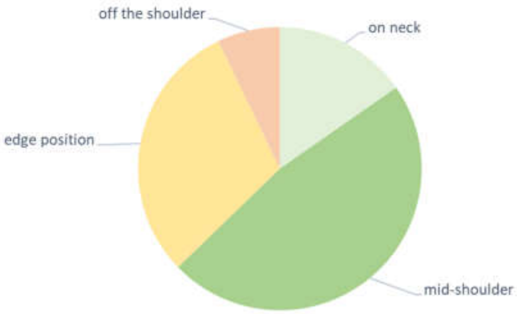


Figure 6a. Shoulder belt position distribution for the 196 women included in the study

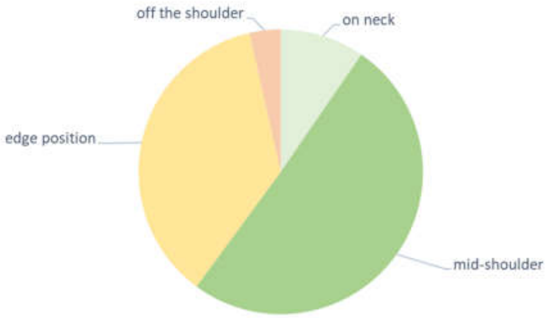
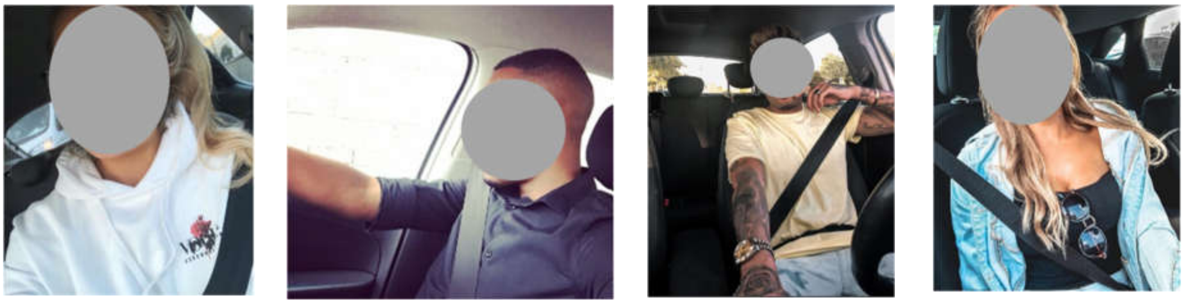


Figure 6b. Shoulder belt position distribution for the 198 men included in the study

All occupants are categorized in one of the shoulder belt position categories, hence no one is assigned the category 'other'. In this study, no really poor shoulder belt position was seen, such as shoulder belt routed under the arm or far down on the arm. Figure 7 displays some of the least favourable shoulder belt positions within this study. For all of them the shoulder belt passes over the arm, below the shoulder. None of them are significantly influenced by making a pose when taking the selfie.



a. b. c. d.

Figure 7. Examples of the most unfavourable shoulder belt positions within the study. All of them are categorized as 'off the shoulder' position.

All of the four examples in Figure 7 are categorized as shoulder belt position 'off the shoulder'. Of the 21 with 'off the shoulder' position, eleven are seated in the front right seat, eight in the left front seat and for two occupants it is not clear whether they are seated in the front or rear seat. There are no obvious differences in trends between the right or left front seat. In most cases it is not possible to see whether they are in a driver or passenger seat (contributions from both left- and right-hand drive cars).

Upper body lateral translation has an influence, but it is not the only reason for 'off the shoulder' position. The majority are sitting centrally in the seat, while seven occupants make poses that influence their lateral tilting, e.g. inboard leaning due to taking the selfie (examples in Figures 11a and 11b), or simply just leaning inboard as in Figure 5d.

Based on estimations of shoulder height in relation to top of seat backrest, shoulder height below or equal are more frequent within this shoulder position category, which also corresponds to the higher share of women. When checking for potential influence of lateral tilting or translation in sitting posture, this trend is still seen. The following numbers are seen (in brackets those who have no or minor lateral translation):

8 (6) shorter; 5 (4) equal; 5 (3) taller. Examples of occupants with different “sitting heights” are shown in Figure 8.

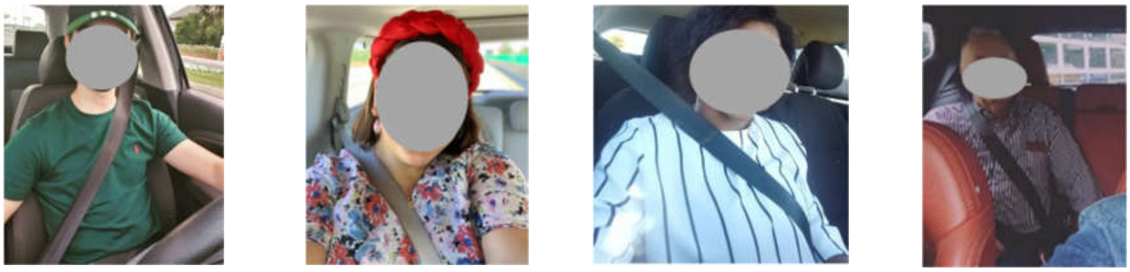
a.shorter *b.equal* *c.taller*

Figure 8. Examples of occupants with different shoulder height in relation to the top of the seat backrest. All three are categorized as ‘off the shoulder’ position.

Of the 49 occupants having shoulder belt towards their neck (category ‘on neck’), 30 are women and 19 are men. As for the occupants in the ‘off the shoulder’ category, the majority are sitting upright and centrally in the seat. Three of the occupants make poses; one of them is shown in Figure 11c.

One of the three rear seat occupants with shoulder belt ‘on neck’ is shown in Figure 9d. Although few, there is a relatively high share of rear seat occupants in this category; three out of the 45 for whom the seat position could be established when viewing the selfies. The comparative numbers for the other shoulder belt position categories are; 5 of 181 with ‘mid-shoulder’ position and no occupant among the 130 ‘edge position’ and 18 ‘off the shoulder’ categories, with known seat position.

Figure 9 displays four of the occupants categorized as ‘on-neck’ shoulder belt position. They are all examples on how design of the safety belt geometry (e.g. the shoulder belt outlet position) and body size and shape influences where the shoulder belt ends up over the shoulder.



a.front left occupant *b.front right occupant* *c.front right occupant* *d.rear seat occupant*

Figure 9. Examples of occupants with ‘on-neck’ shoulder belt position

Among the occupants categorized as ‘on neck’ shoulder belt position, 34 are either below or equal in shoulder height to the seat backrest top, while only five are above (ten cases cannot be judged). Figures 9a and 9c are examples of shoulders below the seat backrest top, while the woman in Figure 9b is judged to have her shoulders above the seat backrest top.

Some vehicles have adjustable shoulder belt outlets. By adjusting them, the occupant can influence the shoulder belt position on the body. In the current study, the shoulder belt outlet was visible only in a few cases, hence no conclusions could be drawn regarding their availability or usage. Nevertheless, some examples are shown in Figure 10, to highlight this issue and as inspiration for further studies. The woman in Figure 10a would benefit from adjusting the belt outlet to a lower position, while the men in Figures 10b and 10c would benefit from adjusting it to a higher position. Figure 10d is an example of optimal position of the shoulder belt outlet, for this man in his chosen adjustment of the seat.

a. 'on neck'   b. edge   c. edge   d. mid-shoulder

Figure 10. Examples of shoulder belt height adjustability.

Discussion

The main objective of this study is to categorize shoulder belt position on a large set of car occupants around the world. To our knowledge, this study is the first of its kind to use "public responses" contributing with photos to study the topic of car occupant protection. Despite limitations due to non-controlled measurement set-up, it provides important contribution on a randomized selection of car occupant sizes and ages. In addition, the contribution is global and adult occupants in a large variety of sizes and vehicles have been categorized, providing input to safety belt usage in everyday situations.

The study identifies that half of the occupants are wearing their shoulder belt in an optimal 'mid-shoulder position'. When adding the occupants with the shoulder belt position 'on-neck', approximately 60% of the occupants are wearing the shoulder belt in a safe position in case of a crash. The remaining (4 in 10) are wearing their shoulder belt on an edge shoulder position or off the shoulder. Depending on the crash situation, and the safety belt technologies (e.g. pretensioners) they are on the borderline for good shoulder belt interaction. By understanding the distribution of shoulder belt positions and the influencing factors behind, improvements can be made targeting a mid-shoulder position for all occupants.

The method used in this study is different from prior studies within this area. It benefits from a large and wide participation, but also struggles with getting aligned input from a methodology and analysis perspective. When calling out for contribution, it is challenging not to reveal too much of the study objectives, while still provide enough information for participants to sign up. Special caution was taken not to mention the exact research questions regarding shoulder belt position. The message to the potential participants included information such as "wearing your safety belt", "gather belt usage information from everyday situations" and "to help improve the usability and acceptance", see Figure 1. However, it cannot be excluded that the participants were influenced by trying to address an optimal routing, according to their own definition. One indication of such efforts is that there was no participant with 'other' shoulder belt position, which could have included routing under the arm, behind the back or very low on the arm. On the other hand, the relatively large number of 'edge position' and 'off the shoulder' cases indicate that the focus was on the safety belt in general, rather than the shoulder belt routing specifically. Nevertheless, it is important that the results of the study are interpreted in the context of the study set-up, looking at trends rather than details in the numbers.

It can be questioned whether the act of taking the selfie influences sitting posture and shoulder belt position. The vast majority of the participants in the study were sitting upright in the seat. 22 of the 394 participants in the study were classified as posing when taking the selfie, defined as influential (see examples in Figure 11). They are distributed among all shoulder belt position categories (4, 4, 8 and 6 from 'on-neck' position moving outboards) and equally many women and men. None of the poses are extreme; typically, they are rotated as in Figures 11b and 11c or leaning laterally as in Figures 11a and 11d. Although likely related to the action of taking the selfie, the postures as such are relevant for car occupants in everyday situations, potentially occurring during activities when riding in the car or during evasive vehicle manoeuvres. When excluding the 22 occupants making influencing selfie poses in the calculating of the shoulder belt position distribution, no major differences (less than 1% in results) are seen in comparison to what is displayed in Figure 4.

a.'off the shoulder' *b.'off the shoulder'* *c.'on neck'* *d. 'mid-shoulder' and 'edge position'*

Figure 11. Examples of occupants assuming a pose when taking the selfie.

The low number of potentially influencing poses was not expected, nor the clear majority of upright and proper sitting postures. The latter might actually encompass a too aligned population in the dataset, as compared to what is likely to be seen in real-world situations. With this limitation in mind, the study still represents an important contribution in terms of the wide variety of occupant sizes, car models and international spread. Hence, the results related to comparison between the different categories, in addition to all the information that can be obtained from each selfie, are valid and provide valuable and unique complement to other studies of adult safety belt fit (Reed et al. 2012 and 2013, Fong et al. 2016, Bohman et al. 2019 and Osvalder et al. 2019).

The method used in this study does not control for the influence of different photo views. In the majority of the cases, the selfie is a front view of the occupant, as shown in most of the Figures in this report. In five of cases the photo was taken from a pure lateral view, making the categorization of the shoulder belt position more difficult. A defined photo view would provide a more precise categorization and thereby improve quality. In the studies monitoring children riding as passengers in normal traffic, a standardized mounting of the cameras was used (Andersson et al. 2010, Jakobsson et al. 2011 and Osvalder et al. 2013). So did Bohman et al. (2019) and Osvalder et al. (2019) when documenting sitting postures and safety belt positions on older and younger adults in stationary cars. While those studies provided more comparative and exact categorizations than possible in the current study, the number of participants is also lower. The study by Fong et al. (2016) using photos taken by the researchers of 380 drivers in their own vehicles, for later analysis of belt fit, share some similarities with the current study, although being limited in occupant ages and location. The present study provides insight into whether the method of crowd sourcing contribution offers relevant data for improving safety belt usability and comfort. The findings confirm that this is the case, mainly motivated by the contribution of the large spread of occupant sizes and vehicles, in addition to the global aspect and the large number of participants.

In total 740 individuals tagged selfies according to instruction. With 394 individuals included in the study, 346 submissions did not fulfil all the inclusion criteria. It should be noted that a large amount of the exclusions (156) were related to accepting the terms and conditions, as sent out after receiving the initial image, reflecting the challenge of using personal data in this type of study. It could also imply that those who chose to participate might be extra motivated and influenced by the safety concept and/or the Volvo brand. 42 selfies were deleted by the owner and therefore not accessible for the study. 25 photos were excluded being duplicates, 40 were due to poor view and a few included too many people in a single photo. The rest (74) did not fulfil the study inclusion criteria which asked for "restrained adult occupant in passenger car". Reasons for exclusion ranged from teddy bears and under aged, to helicopter passenger, including eleven cases with unrestrained occupants.

Participation was evenly distributed between men and women, so the overall conclusions are not influenced by sex. While there were some differences in the four shoulder belt categories, these seem to be more influenced by occupant size rather than sex (in combination with the vehicle and seat position they are in, influencing the shoulder belt routing).

Although it is safe to position the shoulder belt close to the neck, it can cause discomfort whereby actions are likely to be taken. These actions could be critical from a safety perspective, exemplified by placing the shoulder belt under the arm, helping it to stay away from the neck. Brown et al. (2017) conducted a study of 380 elderly drivers, of whom 20% would reposition the safety belt due to discomfort. Actually, every fourth person who repositioned the belt, put the belt behind the back or under the arm (Brown et al. 2017). States et al. (1987) investigated six cases with fatal outcome caused by under-arm use of the shoulder belt. Severe internal organ injuries occurred in those crashes, otherwise judged as survivable crashes; due to the loads into the lower chest and upper abdomen imposed by the shoulder belt in the under-arm position.

Another action to address discomfort when shoulder belt is close to the neck, is to manually route the shoulder belt over the shoulder edge down on the arm. Discomfort, avoiding wrinkles on the shoulder part of the clothes, in addition to mal-instructions (perceived to be safer) are examples of possible reasons behind this re-routing. To really understand the underlying reasons for this action, a study set-up including a dialogue with the participants is needed.

The contribution from this study, related to the topic of "enhancing protection by avoiding actions due to discomfort", is to study the cases with 'on neck' shoulder belt position targeting 'mid-shoulder' position for as many as possible. Among the 49 occupants categorized as 'on neck' shoulder belt position, there is a majority of women as well as shorter occupants (judged based on their shoulder height in relation to the seat back top). Exemplified in most of the selfies included in this report, it is obvious that shoulder belt geometries in the car varies and influences the shoulder belt position. When comparing the four occupants in 'on neck' shoulder belt position shown in Figure 9, the two occupants having their shoulder height above the backrest (one of them in the rear seat) would benefit from a higher shoulder belt outlet, while the other being shorter would benefit from a lower belt outlet in relation to where their shoulders are. Obviously, the seat position and its adjustments (when possible) influences this as well, making this a complex task to address in vehicle design.

If the pelvis is well restrained, the shoulder belt will not interact in an injurious way with the neck/throat, even if the shoulder belt is placed towards the neck. Hence the myth of shoulder belt strangling if too close to the neck is incorrect.

The routing of the shoulder belt is influenced by the body shape. Comparing 22 individuals with variation in age and BMI, Bohman et al. (2019) identified that the participants with higher BMI were more likely to have the shoulder belt closer to the neck due to the lower part of the shoulder belt being higher up on the abdomen. Comparing the occupants in Figure 9, the influence of body shape on belt routing can be seen. Hence, there are several factors influencing the routing and the comfort of the shoulder belt. More studies and of different types are needed to help guide vehicle designs. Such studies should be a combination of controlled user studies with detailed measurement, Naturalistic Driving studies monitoring the occupants when driving/riding in the car, and collecting data on perceptions etc.

In the present study, a substantial number of occupants have shoulder belt position on the edge or off the shoulder. Among the 21 occupants with ‘off the shoulder’ position, upper body lateral translation is seen influencing, however not as the only reason. As for the occupants with shoulder belt in ‘on neck’ position, a trend towards women and occupants with shorter sitting height is seen. Logically it would be the opposite to what is seen for the shoulder belt ‘on neck’ position, and no clear explanation to this can be seen in the data available except that the main influencing parameters are likely due to the combination of vehicle design and occupant sizes in each case. As exemplified in Figure 7, the varieties are so diverse in this data set making these results possible.

It is important to make people aware of possibilities to improve the shoulder belt fit by using the shoulder belt height adjusters, which are available for both front seats in many cars. There are also possibilities to influence the shoulder belt fit by changing the seat position. In the study by Osvalder et al. (2019), it was estimated that for those participants with poor shoulder belt fit, the belt fit would have been improved if the participant had used the shoulder belt height adjuster and/or also adjusted the seat position. Generally, shorter women benefit from raising the seat when possible. This study showed examples of how the height adjuster have been adjusted properly as well as how poor adjustment contribute to poor shoulder belt fit, Figure 11. However, no information on seat position adjustments could be collected.

Shoulder belt position at the ‘edge position’ or ‘off the shoulder’ is considered as non-optimal shoulder belt positions. Depending on crash type and the shortest distance between the shoulder belt attachment points in relation to the occupant’s torso, the shoulder belt could either interact with the torso over the strong parts or moving down the arm while the occupant’s upper torso slides out of the belt. The latter will result in a restraint situation similar to the under the arm position, as described by States et al. (1987). If the safety belt is equipped with a pretensioner being activated, the webbing will be tightened prior to the occupant movement in the crash. In some cases, it can help moving the shoulder belt into a better position. The direction of movement is depending on the positions of the shoulder belt attachment points, between which the webbing will be straightened. If this straight line deviates a lot from where the occupant’s shoulder is, it is not as effective. Nevertheless, the pretensioner will reduce the slack in the safety belt by bulky clothes or similar, which always is favourable for the occupant’s protection. Today most cars are equipped with safety belt pretensioners in the front seats, however this is not the case for all rear seats.

Figure 12 visualizes the consequences of safety belt use and routing for three configurations in a frontal impact with a midsized female human body model; a) optimal belt routing for both lap and shoulder belt ('mid-shoulder'), b) unrestrained, and c) shoulder belt placed under the arm. As can be seen in Figure 12a, the occupant is well restrained over the pelvis area; enabling the torso to bend forward (torso pitch), loading the strong parts of the chest, across the ribcage and over the shoulder, routed in 'mid-shoulder' position. In this way, the loads are distributed over strong parts of the body, controlling the forward head excursion, and the torso pitch helps to lower the loads in the neck. Figure 12b illustrates the consequences when the shoulder belt is in a non-optimal position, in this example placed under the arm. As can be seen, the consequences are less efficient restraint, resulting in shoulder belt interaction with vulnerable body regions such as the softer lower part of the rib cage and the internal organs, in addition to causing increased head excursions, with increased head impact risk. When unrestrained (Figure 12c), the occupant is not connected to the car and will move forward until something stops the movement, in this case the front seat, with obvious increased risk for injuries.

Figure 12. Crash simulations comparing occupant trajectories for a) correctly restrained, b) incorrectly restrained – belt under the arm, and c) unrestrained, with a rear-seated mid-sized female human body model, ViVA (Östh et al. 2017); Initial position (left) and most forward position (right).

Conclusions

The safety belt is the most essential occupant protection system in cars. This study focuses on the shoulder belt position, collecting data from a large and diverse population.

For optimal protection, the shoulder belt should be placed, and remain, on the shoulder during a crash. Studies on real-world usage form an important contribution on which factors influence safety belt usage and positioning. Few studies on occupants' shoulder belt position in cars are available, mostly comprising small samples of occupants. Therefore, this study incorporating a compilation on occupants' shoulder belt positions of a wide variation in occupant sizes, car models and international contribution, is valuable and unique.

This study shows that approximately 60% of the occupants have their shoulder belt on mid-shoulder position or close to the neck. The remaining, almost 4 in 10, have their shoulder belt positioned on the edge of the shoulder or off the shoulder. Depending on the crash and influenced by the safety belt geometry and technology (e.g. pretensioner), the shoulder belt might slip off the shoulder. Whereby, the injury risk will increase, potentially resulting in injuries to internal organs and/or head impacts.

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