Impact of the Penalty Points System on Road Traffic Injuries in Spain: A Time–Series Study

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Objectives. We assessed the effectiveness of the penalty points system (PPS) introduced in Spain in July 2006 in reducing traffic injuries.

Methods. We performed an evaluation study with an interrupted time–series design. We stratified dependent variables—numbers of drivers involved in injury collisions and people injured in traffic collisions in Spain from 2000 to 2007 (police data)—by age, injury severity, type of road user, road type, and time of collision, and analyzed variables separately by gender. The explanatory variable (the PPS) compared the postintervention period (July 2006 to December 2007) with the preintervention period (January 2000 to June 2006). We used quasi-Poisson regression, controlling for time trend and seasonality.

Results. Among men, we observed a significant risk reduction in the post-intervention period for seriously injured drivers (relative risk [RR]=0.89) and seriously injured people (RR=0.89). The RRs among women were 0.91 (P=.095) and 0.88 (P<.05), respectively. Risk reduction was greater among male drivers, moped riders, and on urban roads.

Conclusions. The PPS was associated with reduced numbers of drivers involved in injury collisions and people injured by traffic collisions in Spain. (*Am J Public Health.* 2010;100:2220–2227. doi:10.2105/AJPH.2010.192104)

Traffic injuries cause considerable mortality and morbidity worldwide. Since 2004, traffic deaths in Spain have followed a downward trend. However, more than 135 000 road users were injured and more than 4000 were killed in 2005, numbers which placed Spain above the mean for the European Union (EU; ranked 13th of the 25 member states).[1]

The penalty points system (PPS), introduced in Spain on July 1, 2006, attempts to deter drivers from committing traffic offenses. Because the PPS does not exclusively depend on monetary penalties, it affects all drivers irrespective of their income level.[2] In Spain, drivers start with a 12-point license (8-point for novice drivers), and the points are gradually removed if certain traffic violations are committed, such as exceeding the speed limit, driving while intoxicated, or using a hand-held mobile phone, culminating in license suspension if all points are lost. Only serious violations result in loss of points, with the number of points removed varying with the severity of the offense (Table 1).[3] Several months before its introduction, the PPS was announced via a publicity campaign in all news media, and was included in the media agenda, giving rise to public debate.

Although 20 of the 27 EU member states had adopted a PPS by 2007, to date, few countries have published studies assessing its effectiveness in terms of road safety.[4–9] The few studies that have been published are generally simple before–after analyses, with the exception of those by Zambon et al.[4] and Pulido et al.[9] In addition, most studies have assessed only the impact of PPS on the overall number of people injured or killed, and have not considered gender, type of road user, and other variables that could help to identify in which road user profiles the PPS is effective and in which profiles it is ineffective. In Spain, the effectiveness of the PPS has been assessed only for overall numbers of fatalities on nonurban roads.[9] In addition, none of those studies have analyzed changes in risk among drivers, who are the main target of the PPS.

Our objective was to assess the effectiveness of the PPS in reducing the number of drivers involved in injury collisions (i.e., traffic collisions resulting in injury) and the number of people injured in traffic collisions in Spain. Our hypothesis was that the PPS is effective in reducing traffic injuries and that its effectiveness varies with gender, age, injury severity, type of road user, road type, and time of collision.

METHODS

We performed an evaluation study by using an interrupted time–series design (i.e., a time–series analysis in which the series is divided—or interrupted—by the intervention into 2 periods, preintervention and postintervention, which will be compared).

Two study populations were considered: (1) drivers (injured or unharmed) who were involved in injury collisions in Spain between 2000 and 2007; and (2) people injured in traffic collisions in Spain between 2000–2007.

Sources of Information

We analyzed the Road Traffic Crashes Database of the Dirección General de Tráfico (General Directorate for Traffic). This database includes information from all injury collisions about the characteristics of the collision, the vehicle, and the individuals involved. In Spain, this information is collected by the national police force (for collisions on nonurban roads) and local police forces (for urban roads), and sent to the General Directorate for Traffic.

Variables

The dependent variables were the number of drivers involved in injury collisions and the number of people injured in traffic collisions. These variables were considered separately for men and women[10] and were stratified by age, severity (unharmed [drivers only], slight, serious nonfatal [hospitalized for more than 24 hours],

TABLE 1—Number of Points Subtracted From the Driver's License, by Type of Offense, in Spain's Penalty Points System (PPS): Spain, 2000–2007

2 Points	3 Points	4 Points		6 Points
Speeding >20 km/h to 30 km/h over the limit (<50% of the limit)	Speeding >30 km/h to 40 km/h over the limit (<50% of the limit)	Speeding >40 km/h over the limit (<50% of the limit)	Driving with a blood alcohol content 0.25 mg/L to 0.50 mg/L (0.15 mg/L to 0.30 mg/L professionals and novices)	Speeding >50% of the limit, at least >30 km/h
Driving without headlights when headlights are required	Changing direction illegally	Not obeying stop signs, traffic lights, right-of-ways, and other traffic rules	Overtaking dangerously or in locations with limited visibility	Driving with a blood alcohol content >0.50 mg/L (>0.30 mg/L for professionals and novices)
Circulating with a person aged <12 y on a moped or motorcycle, with the statutory exceptions	Failing to comply with the safety distance	Hindering other vehicles from overtaking	Overtaking putting cyclists at risk	Driving under the influence of drugs or other substances
Using systems to avoid traffic officers' surveillance or to detect speed cameras	Driving while using earphones or hand-held mobile phones	Reversing in motorways	Careless driving	Refusing analysis of alcohol, drugs, and other similar behaviors
Stopping or parking at dangerous places (e.g., road junction, tunnel)	Driving without seat belt, helmet, and other compulsory safety devices	Not obeying traffic officers' signals	Driving without the appropriate license	Dangerous driving, wrong way, races, and other similar behaviors
Stopping or parking disturbing circulation, pedestrians, or in lanes reserved for public transport		Driving on a motorway with a forbidden vehicle	Driving with >50% more than the authorized number of occupants	For professional drivers, exceeding the maximum permitted uninterrupted driving hours by >50% or reducing subsequent rest hours by >50%
		Throwing objects on the road that may produce a fire or accidents		

fatal), type of road user (car, motorcycle, moped user, or pedestrian [only for people injured]), license type (car or larger vehicle license, motorcycle license, moped license [drivers only]), road type (urban, nonurban), and time of collision (weekday-daytime, weekday-nighttime, weekend-daytime, weekend-nighttime).

The main explanatory variable was the intervention: the introduction of the PPS. We created a dummy variable to compare the postintervention period (July 2006 to December 2007) with the preintervention period (January 2000 to June 2006).

In 2004, the Spanish government established road safety as a political priority, and created the Special Road Safety Measures 2004–2005[11] and the Strategic Road Safety Program 2005–2008,[12] which have been observed to have reduced traffic injuries by 9% and 11% among men and women, respectively.[13] We included another dummy variable in the model, which compared the period before (2000 to 2003) with the period after road safety prioritization (2004 to 2007).

We accounted for several variables as potential confounding factors: fuel consumption, unemployment rate, and the gross national product of Spain. We included these variables in the analyses to adjust for exposure changes—in terms of the number of vehicles on public roads and in the distance traveled by those vehicles—resulting from economic changes during the study period.

Also, to determine if there were differences in the effectiveness of the PPS during the first months of the postintervention period (short-term effect) compared with subsequent months (long-term effect), we also performed analyses with another explanatory variable in which the postintervention period was subdivided into three 6-month periods (July 2006 to December 2006, January 2007 to June 2007, and July 2007 to December 2007).

Moreover, because the PPS was widely announced several months before its introduction, it is possible that the cutpoint chosen to define the pre- and postintervention periods (July 1, 2006) was not optimal. To explore this issue, we repeated analyses for 13 other cutpoints: monthly from January 2006 to January 2007. We used the log likelihood to compare the models.

Statistical Analysis

We carried out time–series analyses with regression models adjusted for overdispersion (quasi-Poisson).[14] We compared the number of drivers (or number of people injured) per month throughout the time series, controlling for time trend and seasonal patterns by using linear trend and sine and cosine functions.[15] The model for each outcome can be summarized as follows:

$$(1)\quad \ln[E(Y_t)] = \beta_0 + \beta_1 t + \beta_2 X_t + \sum_k \left[\beta_{3k}\sin\left(\frac{2k\pi t}{T}\right) + \beta_{4k}\cos\left(\frac{2k\pi t}{T}\right)\right] + \beta_5 P_t t + \sum_j \left(\beta_{6j} Z_{jt}\right) + \varepsilon_t,$$

where t is the time period (t=1 for the first month of the series, t=2 for the second, etc.); X_t identifies the pre- and postintervention periods (X_t=1 for the postintervention period);

k takes values between 1 and 6 (k=1 for annual seasonality; k=2 for 6-monthly seasonality, etc.); T is the number of periods described by each sinusoidal function (e.g., T=12 months); P_t is the dummy variable for prioritization, multiplied by the time trend (t) to take into account the differences in the time trend before and after the year 2004[16]; Z_{jt} is other covariables introduced (the confounding variables); j is the number of covariables introduced; and ε is the error term. Only the statistically significant terms were included in the final model. Relative risks (RRs) and their 95% confidence intervals (CIs) were derived from the adjusted models.

We calculated the prevented number of people injured attributable to the PPS as the difference between the number observed in the postintervention period and the number predicted by the statistical models.

To attempt to control for exposure, we also performed analyses with the number of cars, motorcycles, and mopeds registered per month as a denominator. Only results obtained from the models without denominators will be presented, because these denominators are solely an approximation of the true exposure to traffic collisions; at any rate, similar results were obtained for models with and without denominators. To carry out statistical analyses, we used Stata statistical software, release 10 (StataCorp LP, College Station, TX).

RESULTS

During the 8 years of the study period, 1359653 drivers were involved in injury collisions in Spain (annual median=172398), 81.5% of whom were male, and 71.0% of whom were aged 18 to 44 years. The drivers were mainly car drivers (63.8% among men, 80.5% among women). Although 45.2% of male drivers and 36.6% of female drivers were unharmed by their collisions, 11.8% and 8.0% of drivers, respectively, were seriously or fatally injured. More than half of the collisions occurred on urban roads and on weekdays during the daytime. The number of people injured in road traffic collisions was 1193244 (annual median=152264), 65.9% of them men. In this group, 21.7% of men and 15.4% of women were seriously or fatally injured. Their age distribution was similar to that for all drivers, although the proportion of people injured on urban roads and on weekdays during the daytime was slightly smaller.

Drivers Involved in Injury Collisions

The risk for drivers of having an injury collision in the postintervention period was reduced by 10% for driver-fatal collisions (RR=0.90; P=.024) and by 2% for overall collisions (RR=0.98; P>.05).

Gender and severity. Table 2 shows the RRs for drivers of being involved in injury collisions during the postintervention period compared with the preintervention period. The number of drivers per month is shown in Figure 1.

Among men, a 5% reduction in overall risk was observed (RR=0.95; P=.056). A larger reduction (11%) was observed for serious injury collisions (i.e., where the male driver was seriously injured or killed; RR=0.89; P<.05 in both cases; Table 2).

A reduction in overall risk, and in risk of a serious injury collision was observed both for car drivers (RR=0.95; P=.077, and RR=0.86; P<.05, respectively) and moped riders (RR=0.92 and RR=0.90, respectively; P<.05). No reduction in risk was observed for motorcycle riders. Similar results, with greater risk reductions, were observed for the corresponding classes of vehicle license.

Risk of collision was significantly reduced on urban roads, both for overall collisions (RR=0.90) and for serious injury collisions (RR=0.87). On nonurban roads, only serious injury collisions showed a significant reduction in risk (RR=0.90).

Finally, risk was reduced on weekdays only, both during the daytime (RR=0.93; P<.05 for overall collisions, and RR=0.87; P<.05 for serious injury collisions) and nighttime (RR=0.92; P=.084, and RR=0.85; P<.05, respectively).

Among women, there was no overall reduction in risk of collision in the postintervention period (RR=0.99; P=.615). Relative risks among women were similar to the RRs observed among men for most of the variable categories, though generally showing smaller reductions. In fact, significant reductions among women were observed only for 3 categories: female car drivers involved in serious injury collisions (RR=0.88; 12% reduction), female drivers with a car or larger vehicle license involved in serious injury collisions (RR=0.85; 15% reduction), and women with a moped license for overall collisions (RR=0.86; 14% reduction).

Because the type of road user varied between age groups, the age analyses were stratified by type of road user. There were no notable differences in risk between age groups in any of the road user categories considered (data not shown).

Type of road user according to road type and time of collision. Male car drivers involved in injury collisions on urban roads showed a reduction in risk in the postintervention period (RR=0.89; P<.05); a similar, but nonsignificant reduction was observed among female car drivers involved in injury collisions on urban roads (RR=0.96; P=.286). On nonurban roads, a significant reduction in risk was only observed among car drivers for serious injury collisions (men, RR=0.85; women, RR=0.85). When we stratified nonurban roads into high-speed roads (motorways and dual carriageways) and low-speed roads (all others), significant reductions were only observed on low-speed roads (RR=0.84; P<.05 among men and women on low-speed roads; RR=0.90; P=.218 among men and RR=0.87; P=.298 among women on high-speed roads).

Among moped riders, significant reductions were only observed on urban roads, both for overall collisions (RR=0.88 among men, RR=0.90 among women) and for serious injury collisions (RR=0.83 and RR=0.74, respectively). An increase in risk was observed for female moped riders on nonurban roads (RR=1.34; P<.05).

No risk reductions were observed for motorcycle riders on any type of road. However, when we stratified by time of collision, we observed a reduction in the risk among men on weekdays both during daytime (RR=0.90; P<.05) and nighttime (RR=0.87; P<.05), but no reduction of risk among women. Stratifying by time of collision did not noticeably change the results for car drivers or moped riders (data not shown).

People Injured in Traffic Collisions

Risk of injury in a traffic collision in the postintervention period was reduced by 8% for

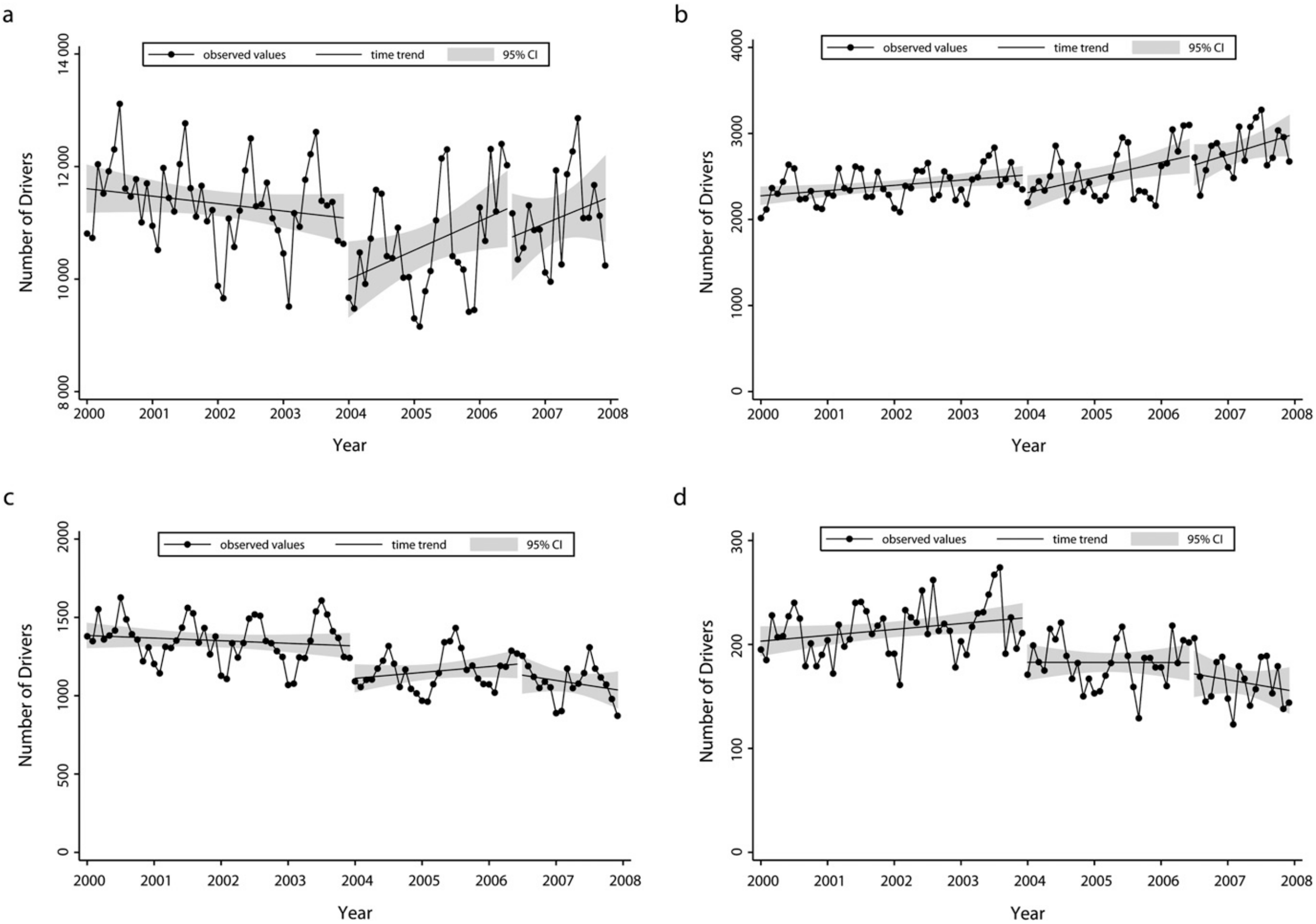
TABLE 2—Adjusted Relative Risks (RRs) for Drivers of Being Involved in Injury Collisions During the Postintervention Period, by Gender: Spain, 2000–2007

	Men		Women	
	Monthly Median[a]	RR[b] (95% CI)	Monthly Median[a]	RR[b] (95% CI)
Overall	11 099	0.95 (0.91, 1.00)	2467	0.99 (0.93, 1.04)
Injury severity				
Unharmed	4653	0.97 (0.91, 1.04)	879	1.01 (0.93, 1.10)
Slight	4514	0.95 (0.90, 1.01)	1306	0.97 (0.92, 1.03)
Serious	1043	0.89*** (0.83, 0.96)	174	0.91 (0.81, 1.02)
Fatal	192	0.89* (0.81, 0.98)	20	1.03 (0.80, 1.34)
Type of road user				
Car driver	6923	0.95 (0.90, 1.01)	1973	0.99 (0.93, 1.05)
Car driver–serious or fatal injury	576	0.86*** (0.79, 0.94)	138	0.88* (0.78, 1.00)
Motorcycle rider	844	0.96 (0.88, 1.03)	70	1.00 (0.87, 1.16)
Motorcycle rider–serious or fatal injury	196	0.94 (0.84, 1.05)	7	
Moped rider	1331	0.92* (0.87, 0.98)	321	0.94 (0.86, 1.04)
Moped rider–serious or fatal injury	243	0.90* (0.82, 0.99)	37	0.88 (0.70, 1.09)
License type				
Car or larger vehicle license	7920	0.92*** (0.88, 0.97)	1930	0.95 (0.90, 1.00)
Car or larger vehicle license–serious or fatal injury	681	0.84*** (0.78, 0.91)	138	0.85** (0.75, 0.96)
Motorcycle license	730	0.92 (0.84, 1.00)	73	0.88 (0.72, 1.07)
Motorcycle license–serious or fatal injury	162	0.98 (0.87, 1.09)	6	
Moped license	884	0.85*** (0.80, 0.91)	199	0.86* (0.76, 0.97)
Moped license–serious or fatal injury	171	0.82*** (0.73, 0.91)	24	0.96 (0.75, 1.23)
Road type				
Urban roads	5818	0.90** (0.85, 0.96)	1392	0.95 (0.88, 1.02)
Urban roads–serious or fatal injury	310	0.87** (0.80, 0.96)	49	0.99 (0.82, 1.20)
Nonurban roads	5316	1.00 (0.94, 1.07)	1090	1.02 (0.95, 1.10)
Nonurban roads–serious or fatal injury	926	0.90** (0.83, 0.97)	142	0.90 (0.79, 1.01)
Stratified by road type				
Urban roads				
Car driver	3373	0.89*** (0.83, 0.95)	1004	0.96 (0.88, 1.04)
Car driver–serious or fatal injury	72	0.90 (0.76, 1.07)	18	1.10 (0.80, 1.50)
Motorcycle rider	575	0.93 (0.85, 1.02)	64	1.00 (0.86, 1.16)
Motorcycle rider–serious or fatal injury	74	0.89 (0.78, 1.02)	4	
Moped rider	1060	0.88*** (0.81, 0.94)	275	0.90* (0.82, 0.98)
Moped rider–serious or fatal injury	135	0.83** (0.73, 0.95)	24	0.74* (0.57, 0.96)
Nonurban roads				
Car driver	3483	1.01 (0.94, 1.09)	974	1.02 (0.94, 1.09)
Car driver–serious or fatal injury	517	0.85*** (0.77, 0.94)	121	0.85** (0.75, 0.96)
Motorcycle rider	292	0.99 (0.89, 1.10)	10	1.08 (0.75, 1.54)
Motorcycle rider–serious or fatal injury	127	0.97 (0.85, 1.11)	3	
Moped rider	286	1.07 (0.98, 1.17)	42	1.34** (1.09, 1.65)
Moped rider–serious or fatal injury	113	0.99 (0.85, 1.14)	12	1.25 (0.85, 1.84)

Notes. CI = confidence interval. The preintervention period was January 1, 2000, to June 30, 2006; the postintervention period was July 1, 2006, to December 31, 2007.
[a]Monthly median number of drivers involved in injury collisions.
[b]Adjusted by time trend, seasonality, and for the effect of prioritization of road safety in Spain in the year 2004.
$^{*}P<.05$; $^{**}P\leq.01$; $^{***}P\leq.001$.

fatally injured people (RR = 0.92; *P* = .065) and by 3% for overall people injured (RR = 0.97; *P* = .254).

The relative risks in stratified analyses were very similar to those observed for drivers, with some exceptions: a significant overall reduction in risk of injury was observed among men (RR = 0.95). Among women, significant reductions were observed in overall risk of serious injury (RR = 0.88), overall risk for moped riders (RR = 0.91), risk of serious or fatal injury on nonurban roads (RR = 0.88), and risk of serious or fatal injury on weekdays during the daytime (RR = 0.86). Moreover, we observed a reduction in risk of



Note. Time series divided into 3 periods: (1) January 2000 to December 2003 (before road safety prioritization); (2) January 2004 to June 2006 (after road safety prioritization and before the introduction of the penalty points system, or PPS); and (3) July 2006 to December 2007 (after the introduction of the PPS; postintervention period).

FIGURE 1—Number and time trend (with 95% confidence intervals) of drivers involved in injury collisions per month in the preintervention and postintervention periods, by injury severity and gender, for (a) overall male drivers, (b) overall female drivers, (c) seriously injured or killed male drivers, and (d) seriously injured or killed female drivers: Spain, 2000–2007.

serious or fatal injury among male pedestrians (RR=0.91; *P*=.079) and female pedestrians (RR=0.88; *P*<.05; Table 3).

In total, 7720 men (5.2% of the expected number; *P*<.05) and 2787 women (3.5%; *P*=.244) were prevented from being injured in traffic collisions by the introduction of the PPS. Of these prevented injuries, 2699 men (10.8%; *P*<.05) and 1074 women (11.7%; *P*<.05) were prevented from being seriously injured, and 471 men (10.6%; *P*<.05) were prevented from being killed. No women were prevented from being killed; an excess of 16 fatally injured women was observed in the postintervention period (*P*=.852).

Short- and Long-Term Effectiveness and Cutpoint Analyses

When we subdivided the postintervention period into 6-month periods, we observed similar risk reductions in all 3 periods: the risk of serious injury was significantly lower for all 3 periods both among men (RR=0.91; RR=0.85; and RR=0.85 for the first, second, and third 6-month periods) and among women (RR=0.90; RR=0.85; and RR=0.84, respectively).

In a comparison of the various intervention cutpoints, the highest log likelihood was observed for the June 1, 2006, cutpoint. This is consistent with the fact that intensity of the publicity campaign was highest just before the introduction of the PPS.

DISCUSSION

Our results show that the introduction of the PPS in Spain reduced both the number of drivers involved in injury collisions and the number of people injured in collisions. For most of the subgroups analyzed, larger reductions were observed among the numbers of serious or fatal injuries. This is consistent with the fact that the PPS penalizes only serious offenses. In addition, the enforcement of speed limits and of drunk-driving laws was

TABLE 3—Adjusted Relative Risks (RRs) for Being Injured in Road Traffic Collisions and the Number of People Injured Prevented During the Postintervention Period, by Gender: Spain, 2000–2007

	Men			Women		
	Monthly Median[a]	RR[b] (95% CI)	Prevented, No.[c]	Monthly Median[a]	RR[b] (95% CI)	Prevented, No.[c]
Overall	7903	0.95* (0.90, 1.00)	7720	4158	0.96 (0.91, 1.02)	2787
Injury severity						
Slight	6169	0.96 (0.91, 1.02)	4494	3483	0.98 (0.92, 1.04)	1706
Serious	1430	0.89*** (0.83, 0.95)	2699	551	0.88** (0.81, 0.96)	1074
Fatal	267	0.89* (0.81, 0.98)	471	76	1.02 (0.86, 1.20)	−16
Type of road user						
Car user	4052	0.96 (0.89, 1.03)	2977	2750	0.98 (0.91, 1.06)	955
Car user—serious or fatal injury	823	0.88** (0.80, 0.97)	1488	383	0.91 (0.82, 1.01)	514
Motorcycle user	815	0.96 (0.88, 1.04)	1071	143	1.00 (0.89, 1.11)	13
Motorcycle user—serious or fatal injury	207	0.94 (0.84, 1.05)	360	23	1.21 (0.92, 1.58)	−100
Moped user	1349	0.92* (0.87, 0.98)	1736	459	0.91* (0.84, 0.99)	714
Moped user—serious or fatal injury	270	0.88** (0.80, 0.97)	513	56	0.87 (0.71, 1.04)	127
Pedestrians	499	0.96 (0.88, 1.04)	341	476	0.97 (0.89, 1.05)	300
Pedestrians—serious or fatal injury	152	0.91 (0.81, 1.01)	241	121	0.88* (0.79, 0.98)	265
Road type						
Urban roads	3605	0.93* (0.87, 0.99)	4604	1981	0.96 (0.89, 1.02)	1626
Urban roads—serious or fatal injury	451	0.87*** (0.81, 0.94)	1048	193	0.95 (0.84, 1.06)	176
Nonurban roads	4317	0.96 (0.90, 1.03)	3154	2119	0.97 (0.89, 1.06)	1169
Nonurban roads—serious or fatal injury	1239	0.90** (0.83, 0.97)	2155	426	0.88* (0.79, 0.98)	847

Notes. CI = confidence interval. The preintervention period was January 1, 2000, to June 30, 2006; the postintervention period was July 1, 2006, to December 31, 2007.
[a]Monthly median number of people injured in road traffic collisions.
[b]Adjusted by time trend, seasonality, and for the effect of prioritization of road safety in Spain in the year 2004.
[c]Negative numbers indicate an excess of people injured in the postintervention period compared with the expected numbers had the intervention not been implemented.
*$P < .05$; **$P \le .01$; ***$P \le .001$.

among the main road safety interventions implemented.

Reductions in risk varied with the type of road user and road type, and were greatest where there was most room for improvement (i.e., among drivers and at locations where few measures had previously been implemented or where measures had not been effective). Specifically, larger reductions were observed among moped riders, on urban roads, on weekdays, and among male drivers.

The greatest reductions were observed among moped riders on urban roads, which might be partially explained by moped riders' lower rates of compliance with road safety legislation. For instance, in 2005 1.8% of motorcycle riders were observed riding without a helmet, compared with 7.4% of moped riders.[17] Notably, almost no reduction in risk was observed among motorcycle riders. The effectiveness of the PPS among motorcycle riders might have been counteracted by an increase in motorcycle mobility observed since the year 2004, following the approval of a normative that enhanced motorcycle use in urban areas.[18]

On nonurban roads, the PPS was associated with a reduction in risk of serious or fatal injury among car drivers only on low-speed roads, whereas on urban roads reductions were observed for car drivers, motorcycle riders (weekdays only), and moped riders. The smaller reductions in risk on nonurban roads could be related to extensive enforcement of traffic laws (e.g., speed limits) before the introduction of the PPS—by means of speed cameras, mostly installed on high-speed nonurban roads—whereas less attention has historically been paid to road safety on urban roads.

The greatest reductions in risk were observed on weekdays, particularly on urban roads. This may be because most interventions implemented previously in urban areas were aimed at reducing alcohol-impaired driving, and were mostly enforced on the weekends.

Finally, greater reductions in risk were observed among male drivers. Again, greater room for improvement could explain such differences by gender, because the effect of road safety prioritization in Spain was greater among women,[13] who have greater willingness for behavior change and exhibit generally safer driving behavior.[19–22]

Contrary to some reports,[23] the results of the present study suggest that the effect of the PPS is maintained through time. Risk reductions were observed throughout a follow-up period of 1.5 years, with similar results among the 3 postintervention periods examined.

Comparison With Previous Studies

Among studies performed abroad, in Italy a 19% reduction in the number of people injured and an 18% reduction in the number of fatalities were observed after introduction of the PPS.[4] Moreover, the numbers of emergency room visits and hospital admissions because of traffic injuries in Italy were reduced by 12% and 16%,[5] respectively. In Ireland, reductions of 44%[6] and 36%[8] in the number of admissions because of traffic injuries were observed 6 months and 1 year, respectively, after the PPS was introduced. Also, the number of acute spinal injuries caused by traffic collisions in Ireland decreased by 48.4% after 6 months, falling to 27% (P>.05) after 2 years.[7]

In the present study, the overall number of people injured in Spain showed a reduction of 5% (P<.05) and 4% (P>.05) among men and women, respectively, and an 11% and 12% reduction for seriously injured people, indicating a less pronounced effect from the PPS in Spain than the effects observed in Italy and Ireland. Such differences could be explained by the use in most of those studies of simple before–after analyses, which tend to overestimate the magnitude of the effect of the interventions assessed.[24] Also, although the PPS is similar in different countries, each country's PPS has distinctive features. Moreover, enforcement levels can differ across countries. Finally, the number of traffic injuries in Spain had already decreased substantially after the prioritization of road safety there in 2004.[13]

In Spain, a previous study had observed a 14.5% reduction in overall fatalities on nonurban roads,[9] a reduction similar to the 10% and 12% reductions, respectively, in the numbers of men and women killed or seriously injured, as observed in the present study.

Limitations and Strengths

Because the intervention was nationwide, no comparison group was available, although time trend, seasonality, socioeconomic variables, and other interventions were accounted for. Moreover, although a comparison group may add evidence to the results, such a group is not essential in time–series analyses, in which percentage of change is compared between time points in the same series.

Appropriate exposure denominators (i.e., kilometers traveled by vehicle) were unavailable (available only for nonurban roads). However, the number of vehicle registrations per month was used instead, and the model was adjusted for fuel consumption.

The validity of the results is subject to data quality. Misclassification has been observed in the police database between mopeds and motorcycles[18] and regarding injury severity, where one third of seriously injured people are classified as being slightly injured.[25] In addition, police-collected data are known to underreport traffic collisions.[25] Nonetheless, reporting has progressively improved in Spain, especially since the year 2005,[13] which goes against our hypothesis.

To our knowledge, this is the first study to assess the impact of the PPS on the number of drivers involved in injury collisions. In addition, our study also analysed the effect of the PPS on the overall number of people injured in traffic collisions. The results we observed among these 2 populations are complementary: our first analysis examined the effect of the PPS on the subpopulation of drivers (the main target of the PPS), whereas the second examined the PPS impact on the overall population. The number of traffic violations was not considered because it is subject to variations in the level of enforcement. However, data from the General Directorate for Traffic suggest that road safety behavior has also improved: the percentage of motorcycle and moped riders who did not wear a helmet decreased from 5.3% in 2005 to 1.3% in 2007; and the number of drivers wearing a seatbelt increased from 81% in February 2006 to 95% in July 2007.[26]

Among studies assessing the effectiveness of the PPS, this study is one of the few that adjusts for secular time trend and seasonality.[24] Compared with autoregressive integrated moving average models,[25] Poisson regression models give similar estimates with a similar goodness of fit and allow the calculation of relative risks, which provide a straightforward interpretation of the intervention's effectiveness.[27,28]

Availability of a large sample size allowed us to stratify the analysis by relevant variables such as age, gender, type of road user, road type, and time of collision. In addition, the long preintervention period provided analytical stability.

Conclusions

In this study, we assessed not only the effectiveness of the PPS but also a number of aspects that allow it to operate correctly. The effectiveness of the PPS depends both on the level of enforcement against target behaviors (real risk of being caught) and public information campaigns (subjective risk of being caught).[2] The PPS is also subject to efficient administration. In Spain, 2 years after the introduction of the PPS, 51.5% of the offenses linked to penalty points were still being processed.[26] Improved performance at the administrative level may have resulted in greater effectiveness of the PPS.

Our results are another example of how coercive legislation is effective in reducing traffic injuries.[29–31] This demonstrated effectiveness contrasts with the scarce literature available on assessing the impact of noncoercive legislation (e.g., infrastructure or vehicle safety requirements).

In conclusion, the PPS was associated with a reduction in both the number of drivers and the number of people injured in traffic collisions in Spain, especially the numbers of seriously or fatally injured people. This reduction was maintained through time. In addition, the PPS especially contributed to reducing those traffic injuries that are more difficult to deal with (i.e., injuries sustained by those road users and occurring in those locations where there was more room for improvement). ■

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A. M. Novoa, K. Pérez, E. Santamariña-Rubio, M. Marí-Dell'Olmo, A. Tobías, and C. Borrell designed the study. A. M. Novoa performed the statistical analyses and wrote the first draft of the article. All of the authors contributed to the interpretation and the discussion of the results, and critically revised the article and approved its final version.

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Human Participant Protection

This study was approved by the ethics committee, "Comitè Ètic d'Investigació Clínica," of the Institut Municipal d'Assistència Sanitària.

References

1. European Road Safety Observatory. *Annual Statistical Reports 2007.* Brussels, Belgium: SafetyNet; 2008.

2. European Transport Safety Council. Combating speed through penalty point systems. Available at: http://www.etsc.eu/documents/Speed%20Fact%20Sheet%202.pdf. Accessed June 19, 2008.

3. Dirección General de Tráfico, Ministerio del Interior, Gobierno de España. *Permiso por puntos* [Penalty points system]. Available at: http://www.permisoporpuntos.es. Accessed January 19, 2008.

4. Zambon F, Fedeli U, Visentin C, et al. Evidence-based policy on road safety: the effect of the demerit points system on seat belt use and health outcomes. *J Epidemiol Community Health.* 2007;61(10):877–881.

5. Farchi S, Chini F, Giorgi Rossi P, Camilloni L, Borgia P, Guasticchi G. Evaluation of the health effects of the new driving penalty point system in the Lazio Region, Italy, 2001-4. *Inj Prev.* 2007;13(1):60–64.

6. Donnelly M, Murray P, Cleary S. Changes in trauma service workload since the introduction of the penalty points system. *Ir Med J.* 2005;98(2):53–54.

7. Butler JS, Burke JP, Healy DG, et al. Trends in RTA related spinal injuries: the post penalty points era. *Ir J Med Sci.* 2006;175(1):20–23.

8. Lenehan B, Street J, Barry K, Mullan G. Immediate impact of 'penalty points legislation' on acute hospital trauma services. *Injury.* 2005;36(8):912–916.

9. Pulido J, Lardelli P, de la Fuente L, Flores VM, Vallejo F, Regidor E. Impact of the demerit point system on road traffic accident mortality in Spain. *J Epidemiol Community Health.* 2010;64(3):274–276.

10. Kunkel SR, Atchley RC. Why gender matters: being female is not the same as not being male. *Am J Prev Med.* 1996;12(5):294–296.

11. Dirección General de Tráfico, Ministerio de Interior. *Plan Estratégico de Seguridad Vial 2005-2008. Medidas Especiales de Seguridad Vial 2004-2005* [Strategic Road Safety Program 2005-2008. Special Road Safety Measures 2004-2005]. Madrid, Spain: Dirección General de Tráfico; 2005.

12. Dirección General de Tráfico, Ministerio de Interior. *Plan Estratégico de Seguridad Vial 2005-2008. Plan de Acciones Estratégicas Claves 2005-2008* [Strategic Road Safety Program 2005-2008. Strategic Key Action Program 2005-2008]. Madrid, Spain: Dirección General de Tráfico; 2006.

13. Novoa AM, Pérez K, Santamariña-Rubio E, et al. Road safety in the political agenda in Spain: the impact on road traffic injuries. *J Epidemiol Community Health.* 2010 Jun 15. [Epub ahead of print].

14. Yannis G, Antoniou C, Papadimitriou E. Road casualties and enforcement: distributional assumptions of serially correlated count data. *Traffic Inj Prev.* 2007;8(3):300–308.

15. Stolwijk AM, Straatman H, Zielhuis GA. Studying seasonality by using sine and cosine functions in regression analysis. *J Epidemiol Community Health.* 1999;53(4):235–238.

16. Langbein LI, Felbinger CL. The quasi experiment. In: Langbein LI, ed. *Public Program Evaluation: A Statistical Guide.* New York, NY: ME Sharpe; 2006:106–133.

17. Dirección General de Tráfico, Ministerio del Interior, Gobierno de España. Observatorio General de Seguridad Vial. *Uso del casco en conductores y acompañantes de vehículos a motor de dos ruedas* [Helmet use in riders and occupants of motorized two-wheeled vehicles]. Madrid, Spain: Investigación, Marketing e Informática; 2005.

18. Pérez K, Marí-Dell'Olmo M, Borrell C, et al. Road injuries and relaxed licensing requirements for driving light motorcycles in Spain: a time-series analysis. *Bull World Health Organ.* 2009;87(7):497–504.

19. Centers for Disease Control and Prevention. Risky driving behaviors among teenagers–Gwinnett County, Georgia, 1993. *MMWR Morb Mortal Wkly Rep.* 1994;43(22):405–409.

20. Fergusson D, Swain-Campbell N, Horwood J. Risky driving behaviour in young people: prevalence, personal characteristics and traffic accidents. *Aust N Z J Public Health.* 2003;27(3):337–342.

21. Laapotti S, Keskinen E. Differences in fatal loss-of-control accidents between young male and female drivers. *Accid Anal Prev.* 1998;30(4):435–442.

22. Jonah BA. Sensation seeking and risky driving: a review and synthesis of the literature. *Accid Anal Prev.* 1997;29(5):651–665.

23. SWOV fact sheet. Demerit points systems. Leidshendam, The Netherlands: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid; 2008.

24. Hauer E. *Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety.* Oxford, England: Pergamon Press; 2005.

25. Pérez K, Cirera E, Borrell C, Plasencia A. Fallecidos a 30 días por lesiones producidas en accidente de tráfico en España [Motor vehicle crash fatalities at 30 days in Spain]. *Gac Sanit.* 2006;20(2):108–115.

26. Dirección General de Tráfico, Ministerio del Interior, Gobierno de España. Balance de 2 años del permiso por puntos [Two year assessment of the penalty points system]. Available at: http://www.dgt.es/was6/portal/contenidos/documentos/la_dgt/recursos_humanos_empleo/oposiciones/Permiso_por_puntos_evolucion_2_anos__Reunion_16-09-2008.pdf. Accessed July 15, 2009.

27. Tobias A, Díaz J, Saez M, Alberdi JC. Use of Poisson regression and box-jenkins models to evaluate the short-term effects of environmental noise levels on daily emergency admissions in Madrid, Spain. *Eur J Epidemiol.* 2001;17(8):765–771.

28. Kuhn L, Davidson LL, Durkin MS. Use of Poisson regression and time series analysis for detecting changes over time in rates of child injury following a prevention program. *Am J Epidemiol.* 1994;140(10):943–955.

29. Shope JT. Graduated driver licensing: review of evaluation results since 2002. *J Safety Res.* 2007;38(2):165–175.

30. Fell JC, Voas RB. The effectiveness of reducing illegal blood alcohol concentration (BAC) limits for driving: evidence for lowering the limit to .05 BAC. *J Safety Res.* 2006;37(3):233–243.

31. Dinh-Zarr TB, Sleet DA, Shults RA, et al. Task Force on Community Preventive Services. Reviews of evidence regarding interventions to increase the use of safety belts. *Am J Prev Med.* 2001;21(4 suppl):48–65.