AVAILABILITY AND (PROPER) ADJUSTMENT OF HEAD RESTRAINTS IN THE NETHERLANDS.

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ABSTRACT

Dutch national accident data show a considerable increase of the number of rear-end collisions during the last 10 years. Also the numbers of cars involved and casualties from these accidents have increased. Neck injuries, typical for rear-end collisions, are expected to become a major health problem, though it is still very difficult to obtain reliable data.
Head restraints, meant to prevent neck injuries during rear-end collisions, are not compulsory in The Netherlands. Traffic observations show, however, that they are available in nearly all modern cars. Their proper adjustment appears to be a great problem. A great number of occupants (both drivers and front seat passengers) are not adjusting the restraint as it is should be, i.e. the top of the restraint is positioned lower than the top of the occupants' ears. The problem may be partly due to incorrect positioning of the restraint by the occupant. On the other hand, the problem may be caused by insufficient maximum height of the restraint. Calculations, using population measurements, have been carried out and it was found that for Dutch male occupants the minimum height of head restraints (as regulated in ECE 25) should be increased considerably to satisfy all but the highest 5-percentile of the population.

1. INTRODUCTION

Head restraints are designed to reduce the possibility of neck injury (specifically so called whiplash injury) during rear-end collisions. In a previous study SWOV established 25% effectiveness for head restraint systems in preventing neck injury (van Kampen, 1982), based on detailed accident data gathered in the mid-seventies. However, since 'whiplash injury' has always been considered to be of minor importance, head restraints have not been made compulsory in The Netherlands, nor in most other European countries.
Recently the question of compulsory installation in EC-countries was discussed again during an EC-meeting in Brussels. The discussion was based on the current Directive 78/932 on head restraints, more or less comparable to Regulation ECE 25.
The Dutch Ministry of Transport and Public Works therefore asked SWOV to update their former study with regard to effectiveness in order to establish the need for a revision of the Dutch position.

A study was carried out using available national accident data, to establish the current problem of rear-end collisions and to evaluate changes and developments. The problem of long term consequences of neck injury was assessed using literature. Observations of cars in traffic were carried out to measure the proper adjustment of head restraints. Calculations were made regarding the required minimum height of head restraints based on measurements of the Dutch population, and a comparison was made with the height-requirements in EEC 25 and EC 78/932. Literature was used to estimate the current effectiveness of head restraints and to establish an indication of cost-effectiveness of compulsory installation of head restraints on front seats of cars (van Kampen, 1993). Some of these aspects are highlighted in this paper. A short review of international literature on the subject of rear-end collisions, neck injury, and head restraints is added for this paper in order to compare the Dutch results with those of other countries.

2. THE PROBLEM OF REAR-END COLLISIONS

2a. Accidents and cars

To establish the size of the problem and the extent of its consequences and to compare these data with those of previous years, SWOV used Dutch national accident data registered by the Police; these are called 'VOR-data' in the tables.

It is well documented that this type of data is incomplete and biased towards the more serious accidents (Harris, 1990). Rear-end collisions tend to be one of the less serious categories of collisions as far as injury is concerned (van Kampen, 1982). It is therefore to be expected that the official data show only 'the top of the iceberg' with regard to the problem of rear-end collisions.

To establish developments and changes, data of 1983-1985 were compared with those of 1989-1991.
The first table shows the numbers of cars, involved in rear-end collisions in The Netherlands and having at least rear-end damage.

Year	Number of cars with rear-end damage	Total number of cars in accidents
1983	2061	44030
1984	2847	43073
1985	2647	40818
1989	3453	42041
1990	3660	43113
1991	3595	39027

Table 1. Development of the number of cars with rear-end damage and total numbers of cars in accidents, 1983-1985 and 1989-1991; VOR-data.

The number of cars involved in rear-end collisions increased during the years considered with some 32%. Since during these years the number of registered accidents and the number of cars involved in these accidents have decreased with 11% (this has been the trend in The Netherlands), the RELATIVE increase of the problem is about 56%.

Another remarkable change has occurred in the distribution of damaged sides of the cars (Table 2.). Differences between 1983 and 1991 are shown.
For this purpose the points of contact on the cars are divided into the categories: right rear, mid rear, left rear, front and rear (chain collision damage).

Point of contact	Year 1983	1991
Right rear	6.9	6.5
Mid rear	81.8	55.2
Left rear	8.6	7.2
Front and rear	2.6	31.1
Total	100.0 (N=1961)	100.0 (N=2532)

Table 2. Distribution of points of contact of the cars for 1983 and 1991; VOR-data.

The decrease of the proportion of cars being hit in the mid rear from 82% in 1983 to 55% in 1993 is compensated by the increase of cars being hit front and rear from 3% in 1993 to 31% in 1993 Apparently there has been a big change from single rear-end collisions to multiple chain collisions. The increase of the number of cars involved (Table 1.) and the change in distribution shown in the previous table, are consistent with the fact that the amount of traffic in the Netherlands has increased considerably during the years observed.

2b. CASUALTIES FROM REAR-END COLLISIONS

The police data are coded according to the outcome of the accident: fatal, hospitalization, and other (lesser) injury.

The number of casualties of rear-end collisions is shown in the next table (Table 3.) The development is shown using the years 1983 and 1991.

Casualty category	Year 1983	1991
Fatal	11	16
Hospital	212	198
Other	877	1624
Total	1100	1838

Table 3. Number of casualties in cars with rear-end damage according to the severity of outcome, for 1983 and 1991; VOR-data.

The total number of casualties from rear-end collisions has increased with more than 50% during the period 1983 to 1991. Since the total (registered) number of casualties has followed the decrease of the number of registered accidents in The Netherlands during this period (from 54251 in 1983 to 48559 in 1991), the relative increase of the number of casualties has been some 87%. This absolute and relative increase therefore is greater than the increase already shown for the number of cars involved in rear-end collisions (table 1.) and the number of rear-end accidents itself (not shown).

2c. THE PROBLEM OF NECK INJURY

Though both the number of fatalities and that of the 'other' casualties have increased, the increase of the latter group is the higher. Therefore, the proportion of other casualties in the total group of casualties has increased. This points to a relative decrease in the severity of this type of accident. However this may not be regarded as proof that rear-end collisions have become a matter of lesser concern than in previous years.
In the first place there is a clear trend towards more rear-end accidents and casualties each year. In the second place, as already mentioned, the under-reporting of accidents resulting in 'minor injury' is very high. In the third place, the problem of the resulting neck injury (mostly 'whiplash injury') is gradually rising from its former status of "AIS 1" to an injury that in a certain amount of cases will cause definite long-term health problems.

In a recent Dutch publication on whiplash injury (Fischer et al, 1992) contributions of major Dutch and foreign experts in the fields of neurology, biomechanics, epidemiology etc. have been published. Among these we find contributions from Wismans and Janssen from TNO, well known to IRCOBI (see paragraph 3).
In one of the contributions by Clay, epidemiologist, we find data on the estimated growth of the number of whiplash casualties in The Netherlands.

Clay estimates that the annual growth of the number of casualties with whiplash injury resulting from rear-end collisions is at least 10,0000 people. (This is about 4 to 8 times as much as could be expected from analysis of the official, registered accident data).
As far as the severity of the whiplash-problem is concerned there are only few quantitative pointers in the publication.
Van Wijngaarden cites from literature that in 70% of all cases in a group of whiplash-patients health problems disappeared, while in the remaining 30% severe long-term health problems remained, such as pain, concentration limitations, dizziness etc.

It appears that reliable quantitative data on the extent, the nature, and the severity of the problem of neck injury are still required as far as the Dutch situation is concerned.

3. AVAILABILITY AND ADJUSTMENT OF HEAD RESTRAINTS IN CARS

For the purpose of the study, observations were carried out to establish:
a. the presence of head restraints on the front seats of cars
b. the adjustment of head restraints

ad a. The observations were carried out at different parking lots near the office of SWOV during early 1993.
In total 500 observations were made. In order to establish the age of the car, the first letters of the registration number were noted at the same time and these were later translated to model years using the appropriate key.

Presence appeared to be almost 100% in cars since model year 1988; presence was 90% or more in cars from 1980 to 1988. This means that head restraints are standard accessory of modern cars and have been for a considerable time.

ad b. The adjustment of head restraints was observed in cars passing an observer seated 'at ear-level' in a car parked along the roadside nearest the occupant-side to be observed.
Some 500 drivers and 500 front seat passengers were observed; sex of the occupant and car make and model were noted while the (proper) adjustment was registered according to 3 categories:

1.CORRECT-positioned were considered those head restraints that were above or just at ear-level;
2.INCORRECT-positioned were considered those head restraints that were clearly below ear-level;
3.ALMOST-CORRECT were those head restraints that were just below ear level.
After some adaption to the observation method, the area in which the qualification 'ALMOST-CORRECT' was given, could be restricted to about 2 cm under below ear level.
The results show clearly that a great problem exists regarding the proper adjustment of head restraints. The next table (table 5.) gives the overall results.

Adjustment	Drivers	Passengers
Incorrect	36.3	30.3
Almost-correct	24.5	20.7
Correct	39.1	48.9
Total	100% (N=501)	100% (N=501)

Table 5. Percentage distribution of observed adjustment of headrests for drivers and passengers in cars; SWOV-data.

Less than 40% of the drivers and 50% of the front seat passengers had their head restraints adjusted to the correct level.
At least 36% of the drivers and 30% of the passengers had adjusted the restraint incorrect (i.e. too low).
The difference between drivers and passengers is probably caused by the different proportion of females in the two groups. For this reason males and females were observed in separate groups (see tables 7. and 8.)

Another difference in adjustment of head restraints was expected due to car length. The observed data on car make and model were translated to three different car length categories:
1. cars less than 400 cm (SMALL)
2. cars between 400 cm and 450 cm (MEDIUM)
3. cars over 450 cm (LARGE)

The next table (Table 6.) shows the observed adjustment for drivers according to car length:

Adjustment	Car length Small	Medium	Large
Incorrect	39.8	37.2	27.6
Almost-correct	27.7	23.6	23.6
Correct	32.4	39.1	48.6
Total	100%	100%	100%
(N=)	(108)	(317)	(76)

Table 6. Percentage distribution of observed adjustment of headrests in cars for drivers, according to car length; SWOV-data.

As shown in this table car length seems to have influence on the quality of adjustment of head restraints. There is a tendency towards better adjustment in the longer cars. However, due to different proportions of male and female drivers in the different car length categories, this phenomenon should be studied for both sexes separately.
The adjustment according to sex of the drivers is shown in the next two tables (table 7 for male drivers and table 8 for female drivers).

Adjustment	Car length Small	Medium	Large
Incorrect	60.7	47.8	35.0
Almost-correct	17.8	20.9	24.5
Correct	21.4	31.1	40.3
Total	100%	100%	100%
(N=)	(28)	(186)	(57)

Table 7. Percentage distribution of observed adjustment of headrests in cars for male drivers according to car length; SWOV-data.

Male drivers show a very high proportion of incorrect adjustment (60%) in the small car category and accordingly a very low proportion of proper adjustment (21%).

Even in the largest cars however, their proportion of proper adjustment is not more than 40%.

Adjustment	Car length Small	Medium	Large
Incorrect	32.5	22.2	5.2
Almost-correct	31.2	27.4	21.0
Correct	36.2	50.3	73.6
Total	100%	100%	100%
(N=)	(80)	(131)	(19)

Table 8. Percentage distribution of observed adjustment of headrests in cars for female drivers according to car length; SWOV-data.

Female drivers (Table 8.) have far higher scores of proper adjustment.
In the longest cars they reach a level of more than 70% proper adjustment, though it should be noted that the absolute number of cars in that category is rather small.

The results show that the quality of adjustment of head restraints, even in long cars is very poor for males and clearly better for females. If the category 'almost-correct' adjustment is added to incorrect adjustment (where it in fact belongs) even females score a 50% incorrect adjustment in cars up to medium length.

According to literature on the subject of proper adjustment, also the horizontal distance between head and head restraint is considered to be of importance (Ollson and Bunketorp, 1990).
In this study it was concluded that a distance of more than 10 cm increases the risk of neck injuries. Horizontal distance was not specifically observed in the SWOV-study because of the difficulties involved. The impression exists, however, that horizontal distances of more then 10 cm are rare.

4. REQUIRED MINIMUM HEIGHT OF HEAD RESTRAINTS

Head restraints can only perform properly if the head of the occupant is supported at or above its centre of gravity.
It is assumed that head restraints are positioned properly if the top of the ears (sometimes eyes are chosen) are at the same level or lower than the top of the head restraint (Wismans and Janssen in: Fischer et al, 1992).

In the current ECE/EC-regulations the minimum height of fixed (non-adjustable) head restraints is 75 cm measured between the R- or H-point and the top of the head restraint. For adjustable head restraints this minimum height of 75 cm is applicable to the mid-position of the restraint system, thereby offering a somewhat greater height in the upper position.

The author of this paper has long suspected that this minimum height requirement was insufficient for the Dutch population.
In order to establish the facts in this matter it became necessary to use body-measurements of the Dutch population.
For the purpose of this study, this data was derived from existing population measurements, carried out periodically and reviewed when necessary. This data contains among others the sitting height of seated persons, measured from seating surface to top of the head (crown). All data can be related to the different percentiles of the Dutch population, separately for males and females.

These data are called 'DINED-tabel' (Molenbroek and Dirken, 1986).
Recent communication with the author revealed that since publication of the data, the length of the average Dutch male and female had increased a bit, but not much.
Therefore this data is still valid for 1993 but may be seen as a minimum with regard to the problem of the minimum height of the head restraint.

The seating height H in the population data is measured from seating surface to crown, while the minimum height h of the head restraint according to ECE 25/EC 78/932 is measured between R-point and the top of the head restraint (see Figure 1.).

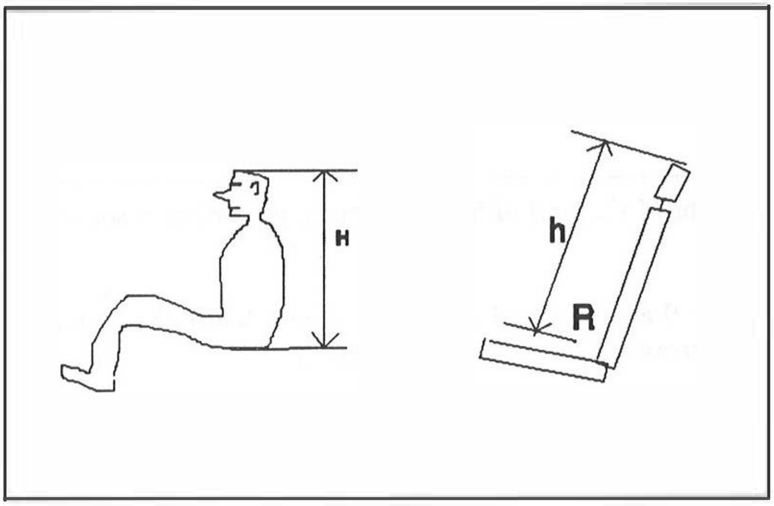

Figure 1. Seating height H compared to minimum height h of head restraint.

It is necessary tot calculate two measurements in order to make a comparison between H and h (see figure 1):
1. distance between seating surface and R or H-point (A)
2. distance between crown and the centre of gravity of the head, symbolized by the top of the ears (B).

According to published Swedish population data (Aldman and Lewin, 1977), in which body dimensions were given related both to the seating surface and to the H-point, the H-point of males is situated some 5 cm above the seating surface. For females this distance is about 7 cm.
For the purpose of this paper the distance A for males is chosen as the most appropriate for the problem (A = 5 cm).
Since no population measurements of the height of the ears above seating surface were available, the population measurements of the distance between seating surface and eye (E) were used. The differences between E and H were both for males and females some 12 cm. In other words, the eyes are situated some 12 cm below the crown. The top of the ears is for most people situated somewhat higher than the eyes; according to observations of the author not more than a few centimetres. In view of this, the distance B between crown and top of the ears is, in this paper, determined to be 10 cm in this paper (B = 10 cm).
Though in reality both A and B vary with the population, for the purpose of this paper both are considered to be fixed values.

The required minimum height M is calculated as the difference between H and the sum of A and B: $M = H - (A + B)$. According to these calculations, the following table has been made, showing the required minimum height of head restraint systems in cars for the Dutch population of males and females (older than 20) according to percentile.

Percentile	Minimum height M of head restraints (mm)	
	Males	Females
1	709	647
5	732	669
10	745	681
25	766	701
50	789	724
75	811	746
90	832	766
95	845	778
99	868	800

Table 9. Calculated required minimum height M (in mm) of head restraints, according to sex and percentile.

In the following figure the results from table 9 are presented as a graph in which also the current minimum height (h = 75 cm) from the international regulations is presented.

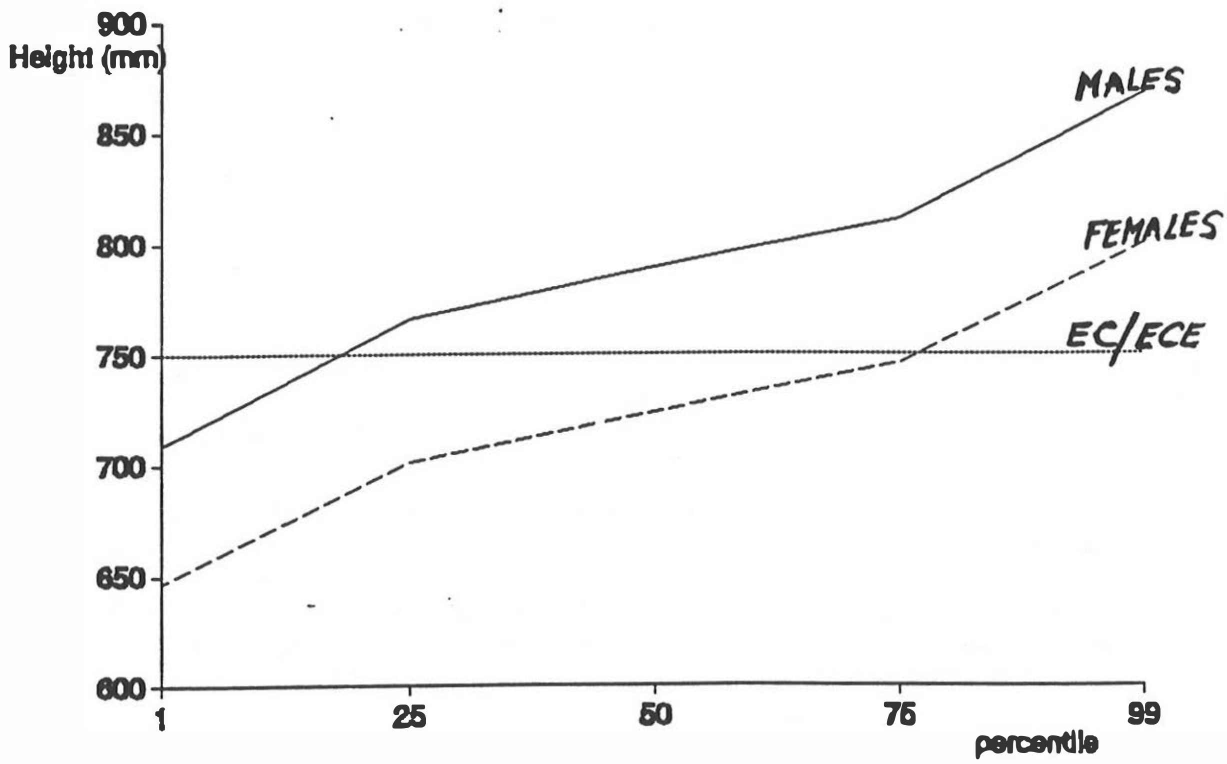

Figure 2. Calculated required minimum height of head restraints for Dutch males and females according to percentile.

Before discussing the implications of the calculations presented in Table 9, it is necessary to point out that care should be taken in using the figures as given. This is based on the following restrictions:
1. the population data from the Dutch source are measured without clothing while seated upright; occupants in cars are clothed and not seated upright but backwards to a certain degree.
2. it should also be noted that some of the dimensions are estimated from existing population data;
3. furthermore all distances are rounded.
4. finally, the method of measuring dimension H differs from that of measuring distance h as illustrated in figure 1.

Bearing this in mind, there is still good reason to be very much concerned about the results of table 9. Since the required minimum height M is to be compared with the height h in the existing regulations (which is at the moment 75 cm), it is clear that Dutch males longer than the 25th percentile may not be protected at all by a (fixed) head restraint which complies to the regulation. Dutch females are protected up to the 90th percentile.
To protect Dutch males up to the 95th percentile and all females, the minimum height h of head restraints should be raised to 85 cm.

These results suggest therefore that head restraints, dimensioned according to the minimum height-requirement in ECE and EC regulations, do not provide sufficient protection for the Dutch population.

However, the situation may be somewhat better than it appears, for two reasons:
1. Adjustable head restraints should have, according to the regulations, at least a one step higher position than the 75 cm prescribed for the middle position.
2. Manufacturers may voluntarily provide head restraints that have a greater height than the minimum of 75 cm.
No quantitative information on how many manufacturers do provide greater height is available for cars on the Dutch market.

5. DISCUSSION

Availability and adjustment

The results of both the presence-observations and the adjustment-observations of head restraints, carried out by SWOV, are in line with results from a German study carried out by BAST in 1990 (Friedel et al, 1992). In this German study the presence of head restraints was 97%. In 88% of the cars adjustable head restraints were available; 45% of the male drivers had their head restraint incorrectly (i.e. too low) adjusted, against 22 % of the female drivers. It is mentioned that in some cases the head restraints, when placed in the highest position, were too low for middle sized drivers.
The problem of incorrect adjustment is more or less universal, as illustrated in a Swedish study (Carlsson et al, 1985). In this report several other studies are referred to from which the general conclusion was that most adjustable head restraints are left in their lowest position.

Occupant height and injury frequency

Another interesting topic in the Swedish report is the head restraint height. A significant correlation was found between height and neck injury frequency. In view of the results of the SWOV-study concerning the incorrect adjustment of head restraints, this correlation might be explained by the fact that larger occupants are more often unprotected than smaller occupants. In other words, the correlation found in the Swedish study may not be based on biological differences between large and small people.
On the other hand, in another Swedish study (Lövsund et al, 1988), no significant correlation between occupant body height and neck injury frequency was found, unless the statistical

significant difference between male and female neck injury frequency is considered as such.

Short-term and long-term safety improvement
It can be assumed, in view of the results of the German study (Friedel et al, 1992) that also in the Dutch situation the majority of available head restraints are adjustable ones. If occupants could be motivated to adjust these head restraints properly, there would be a considerable safety improvement. The question is whether car occupants are willing to be motivated even if clear safety arguments are used. However, human behaviour being as it is, it may be doubted whether the adjustment change needed, can be reached.
According to the author of this paper, the best possible solution for the problem of incorrect adjustment are integrated (non-adjustable) head restraints, assuming that these have sufficient height for the car occupants concerned (i.e. at least 95% of the males).
This clearly is a long-term solution, since agreement will have to be reached on a number of topics during discussions in the international working groups of ECE and EC before any changes to the current regulations can be made.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The officially registered number of rear-end collisions in The Netherlands has increased considerably during the period 1983-1991. This has been shown by an absolute increase of 29% in the number of cars with at least rear-end damage. The relative increase (related to the number of cars involved in registered accidents) has been 56%.

A considerable shift was found from single rear-end damage to damage to both rear- and front-end of the same cars. This is due to the increase in traffic density during the years considered, causing more collisions involving more than two vehicles.

The increase of the number of registered casualties from these accidents was even greater: an absolute increase of 54% and a relative increase of 87% (related tot the total numbers of casualties from registered traffic accidents).

It is estimated that the annual growth of whiplash cases due to rear-end collisions is at least 10.000. There are also indications that a substantial proportion of these casualties will have serious lasting health problems.
However, the real extent and severity of the problem of neck injury and its long term consequences are still very much unknown, due to difficulties in gaining relevant and reliable accident and injury data. It is recommended to perform relevant studies in order to tackle this problem.

The presence of head restraints on the front seats of cars in The Netherlands is almost 100% for cars of less than 5 years old. Presence in older cars is about 90%.
No information is available about the proportion of adjustable head restraints as opposed to fixed ones.

The quality of adjustment of head restraints is very poor.
The observed amount of incorrect adjustment is more than 50%. Only some 40% of the male and some 50% of the female front seat occupants warrant the qualification 'proper' adjustment, which means that the head restraint reaches at least to ear level.
Horizontal distance, though not specifically observed, was thought to be within safe limits (i.e. less than 10 cm).

It could not be established whether this high level of incorrect adjustment was due to the fact that the occupant had not positioned the restraint system properly, or whether the restraint system itself lacked sufficient height. Both possibilities are applicable.

It was calculated that the minimum height requirement (h = 75 cm) in the current EC and ECE-regulations is insufficient to satisfy the height-requirements of the Dutch adult population. To protect at least 95% of the Dutch male population and all Dutch females, the minimum height requirement should be raised to 85 cm.
In practice the problem may be less than suggested due to the fact that the height of adjustable head restraints, if built according to the standard, will be a little greater than 75 cm.
There is no knowledge about the proportion of head restraints in cars on the Dutch roads complying to the minimum height requirement and the ones that are above this level.

6.2. Recommendations
There are at least two ways to ensure improvement of this unwanted situation:
1. short-term improvement could be reached by providing information to car occupants on the importance of proper adjustment of available (adjustable) head restraints.
2. long-term improvement could be reached by adjusting the current minimum height-requirement in ECE 25 and EC-78/932 to a more appropriate level. If the height of a 95% male occupant is to be considered as criterion, the minimum height should raised to about 85 cm.

However the best possible solution of the problem of incorrect adjustment is the application of fixed or integrated head restraints complying to the dimensions of the whole range of occupants (from 5% females to 95% males).

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