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BRIEF COMMUNICATION

Changes in rates of suicide by car exhaust asphyxiation in England and Wales

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ABSTRACT

Background. Self-asphyxiation using car exhaust gas is a common method of suicide in England and Wales, particularly in young males. The introduction of catalytic converters has reduced the toxicity of car exhausts. The main aims of the study were: to seek evidence of a fall in car exhaust suicides in the general population and in age and gender groups; to relate any fall to changes in car exhaust systems, particularly since legislation on car exhaust emissions in 1993; and to examine rates of suicide by other methods for evidence of method substitution.

Methods. Population study in England and Wales using national suicide statistics for 1987 to 1998.

Results. There was a fall in suicide by car exhaust asphyxiation in all age and gender groups. This change was most marked after 1993. The overall population suicide rate (all methods) also fell but there was no overall change in suicides by young males or females. In these groups suicide by hanging increased.

Conclusions. Legislation on catalytic converters appears to have contributed to a fall in car exhaust suicides. However, the effect on overall suicide rates in young people has been reduced by method substitution.

INTRODUCTION

Suicide prevention is a National Health Service (Department of Health, 1999) and World Health Organization (1998) priority. One approach to prevention is to restrict the availability of common methods (Gunnell & Frankel, 1994). In England and Wales the removal of carbon monoxide from the gas supply 30 years ago led to a fall in suicide using domestic gas and an equivalent drop in the overall suicide rate (Kreitman, 1976). However, restricting one method can lead to substitution of others (Burvill, 1989).

In the last two decades, a rise in suicide by young men has occurred in several countries; in England and Wales this has been associated with an increase in suicides by car exhaust asphyxiation (Department of Health, 1992). Similarly, a recent fall in the suicide rate in England and Wales has been attributed to the removal of carbon monoxide from car exhaust gases, mainly by catalytic converters (Kendell, 1998; McClure, 2000). However, these reports did not include data on car exhaust suicides by young men specifically; little statistical information on changes in car exhaust systems was presented; estimates of suicide and car exhaust asphyxiation deaths were inexact.

We therefore examined suicide data for England and Wales in order to answer the following questions: How large is the fall in suicide by car exhaust asphyxiation?; Is this fall reflected in a decrease in the overall suicide rate?; Is it found only in young men or in all age and gender groups?; Is the fall in car exhaust suicide secondary to a general drop (by all methods) in suicide by young men?; Is it linked

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Table 1. *Rate of suicide by method (per 100000) for the period* 1987–1998

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Car exhaust asphyxiation												
Men 15–44	4·92	5·94	5·29	6·50	6·35	6·29	4·99	5·11	5·12	4·01	3·39	2·81
Men ⩾ 45	3·62	4·51	3·94	4·70	4·07	5·39	4·13	3·84	3·05	3·10	2·39	2·04
All men (> 15)	4·37	5·33	4·71	5·72	5·36	5·89	4·61	4·54	4·18	3·59	2·93	2·46
Women 15–44	0·56	0·90	0·74	0·75	0·69	0·65	0·59	0·59	0·57	0·56	0·40	0·25
Women ⩾ 45	0·46	0·49	0·38	0·49	0·48	0·49	0·46	0·35	0·22	0·40	0·31	0·21
All women (> 15)	0·51	0·70	0·56	0·62	0·59	0·58	0·52	0·47	0·40	0·48	0·36	0·23
Both genders (> 15)	2·37	2·93	2·56	3·09	2·90	3·15	2·50	2·44	2·23	1·99	1·61	1·32
Both genders (all age groups)	1·93	2·38	2·09	2·51	2·35	2·54	2·02	1·97	1·80	1·61	1·30	1·06
Hanging												
Men 15–44	4·04	4·55	4·31	4·97	5·37	5·22	5·77	6·21	6·60	5·97	7·12	9·42
Men ⩾ 45	5·55	4·86	4·82	4·91	4·51	4·19	4·70	4·64	4·75	4·83	5·34	6·21
All men (> 15)	4·71	4·69	4·53	4·94	5·00	4·76	5·29	5·50	5·76	5·45	6·31	7·95
Women 15–44	0·63	0·64	0·80	0·84	0·78	0·69	0·79	0·69	0·96	1·15	1·08	1·22
Women ⩾ 45	1·03	1·00	0·88	0·74	0·74	0·82	0·69	0·62	0·75	0·68	0·80	0·95
All women (> 15)	0·82	0·81	0·84	0·79	0·76	0·75	0·74	0·65	0·86	0·92	0·94	1·08
Both genders (> 15)	2·69	2·68	2·62	2·80	2·81	2·69	2·94	3·00	3·24	3·12	3·55	4·43
Both genders (all age groups)	2·21	2·20	2·14	2·28	2·29	2·20	2·40	2·45	2·63	2·54	2·89	3·59
Self-poisoning (solids and liquids)												
Men 15–44	3·09	3·32	3·10	3·40	3·93	4·04	3·73	4·11	3·94	4·03	4·31	4·22
Men ⩾ 45	4·68	4·72	4·22	3·82	3·84	3·79	3·38	3·10	3·53	3·53	3·94	3·22
All men (> 15)	3·77	3·92	3·58	3·58	3·89	3·93	3·58	3·66	3·75	3·80	4·14	3·76
Women 15–44	2·52	2·32	2·37	2·30	2·20	2·50	2·41	2·43	2·62	2·42	2·72	2·48
Women ⩾ 45	5·15	5·35	4·40	4·32	3·97	4·31	3·60	3·31	3·60	3·04	3·09	3·17
All women (> 15)	3·79	3·78	3·35	3·28	3·06	3·39	3·00	2·87	3·11	2·73	2·91	2·83
Both genders (> 15)	3·78	3·85	3·46	3·42	3·46	3·65	3·28	3·25	3·42	3·25	3·51	3·28
Both genders (all age groups)	3·08	3·14	2·82	2·78	2·81	2·95	2·66	2·63	2·77	2·63	2·84	2·66
Other methods												
Men 15–44	5·09	5·96	5·74	5·40	5·32	4·94	5·15	5·11	4·76	4·99	4·52	4·62
Men ⩾ 45	8·23	8·50	6·66	6·71	6·82	6·37	6·36	5·91	5·54	4·95	4·86	4·94
All men (> 15)	6·42	7·05	6·14	5·97	5·97	5·57	5·69	5·47	5·12	4·98	4·67	4·77
Women 15–44	1·73	1·77	1·26	1·38	1·37	1·32	1·21	1·15	1·05	1·12	1·17	1·10
Women ⩾ 45	4·44	4·24	3·70	3·23	3·13	2·51	3·04	2·48	2·45	2·04	1·96	1·86
All women (> 15)	3·04	2·96	2·44	2·28	2·23	1·90	2·12	1·81	1·75	1·58	1·57	1·48
Both genders (> 15)	4·67	4·93	4·22	4·06	4·04	3·70	3·85	3·59	3·39	3·23	3·08	3·08
Both genders (all age groups)	3·83	4·04	3·46	3·32	3·29	3·00	3·13	2·92	2·75	2·62	2·50	2·52
All methods												
Men 15–44	17·15	19·78	18·45	20·27	20·98	20·49	19·64	20·54	20·42	19·00	19·34	21·07
Men ⩾ 45	22·08	22·59	19·63	20·13	19·25	19·74	18·57	17·50	16·87	16·41	16·52	16·41
All men (> 15)	19·26	20·98	18·96	20·21	20·23	20·16	19·16	19·17	18·81	17·82	18·05	18·94
Women 15–44	5·43	5·63	5·17	5·26	5·05	5·16	4·99	4·85	5·20	5·25	5·37	5·04
Women ⩾ 45	11·08	11·09	9·35	8·79	8·32	8·12	7·79	6·76	7·02	6·16	6·15	6·19
All women (> 15)	8·15	8·26	7·19	6·97	6·64	6·62	6·38	5·80	6·11	5·71	5·77	5·62
Both genders (> 15)	13·50	14·40	12·87	13·37	13·21	13·19	12·57	12·28	12·28	11·60	11·75	12·11
Both genders (all age groups)	11·04	11·76	10·50	10·89	10·74	10·69	10·21	9·97	9·95	9·41	9·54	9·83

to the number of cars with catalytic converters and in particular to recent legislation on car exhaust emissions?; Is there evidence of method substitution?

METHOD

Mortality and population data were obtained for England and Wales from 1987 to 1998, (Office For National Statistics, 1998, 1999), the midpoint being January 1993, the date on which European legislation requiring all new cars to have catalytic converters came into effect (European Community Directive, 1991). We included deaths in those aged 15 or above that were recorded as suicide or undetermined external cause (open verdicts), excluding code E988.8 (mainly 'accelerated registrations' of homicide). Deaths by carbon monoxide poisoning are recorded under ICD-9 codes E952.0/E982.0 (motor vehicle exhaust poisoning) and E952.1/E982.1 (other carbon monoxide poisoning). Inclusion of this second category is important because of a systematic problem of coding following the introduction of a revised coroners' reporting form in 1993 – the

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new form requires separate recording of the role of car exhausts in deaths from carbon monoxide poisoning (Office For National Statistics, 1998). Since this date, an increase (from approximately 50 to over 300 cases annually) has occurred in deaths recorded as 'other carbon monoxide poisoning', indicating that a substantial number of car exhaust deaths have been included in this broader category. Information on best available estimates of the number of licensed cars with and without catalytic converters was obtained from the Department of Transport (1998).

Statistics

We used hierarchical multiple linear regression statistics to study changes in the percentage of suicides using different methods. The predictor variables were year, period (1987–1992 = period 1, 1993–1998 = period 2) and an interaction term (the product of these two variables). The first two variables entered into the equation tested main effects. A significant increase in R^2 (proportion of variance explained) obtained with the interaction term would indicate a change in the gradient of the regression line from 1993 onwards. All analyses were carried out using the SPSS (1999) package.

RESULTS

Table 1 shows suicide rates by age and gender for the three commonest methods: car exhaust asphyxiation, hanging and self-poisoning by solid or liquid substances. There is a fall in deaths from car exhaust asphyxiation in all groups. There is a decline in the overall suicide rate (all methods combined), which is more marked in women and is not found in 15–44 year olds of either gender. In this younger group there are increases in rates of suicide by hanging in both genders and by self-poisoning in men. Suicides by car exhaust in the total population decline from a peak in 1992, though in women and younger men the fall appears to have begun before this date. The total number of suicides by this method decreased from 1304 in 1992 to 558 in 1998. Fig. 1 illustrates these changes for car exhaust asphyxiation and hanging as a percentage of all suicides.

The hierarchical multiple regression analyses showed that for both car exhaust asphyxiation and hanging, there was a significant increase in R^2 when the interaction term (year × period) was entered, indicating a change in the trend for both these methods from 1993 onwards (Car exhaust asphyxiation: cumulative $R^2 = 0{\cdot}934$; increase in $R^2 = 0{\cdot}507$; F test on increment = 60·98; df = 1,8; $P < 0{\cdot}001$. Hanging: cumulative $R^2 = 0{\cdot}922$; increase in $R^2 = 0{\cdot}134$; F test on increment = 13·744; df = 1,8; $P = 0{\cdot}006$).

Table 2 gives data on the number of cars with and without catalytic converters. There is a consistent annual increase in the number and proportion of cars with catalytic converters and a corresponding decrease in the number and proportion of suicides by car exhaust.

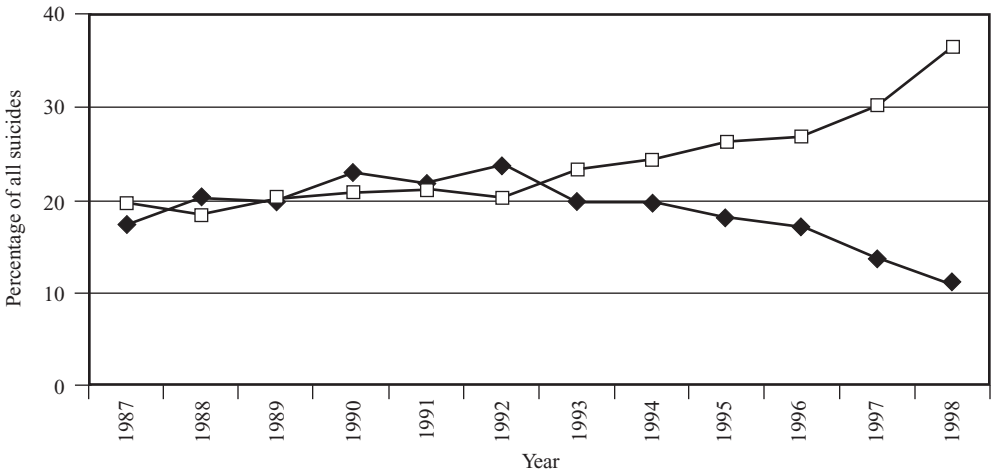

FIG. 1. Percentage of suicides by hanging (□) and by car exhaust asphyxiation (◆).

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Table 2. *Number of cars and various subgroups (thousands) and relationship to car exhaust suicides for the period* 1987–1998

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total cars, *N*	17421	18888	19720	20230	20253	20444	20755	21199	21394	22238	22832	23293
Diesel cars, *N*	311	418	528	638	751	920	1226	1576	1891	2182	2441	2580
Petrol cars, *N*	17110	18470	19192	19592	19500	19750	19528	19621	19500	20052	20385	20591
Petrol cars without a catalytic converter, *N*	—	—	—	—	—	—	18184	16895	15352	14400	13068	11505
Petrol cars without a catalytic converter/all cars (%)	—	—	—	—	—	—	87·6	79·7	71·8	64·8	57·2	49·4
Suicides by car exhaust asphyxiation, *N*	969	1204	1056	1275	1199	1304	1038	1016	934	837	679	558
Total suicides, *N*	5527	5913	5302	5521	5467	5467	5217	5113	5135	4872	4956	5135
Suicides by car exhaust asphyxiation/all suicides (%)	17·5	20·4	19·9	23·1	21·9	23·9	19·9	19·9	18·2	17·2	13·7	10·9
Suicide rates (car exhaust asphyxiation)	2·37	2·93	2·56	3·09	2·90	3·15	2·50	2·44	2·23	1·99	1·61	1·31
Overall suicide rate	13·50	14·40	12·87	13·37	13·21	13·19	12·57	12·28	12·28	11·60	11·75	12·11

DISCUSSION

We have confirmed that there has been a fall in suicide by car exhaust asphyxiation in recent years. In the 6 years from 1993 the annual number of suicides by this method fell by 746. The overall suicide rate also decreased during the same period but the pattern varies according to age and gender. Most importantly, there was no change in the suicide rates in young men and women. Although car exhaust suicides in these groups declined, there was a compensatory rise in suicide by other methods, mainly hanging. These changes in method were most marked after 1993, when legislation on catalytic converters was implemented. Catalytic converters reduce the carbon monoxide content of car exhaust emissions from around 3·5 to 0·5%.

The suicide figures in this study include deaths from undetermined external cause, in keeping with most reports of national suicide statistics (Kelly & Bunting, 1998). A previous report on car exhaust suicides excluded these deaths (Kendell, 1998), which account for up to 9% of cases annually. The inclusion of the 'other carbon monoxide poisoning' code gives the most accurate estimate of car exhaust deaths. A previous study reported a larger fall by this method than we have found, because its figures for recent years did not include deaths coded in this way (McClure, 2000).

The finding that a sustained fall in car exhaust suicides in the general population began in 1993 suggests that the European directive on catalytic converters was contributory. However, the decrease was apparent in women and young men before this date. This may reflect an earlier increase in the proportion of cars with catalytic converters and a rise in the number of diesel cars which emit only traces of carbon monoxide. Legislation appears to have added to an existing trend.

The simultaneous increase in hanging, also reported by McClure (2000), seems to be an example of method substitution, although it is possible that this has been the primary change. Self-poisoning also increased in young men but fell or stayed the same in the other groups in whom car exhaust suicides fell. The rise in hanging is a cause for concern as this method is difficult to prevent by restricting access to means. Although hanging is the main method of suicide

on in-patient wards (Appleby *et al*. 1999) and in prisons (Dooley, 1990), where suicide prevention may be aided by removing potential ligatures and ligature points, less than 10% of general population suicides by hanging occur in these settings.

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REFERENCES

Appleby, L., Shaw, J., Amos, T., McDonnell, R., Harris, C., Kiernan, K., McCann, K., Davies, S., Bickley, H. & Parrons, R. (1999). *Safer Services. Report of the National Confidential Inquiry into Suicide and Homicide by People with Mental Illness*. Department of Health: London.

Burvill, P. W. (1989). The changing pattern of suicide by gassing in Australia, 1910–1987: the role of natural gas and motor vehicles. *Acta Psychiatrica Scandinavica* **81**, 178–184.

Department of Health (1992). *The Health of the Nation*. HMSO: London.

Department of Health (1999). *Saving Lives: Our Healthier Nation*. HMSO: London.

Department of Transport (1998). *Transport Statistics Report. Vehicle Licensing Statistics*. HMSO: London.

Dooley, E. (1990). Prison suicide in England and Wales. *British Journal of Psychiatry* **156**, 40–45.

European Community Directive (1991). *Directive 91/441 L242, 30 August 1991. Statutory Instrument 1992, 2909*.

Gunnell, D. & Frankel, S. (1994). Prevention of suicide: aspirations and evidence. *British Journal of Medicine* **308**, 1227–1233.

Kelly, S. & Bunting, J. (1998). Trends in suicide in England and Wales, 1982–1996. *Population Trends* **92**, 29–41.

Kendell, R. E. (1998). Catalytic converters and prevention of suicides. *Lancet* **352**, 1525.

Kreitman, N. (1976). The coal gas story. United Kingdom suicide rates, 1960–71. *British Journal of Preventive and Social Medicine* **30**, 86–93.

McClure, G. M. G. (2000). Changes in suicide in England and Wales, 1969–1997. *British Journal of Psychiatry* **176**, 64–67.

Office for National Statistics (1998). *Twentieth Century Mortality*. ONS: London.

Office for National Statistics (1999). *Mortality Statistics: Cause 1998*, Series DH2 no. 24. TSO: London.

World Health Organization (1998). *Health 21. Health for all in the 21st century*. WHO Regional Office for Europe: Copenhagen.