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lap belts and three-point belts

A comparison of effectiveness

INSTITUTE FOR ROAD SAFETY RESEARCH SWOV

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Contents

Foreword

Many reports have been published in recent years on car seat belts and more particularly on their usefulness in case of accidents. However, there are not many publications dealing with the comparison of the known types of seat belt (lap belts, three-point belts and diagonal belts).

There is a chance that international discussions on the design principles of seat belt anchorage points and seat belts in motor cars, may result in proposals that the use of lap belts should be discouraged, if not completely banned, based on an assumed considerable difference between the effectiveness of three-point belts and lap belts. The Dutch Department of Road Transport RDW of the Ministry of Transport and Waterways, representing the Netherlands on EEC and ECE-level, requested the Institute for Road Safety Research SWOV on December 18th 1974 to reconsider this problem and to draw up a report, on the basis of the SWOV accident analysis and studies carried out by other researchers.
On each occasion the Dutch representatives emphasised that – although three-point belts ensure a better protection than lap belts – the difference in effectiveness does not indicate that the use of lap belts should be prohibited. A more recent investigation proved that the protection for certain people in conjunction with certain car types is not adequate in the case of using three-point belts and that the difference in effectiveness between lap belts and three-point belts is still less important than has been assumed until now.
The report on this investigation was put up for international discussion in February and March 1975.

The considerations contained in the present report on the differences in effectiveness are based on data derived from several studies relevant to this subject.
In the first place the SWOV-*accident investigation* should be mentioned; this is a very extensive investigation, covering about 22,000 drivers, the data for which refer to Dutch passenger car accidents and had been collected from the end of 1968 till the beginning of 1971 (a short description of this investigation can be found in Par. 1.1.).
A special feature of this investigation was the fact that the Netherlands offers the unique situation in which all three types of seat belt are used in cars in a more less equal number, so that sufficient material could be collected for all three types – a situation which still prevails, to some extent, in this country.
Although an earlier publication (Edelman & Van Kampen, 1974) dealt thoroughly with the *injury pattern,* established for persons not using seat belts and using different types of seat belt, with an intercomparison of these results, the conclusions drawn from this publication are summarised where they seem to be applicable.

In the second place, a critical assessment has been made of reports on foreign accident investigations, which were known by SWOV. These reports have been

carefully sifted with regard to the *statistical reliability* of the presented material; the criteria for reliability being that they refer to a sufficiently large number of cases (accidents) and that the results are given with an indication of the limits of reliability.

In the third and last place practical aspects have been taken into account, for example, the applicability of seat belts in cars, problems with the correct position of the anchorage points, and the comfort of the belt users.

Although the present report is mainly concerned with a comparison of lap and three-point belts, diagonal belts will be discussed as well, since this type of belt also featured, in fairly large numbers, in the SWOV investigation.

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Introduction

In most countries where accident investigations are being carried out (such investigations necessarily forming the basis for determining whether the use of seat belts reduces the number and severity of injuries, if at all) mainly one type of belt is in use. Therefore it is hardly possible to make assessments concerning the differences in effectiveness of various types of belt, on accident data referring to one type of seat belt only. In spite of this there are publications presenting conclusions on the assumed effectiveness of seat belts, other than those which were actually investigated. This mainly occurs in the case of three-point belts and lap belts, the prevailing opinion favouring the three-point belt.

Moreover, the assessment of effectiveness of a given type of seat belt cannot be accepted exclusively on the basis of, for example, laboratory tests with dummies and bodies. The biomechanical knowledge and the representativeness of such tests, necessary for the right interpretation of such results, are not yet developed to the required degree. However, such tests can be useful as auxiliary means for improving the safety of cars, as has been proved by the abundance of results obtained by the ESV (Experimental Safety Vehicles) Studies. The assumed effect of improvements will still have to be tested by means of accident investigation.

Accident investigation, carried out on a quantitatively and qualitatively representative number of accidents, is the only way to determine the effect of seat belts and other safety measures.
Based on the data obtained, together with (national) accident statistics, it is then possible to establish the expected reduction of fatalities and injuries (effectiveness) in connection with seat belts.
The practical reliability of data and particularly the knowledge of reliability *limits* will play an important and relevant part in assessing the results.

1. The SWOV-accident investigation

1.1. **General**

From September 1968 to January 1971 police and ANWB road patrol reported accidents involving motor cars, both in and outside of built-up areas. The regions concerned were representative for the major part of the country.
General data referring to the accidents were collected by means of questionnaires, which had to be completed and returned by the drivers involved. The questionnaire covered mainly general data relating to the circumstances of the accident, personal data of the driver and passengers, and information about injuries, if any. 60% of the persons involved returned the completed questionnaire, the total amounting to more than 22.000 drivers.
On the basis of information provided by the drivers, the medical data has been amplified, checked and then classified (see Par. 1.2.).
The damage caused to the cars was reported in detail by special teams, who traced the cars involved from data supplied by the driver or police. However, this system did not function entirely satisfactorily. A considerable improvement was obtained by processing damage reports concerning cars involved in accidents and found in garages, repair workshops and scrap car yards all over the country, for which SWOV then obtained the corresponding data of the accident in which the car was involved, from the police. This information was subsequently incorporated in the normal registration system, based also on the data supplied by the drivers. This amplification of data did not cause a significant shift in the representativeness of the total amount of accidents with regard to the accident registration in the Netherlands. A damage report was established for about 35% of all accidents.
In addition, a more concise damage report has been drawn up by the damage team for each of the 22,000 cars, on the basis of the data supplied by drivers or police. After having studied the reports, a satisfactory correlation was established between the two kinds of damage reports obtained as described above.

After coding the material, all data on the accidents investigated were processed by a computer; and analyses were carried out, partly by means of multivariate techniques. More information concerning this investigation can be found in the publication by Paar & Van Kampen (1972).

1.2. **Collection and classification of injury data**

The amplified special form for medical data referring to each injured driver or passenger was put at the disposal of Dr. J. Masereeuw (surgeon), who at that time was on the staff of the Institute of Biomechanics and Rehabilitation of the Free University, Amsterdam. Based on a code-list, Dr. Masereeuw assessed the type and

severity of injuries (insofar these were indicated by the driver or police). In the case of serious injuries or doubtful cases, Dr. Masereeuw contacted the general practitioner or specialist treating the patient in question.
The code-list, with the indication of about 150 different types of injuries, was additional to the system published by the Medical Records Association SMR, Utrecht (SMR, 1969), based on international agreements. The classification according to the severity of each injury can be compared approximately to the AIS (Abbreviated Injury Scale)-system, (Fenner, 1969 States et al, 1971). The most serious injury was taken as decisive for the overall injury-severity category, the condition of the person involved being indicated by the following classification:
0 = no injury
1 = light injury
2 = moderate injury
3 = severe injury
4 = dangerous injury
5 = life-threatening injury
6 = fatal injury

It has to be observed that specific injury data could be obtained from only about 50% of the persons sustaining fatal injuries. The difficulties usually encountered in carrying out autopsies in the Netherlands cause a considerable loss of very important information (Aarts, 1973).

1.3. **Comparison of various types of seat belt**

The following analysis covers both the groups of drivers (about 22,000 persons) as well as the group drivers + front-seat passengers (about 31,000 persons). A separate group comprising front-seat passengers only, was not regarded large enough for accurate analysis and break-down according to all the influencing factors, relevant to the subject.
Both when comparing the group of belt-users and non-users, and when comparing the users of various types of belt, it is of great importance that no significant differences exist with regard to the most decisive accident parameters, such as type of collision, severity of damage, etc. This aspect has always been most carefully taken into account in the SWOV-accident investigation.

Tables 1 and 2 give the breakdown in percentages according to the injury-severity, both for non-users and users of various types of seat belt, for the group of drivers and drivers + front-seat passengers, respectively. The injury-severity categories 1 to 6 are so grouped that fluctuations, not relevant to the comparison of the differences in belt types, and very small numbers are eliminated.
From Tables 1 and 2 it can be seen already that the differences in injury-severity with regard to the three belt-types are small compared to the differences between the group of non-users on the one hand and the group of all belt-users on the other hand. A statistical analysis, which is of no great subsequent importance to this analysis, yielded a significant difference between the belt-users and non-users in favour of the belt-users (see later in section 'Effectiveness').

Drivers

Injury-severity	Non-users	Lap belt users	Three-point belt users	Diagonal belt users	All users
0	63,5	65,9	68,2	65,4	66,5
1 + 2	29,1	30,0	28,2	30,1	29,4
3 + 4	5,0	3,2	3,1	3,7	3,4
5 + 6	2,0	0,8	0,5	0,6	0,6
Unknown	0,4	0,1	0	0,1	0,1
Total	100% (20.571)	100% (370)	100% (443)	100% (459)	100% (1272)

Table 1. Break-down of injury-severity for drivers using no belt, a lap belt, a three-point belt, or a diagonal belt, and all drivers using a belt together (percentages).
(The figures in brackets indicate absolute values for the groups in question).

Drivers + Front-seat passengers

Injury-severity	Non-users	Lap belt users	Three-point belt users	Diagonal belt users	All users
0	60,9	65,3	66,3	64,0	65,1
1 + 2	31,0	30,2	29,5	30,9	30,2
3 + 4	5,5	3,4	3,3	3,4	3,3
5 + 6	2,2	1,1	0,8	1,6	1,2
Unknown	0,4	0	0,1	0,1	0,1
Total	100% (28.953)	100% (440)	100% (621)	100% (619)	100% (1680)

Table 2. Break-down of injury-severity for drivers + front-seat passengers, using no belt, a lap belt, a three-point belt or a diagonal belt, and all persons using a belt together (percentages).
(The figures in brackets indicate absolute values for the groups in question).

For the subject of the present report the comparison of users of *lap belts* with users of *three-point belts* is of importance.
For this purpose a more thorough analysis has been carried out, with the aid of *Tables 3 and 4*, covering the group of drivers + front-seat passengers, whereby various different injury-severity categories have been combined in turn, in order to establish the extent of injury-severity differences existing between users of lap belts and users of three-point belts. From all the possible combinations, those two were selected, in which the greatest possible differences could be established.
For both cases the statistical analysis (yielding as result a low chi-square and a high p-value) allows the conclusion to be drawn that the zero-hypothesis, accepted as an initial assumption (i.e. that no significant injury-severity differences exist for users of lap belts and those using a three-point belt) *cannot be rejected.*
Thus, from the statistical viewpoint there is *no difference between lap belts and three-point belts as regards the injury-severity.*

A corresponding analysis has been carried out for the group of drivers alone, which is not included in the present publication. The results and conclusions of this analysis are in complete agreement with the statements regarding the group of drivers + front-seat passengers.

In investigations carried out on the basis of random tests, as in the present case, there is always a certain degree of probability relating to the results, this degree never reaches 100%. Thus, there is always a (slight) chance that deviating results may be obtained. In the following, we shall indicate, how great is the chance, that differences exist between lap belts and three-point belts as regards the injury-severity, and the extent of such possible differences.
From Table 3 it can be determined that the chance of a difference of 7% or greater, between the two groups, is less than 5%.
From Table 4, the chance of a difference of only 3% or greater, between the two groups is less than 5%.
These data show that the *possible* differences between users of lap belts and those of three-point belts with regard to the injury-severity, are of a very small order of magnitude. Moreover, these differences (if any) become smaller as the injury-severity increases.
The corresponding analysis of the group of drivers only, gave similar results.

Effectiveness

The following gives a review of the effectiveness of lap belts and three-point belts. In view of the indicated conformity between both types, the effectiveness of lap belts and three-point belts is considered as a whole. The term 'effectiveness' can be determined as follows:

The effectiveness of a seat belt is indicated by the percentage by which the number of persons with a given degree of injury severity from the group non-users, is reduced by using a seat belt (under otherwise comparable conditions for users and non-users of seat belts).

Drivers + Front-seat passengers

Injury-severity	Lap belt users	Three-point belt users	Total
0	287	412	699
1 t/m 6	153	208	361
Total	440	620	1060

$X^2 = 0.023$; df = 1; $p < .90$

Table 3. Absolute break-down of injury-severity according to non-injury versus injury of drivers + front-seat passengers, using lap belts or three-point belts.

Drivers + Front-seat passengers

Injury-severity	Lap belt users	Three-point belt users	Total
0 t/m 2	420	595	1015
3 t/m 6	20	25	45
Total	440	620	1060

$X^2 = 0.1667$; df = 1; $p < .70$

Table 4. Absolute break-down of injury-severity according to non-injury + non-severe injury versus at least severe injury of drivers + front-seat passengers, using lap belts or three-point belts.

The effectiveness can be established for any *injury-severity* separately or for any combination thereof, as well as for each *type of belt* separately and any combination of types of belt. *Table 5* gives a selection of the possible variations.
It is evident that the effectiveness decreases for categories of lower injury-severity, the lowest degree of effectiveness being obtained in the categories 1 to 6 inclusive. The table shows that the chance of being injured is reduced by about 10% when using lap or three-point belt. In this connection it should also be noted, that the evidently small effect of using a belt, on the chance of remaining completely uninjured in case of an accident, is also related to the fact that a large number of 'non-injured' persons occurs in the total SWOV sample (also in the group of non-users); furthermore it is related to the fact that the term 'injured' is somewhat ill-defined, as the degree of the injury becomes less serious.
The extremely high effectiveness, shown in Table 5, relating to fatal and life-threatening injuries, again emphasises the important reduction in the number of fatalities and very severely injured persons, due to the ever increasing use of lap and three-point belts.

As in the case of all numbers and percentages, obtained in random tests, so also in this analysis, the percentages given include certain tolerances, indicating the limits within which a given certainty exists, that the percentage is correct. Thus, the tolerance for both maximum effectiveness percentages given in Table 5, is about 10% (at a confidence level of 95%). The tolerances for the other percentages are smaller (up to about 2%), because the groups for which these data have been established, were larger.
This is also an explanation for the 60-% effectiveness relating to fatal injuries, as given in the publication (referred to above) of Edelman & Van Kampen (1974). This percentage has been applied by SWOV to the national accident statistics. To be on the safe side, the lower limit of the effectiveness determined at that time, for *lap, three-point* and *diagonal belts* has been used. Since Table 5 does not include the diagonal belt, which is slightly less effective, the effectiveness here indicated for fatal injuries in connection with lap and three-point belts will be somewhat higher (about 90%). Thus, taking into account the tolerances, a *minimum effectiveness* of about 75% can be accepted relating to fatal injuries, for the combined groups of lap and three-point belts.

Injury patterns

As mentioned earlier, Edelman & Van Kampen (1974) investigated thoroughly the background of many different injury patterns, for persons using various types of seat belt in the Netherlands. Also the corresponding differences relating to persons not using a belt are covered in this publication. It is relevant here to repeat the conclusions, since a complete picture of similarities *and* differences can be obtained in this way.
As mentioned earlier, the differences do not appear initially in the injury-severity (unless the combined group of belt-users is considered against the group of non-users), but differences do appear in the diversity of injuries, which form together the *injury patterns.*

Injury-severity	Effectiveness	
	Drivers only	Drivers + Front-seat passengers
6 (Fatal injury)	93%	94%
5 + 6 (Life-threatening + Fatal injury)	70%	59%
3–6, incl. (Severe, Dangerous, Life-threatening and Fatal injury)	46%	45%
1–6, incl. (All injury-severities excl. no-injury)	7%	8%

Table 5. Some effectiveness percentages for lap and three-point belts (taken together).

With regard to the interpretation of the conclusions it is important to know, that the multivariate analysis which yields the above results, can not give complete information as to the quantitative aspect of the differences. This means that essentially a *qualitative* relationship is established, indicating in this case, that a given injury (or a given injury-severity) is more closely associated with *one type of belt than with another.* All the injuries and the injury-severities investigated can, theoretically, occur for users of all types of belt; the analysis only indicates the *direction* in which a *shift* occurs.

The most important conclusion, which also explains to a great extent the beneficial effect of all three types of seat belt, is an association with the *absence of skull injuries* in the case of persons using a belt as compared with persons not using belts. This means, that persons using a belt are *less exposed to* sustaining skull injuries than non-users but not excluding the possibility that belt-users also may sustain skull injuries. Since it is mainly the (serious) skull injuries, (including injuries of the brain) which are liable to cause a relatively high number of fatalities, it will be evident, that this effect of seat belts is of the highest importance.
Another significant conclusion in view of the differences between users and non-users of seat belts refers to the close correlation of the first group with the injury-category 'no injury'.

The analysis concerning the mutual differences in injuries and injury-severity to users of different types of belt, shows shifts mainly of slight injuries, within the injury pattern. Non-severe injuries (injury-categories 1 + 2) formed the largest numbers in the investigation, thus providing excellent material for the multivariate analysis technique, which is characterised by the fact that the effect of all variables concerned can be considered simultaneously.
Three-point belts seem to be associated with the *absence of injury,* (the category 'no-injury' occurs more often here than in connection with other types of belt), also with the *absence of injury* to the right arm and to the skull. This last effect can be observed for all three types of belt, but it is most significant in the case of the three-point belt.
Lap belts are more associated, among others, with slight injuries of the face, as well as bruises on the abdomen. The higher frequency of facial injuries is evidently the result of the 'jack-knife effect', while the second group of injuries most probably is related to the incorrect arrangement of the lap belt (across the abdomen).
Diagonal belts display the largest number of associations with injuries, among which some of moderate severity, for example, bruises on the back and chest.
Diagonal belts and three-point belts, (both having a shoulder strap which is not present in the lap belt), are associated with neck injuries of a slight character (in the investigation indicated as 'whiplash'). Evidently this is an injury caused by the forward jerk of the head. This type of injury occurs less frequently when using a lap belt, because the upper part of the body is not directly restrained.

For more information refer to the publication of Edelman & Van Kampen (1974). This publication also gives an explanation as to why lap and three-point belts (and, to a lesser degree, also diagonal belts) display a comparable effectiveness, based on human anatomy and the various movements, which result from the different seat belts in an accident.

2. Investigations of other institutes

In view of the selection of the investigations to be discussed hereafter the following should be noted.
Nearly all of the about 50 accident investigations SWOV knows of relate to lap belts (used particularly in the U.S.A. in relatively high numbers), and only a limited number to three-point or diagonal belts. These investigations dealt almost exclusively with the effects of only one type of seat belt, for the simple reason that only one type was found available in sufficiently large numbers for investigation.
A condition of the selection was that the sample must allow a statistically representative analysis, i.e. that it must cover at least several hundred persons using the same type of belt. On account of this many investigations had to be eliminated from further analysis at the start.
Investigations into accidents with an unbalanced composition of the severity of injuries, also had to be discarded (for example investigations exclusively into fatal accidents or into accidents only involving very serious injuries), since these would have distorted the representativeness of the sample, and made impossible the assessment of actual effectiveness.
Another important criterion was the comparability of the groups, the differences or similarities of which had to be established (for example, belt-users against non-users). Investigations which did not take this factor into account also would not be considered further.

The comparison of results obtained by researchers from abroad, with one another, and with those obtained by SWOV was further complicated by the differences in the grouping of the applied accident parameters, the most important being the injury-severity scale. In the SWOV investigation, a classification into 7 categories (0 to 6 incl.) was used (see Par. 1.2.). This grouping is more or less in accordance with systems used elsewhere; but no exact comparison between the systems applied could be established.
In order to ensure a better comparison SWOV is in favour of an international injury classification system. Fortunately, efforts are being made in this direction, both within the framework of the 'NATO - CCMS Accident Investigation Program' and also, and more recently, through an international SAE-working group.

The following part contains data relevant to the present subject, collected from the investigation reports which remained after sorting through the investigations. The complete results of the investigations can be found in the original publications. The following investigations are, in the opinion of SWOV, on a very high level, both as regards quality and quantity.

1. **Safety belt effectiveness in rural California automobile accidents** (Tourin & Garrett, 1960)

This somewhat out of date study of accidents occuring outside built-up areas, is concerned with data relating to *lap belts* only. The injury classification comprises, among others, 'fatal', 'serious' and 'slight' injuries.
The effectiveness percentage of lap belts was only determined for serious + fatal injuries. These categories should, in general, correspond to the categories 3 to 6 inclusive of the SWOV investigation. The reduction of 35% which was established is a satisfactory correlation therewith (see Chapter 1, Table 5).

2. **Statistical analysis of 28,000 accident cases with emphasis on occupant restraint value** (Bohlin, 1968)

This investigation covered only accidents with Volvo cars. It could have formed an ideal basis for an objective comparison of various types of belt but for the fact that *three-point belts* are fitted in Volvo cars, almost exclusively.
The data for calculating the effectiveness percentages (which, the Volvo report states, should be treated with caution), yielded the following values (calculated by SWOV):

Drivers	Fatal injury	83%
	Fatal + serious injury	45%
	Serious injury alone	40%
Passengers	Fatal injury	80%
	Fatal + serious injury	68%
	Serious injury alone	67%

Various authors referring to this investigation were, primarily, greatly impressed by the observation that below a collision speed of about 95 km/h not one person, using a three-point belt, was killed. However, the possibility of being killed at relatively low speeds might be independent of belt use, for example, in the case of those collisions from the side with heavy trucks, where the severity of the impact depends almost completely on the other party. Such kinds of accidents (most probably by chance) are not included in the Volvo investigation.

On comparing the above-mentioned effectiveness percentages with the corresponding SWOV results, one has to proceed with great care, primarily due to the uniform car-type covered by the Volvo investigation. However, while no large deviations can be observed in the results, there are differences in both directions.

3. **Efficacy of seat belts in injury and non-injury crashes, in rural Utah** (Kihlberg, 1969)

In this investigation only the effectiveness of *lap belts* was studied. The classification applied, according to injury-severity, comprised a category of 'fatal injury', further-

more the categories of 'serious injury', 'moderately serious injury', 'slight injury' and 'not-injured'.
The effectiveness percentages can be summarised as follows:

Drivers	Fatal + serious injury	54%
Passengers	Fatal + serious injury	47%
Drivers + passengers	Fatal + serious injury	49%

These data can again be compared to the corresponding SWOV injury-severity categories 3 to 6 inclusive (see Chapter 1, Table 5). The results indicate an approximately comparable effectiveness.

4. **Study of seat restraint use and effectiveness in traffic accidents** (Highway Safety Foundation, 1970)

Although in this investigation both three-point belts and lap belts were analysed, the number of three-point belts was not sufficiently large for basing an assessment thereon.
The effectiveness percentages for *lap belts* were the following:

Drivers + passengers	Fatal injury	82%
	Fatal + serious injury	54%

These values are also in conformity with those of SWOV.

5. **The reduction of collision injuries: Past, present and future** (Nahum et al; 1970)

This investigation also analysed lap belts and three-point belts, but in this case also the number of three-point belts was not sufficient to establish significant differences. Although, as a result of the insufficient test material there was no justification to draw final conclusions, the report in question asserts an (assumed) higher effectiveness for three-point belts.
Due to the character of the regression analysis applied, it was also not possible to establish specific effectiveness data for lap belts. Nevertheless, mention is made of a 'highly significant effect in the reduction of injuries when lap belts are used by passengers'. The values obtained, show, in the opinion of SWOV, that lap belts and three-point belts display an effectiveness of the same order of magnitude.

6. **Effectiveness of lap seat belts and the energy absorbing steering system in the reduction of injuries** (Levine & Campbell, 1972)

The accident data relating to the year 1968 collected in this investigation proved that the average effectiveness percentage of *lap belts* with regard to serious injuries amounts to 43% (the corresponding SWOV value is about 30%). A distinct correlation was found between effectiveness and collision speed, in the sense that effectiveness *increases* with *higher collision speed.* This statement is in complete accordance with the findings of the SWOV investigation.

7. **Seat belt usage and benefits in North Carolina accidents** (Council & Hunter, 1974)

This study is partly a continuation of the preceding investigation. The report mentions that due to not having a sufficiently large group of three-point belt users for analysis, no comparison could be made between lap and three-point belts. In spite of this the authors try to prove that the three-point belt is more effective than the lap belt. Although, in relation to drivers a *lap belt* effectiveness of 53% with regard to fatal + serious injuries was established yet.

8. **Comparative injuries to belted and unbelted drivers of sub-compact, compact, intermediate and standard cars** (Campbell et al. 1974)

In this investigation again only *lap belts* are considered. 'Study shows dramatic seat belt benefits' – concludes the research institute involved. The results seem to be valid for all categories of cars investigated, from the smallest sub-compact to the standard American car.
The average effectiveness percentage for all the above car types, with regard to fatal injuries amounts to 70%. It is also pointed out that 'these results suggest a much greater effectiveness than has been expected up till now, even as great as that assumed for three-point belts and passive systems'.

3. Applicability and comfort aspects of lap belts and three-point belts

In view of the fact that the lack of applicability (for example due to a wrong arrangement of anchorage points) and the lack of comfort, have an unfavourable effect on the use of seat belts, or at least may prevent their proper use, the assessment of differences between the types existing at present, is of great importance. Although these problems are not very thoroughly discussed, they give a true picture of the present situation in the Netherlands and most probably in other countries as well.

3.1. **Anchorage points**

In the existing regulations, furthermore in the international regulations which are now under preparation, the possibility that the anchorage points of seat belts cannot be provided at the same place in each type of passenger car, is duly taken into account. For the attachment of the uppermost point of the three-point belt, the B-pillar is selected, as a rule, this position determining the position of the shoulder strap of this belt in relation to the upper part of the user's body. This presents two problems.
Firstly, fastening has to be possible for people of all sizes, short and tall people, who have to adjust the car seat forward or backward depending on girth and leg length.
Secondly, the anchorage point must be fitted at the correct place, in small and large cars, as well as in two or four-door cars.
In some combinations of the above-mentioned factors (e.g. relatively tall persons and small four-door cars, in which the passengers sit towards the rear, with the result that the B-pillar is situated relatively far forward) it is practically impossible to fasten the three-point belt in a satisfactory manner, i.e. so that is is strapped tightly over (the upper part of) the body. It is evident (and repeatedly reported from actual case-studies) that in such a situation the use of a three-point belt does not ensure sufficient protection. For obvious reasons no details will be given here concerning the various combinations of makes and types of cars and seat belts displaying the above-mentioned drawbacks, but the percentage of such cars on the Dutch market can be assumed to be at least 10%.
In such cases, only the use of *lap belts* is possible. The fitting of the lap belt is possible in any type of passenger car, and the anchorage points can always be arranged to be in the correct place, with regard to the person using the belt.

In addition to problems with three-point belts used by tall people, attention must also be paid to problems for children (and other relatively small persons).
The majority of investigators are of the opinion that children under a given age (ranging from 10 to 15 years) should not use three-point belts, designed for grown-up people. There is the risk of injuries to the neck, caused by the incorrectly arranged

shoulder strap; furthermore there are reasons to assume that the mechanical characteristics of the belt, (mainly of the shoulder straps which are of the greatest importance) are not suitable for the body of a child.
However, these problems can be almost completely eliminated by the use of *lap belts*. Certainly, if there is no special safety device in a car provided for children, a satisfactory solution is offered by the use of lap belts from the age when children can sit unaided. It is safer for a child to sit on a front-seat with a *lap belt* than in the back of the car without a belt.

3.2. **Comfort**

Inquiries in many countries have already made it generally known, that objections will be raised against seat belts because of the unfavourable effect they might have on comfort. In addition there are well-known psychological objections, based mainly on a kind of phobia caused by being 'shut-up' in the car.

One of the objections against the use of static three-point belts is the often discussed fact that it makes it nearly impossible to operate the dashboard controls easily. For this reason the three-point belt is often worn loosely enough so that the dashboard controls can be reached. This solution, however, is not satisfactory, since slackness reduces the effectiveness of the belt.
There are two solutions to this problem. First, a *lap belt* can be used, which overcomes nearly all of the (psychological) objections to the use of a belt. Second, a three-point belt can be used, which is provided with an automatic take-up device, together with a locking device (*three-point belt with locking retractor*). This last version is provided in some of the higher priced passenger cars.

However, as mentioned in the preceding paragraph, the *application* of three-point belts (including three-point belts with locking retractor) is not desirable in some types of car and for certain persons, while the *fixing* of the belt is not even possible in every car. This last fact is more important for the three-point belt with locking retractor than for the static three-point belt.
The problem is aggravated by *cost aspects,* since static three-point belts and belts with locking retractor are (considerably) more expensive than lap belts.
Another factor which increases the opposition to fitting three-point belts (with or without retractor) is *the more complicated mechanism handling* as compared with that of the lap belt, which is very simple, and nearly always can be handled in only one way.
In any case, lap belts cause a minimum of inconvenience to the belt user, since they are fastened across a natural 'pivoting' point of the human body, thus freely permitting normal movement. They can always be applied and be worn in the correct manner (i.e. *tightly* fastened and in the *right place* across the body).

4. Conclusions

The results of the SWOV-accident investigation prove, that if there are any differences in the effectiveness of lap belts and three-point belts, these are so small that they cannot form a basis for giving preference to one type over the other.
Furthermore, in spite of the results of this investigation which show some disadvantageous effects of diagonal belts (as compared to lap belts and three-point belts), involving a higher injury risk, which leads to the conclusion that general use of this type should not be favoured, a complete condemnation of diagonal belts seems exaggerated.

The discussion of the results of the investigations in other countries proves that the effectiveness percentages of both lap belts and three-point belts, show, independently, very high values.

Although the comparison of the results of the SWOV-accident investigation and those obtained in foreign countries, must be made with care, due to differences in certain parameters, in none of the relevant comparisons large differences in effectiveness can be established. When the tolerances are taken into account, the differences which may exist are not (or are hardly) significant.

On the basis of the afore-mentioned data, it is justifiable to draw the conclusion, that both lap belts and three-point belts are highly effective measures for safety in traffic.

If, in addition, the possibilities of application and aspects of comfort are taken into account, it can be concluded that lap belts are very reliable safety means.
Three-point belts, displaying an equivalent (or possibly a somewhat higher effectiveness) with regard to reducing the risk of injuries, cannot be applied in some cases, due to the body measurements of the persons concerned, in conjunction with certain special features of cars. For the same reasons the three-point belt with locking retractor (a still more expensive measure) cannot form a suitable safety measure in all cases.

Up-to-date safety measures, such as cage-structures with adjusted crush zones, energy-absorbing steering columns, other internal and external energy-absorbing elements, windshields of laminated glass, etc. can adequately contribute towards reducing the drawbacks (if any) of lap belts, as compared to three-point belts.

Consequently, in view of the above comments, the prohibition of the use of lap belts in future international regulations for seat belts would be unfounded and unjust, and especially so, if the regulations involved the compulsory use of the belt.
At present, the use of three-point belts does not ensure an adequate measure of protection for some belt users, adults as well as children.

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