



Original article

Use of back protector device on motorcycles and mopeds in Italy

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Abstract

The international scientific literature reports no data on the prevalence and effectiveness of back protector devices (BPD). In Italy, no data have been collected on BPD because their use is not mandatory. To fill this gap, the National Institute of Health implemented a cross-sectional study in collaboration with the National Traffic Police. Accident cases were collected from 1 December 2011 to 25 October 2013. Overall, data from 2104 accidents involving 2319 injured subjects were analysed: 1821 (78.5%) of these were motorcyclists and 498 (21.5%) mopedists. The use of Hard-shell BPD or jackets with airbags in motorcyclists is higher than in moped drivers (16.2% vs 1.3%, $P=0.000$). Concerning level of protection, there are no differences between drivers and passengers. In most severely injured motorcyclists (i.e. hospitalized or deceased), the percentage of injuries to the spine was lower (13.6%) among those who used a high-level safety device (hard-shell BPD and/or airbags) and rose to 27.3% among those who used only protective clothing ($P=0.022$). When the variables potentially affecting the results of not using a high-safety device were controlled, a bivariate analysis showed that the odds of serious spinal injury were 2.72 times greater ($P=0.049$) and a multivariate analysis showed that they were 2.81 times greater ($P=0.012$). This study points out that greater use of BPD could reduce the number of injuries to the spinal column resulting from road traffic accidents involving motorized two-wheeled vehicles.

Key words: Spinal injuries, motorcycles, protective devices, two-wheeler injuries, back protector device

Key Messages

- Despite the overall decrease in casualties related to road traffic accidents (RTAs) in Italy from 2001 to 2012, the percentage of motorcycle casualties increased from 19.5% to 25.8% of the total RTA deaths.
- The prevalence of use of BPDs in the Italian population of motorized two-wheeler drivers is estimated at 12.8%.
- The non-use of BPDs is evidenced as important risk factor for spinal injury: 63.2% of serious spine injuries in the group of unprotected people is attributable to the nonuse of a BPD.
- BPDs (hard-shell or jackets with airbags) seems effective in decreasing the number and the severity of injuries to the spinal column. The quantification of the potential reduction of the incidence of serious spinal injuries due to RTAs involving motorized two-wheelers is -60.0% if all the users of two-wheeled motorized vehicles are using a BPD.

Introduction

According to the Haddon Matrix,^{1,2} safety devices are the most effective interventions applicable to the “human” component for crash and injury prevention during the phases of a crash. Recent data³ show that every year road traffic accidents (RTAs) lead to 3653 deaths in Italy. According to the Italian National Institute of Health estimates, which are based on the Italian injury pyramid and produced by the SINIACA-IDB surveillance network of the external causes of injuries,^{4,5} there are about 10 000 severely disabled,⁶ 70 000 hospitalizations⁶ and over 1 000 000 emergency department (ED) attendances per year.⁶

Accident trends for motorcycle drivers indicate that the decrease in mortality from 2001 to 2012 was lower (-27.4%) than the decrease in RTA total casualties during the same period (-45.3%).³ Conversely, the percentage of casualties involving motorcycles drivers increased from 19.5% to 25.8% of all RTA deaths. This was also due to the dramatic increase in the number of motorcycles in circulation: from 3 732 306 in 2001 to 6 482 796 in 2012 (i.e. a 73.7% increase).⁷ Greater use of motorcycles has contributed to changing the transportation habits of Italians. Mobility is an essential component for quality of life in large urban centres, and there is an increasing need for efficiency and improvement of all types of transportation. As mobility becomes an ever greater challenge for both citizens and municipal governments, smaller, lighter and more specialized vehicles will help avoid traffic congestion, solve parking problems, allow for spare time and improve air quality as well as quality of life.

Recent studies reported that among all RTA victims, 22.2% suffered from spinal trauma,⁸ and major spinal traumas constituted more than 10% of all motorcycle injuries⁹ and were among the most disabling injuries. In particular, spinal cord injuries have a 25.8% mean disability weight and a 100% proportion of lifelong consequences.¹⁰⁻¹² In Italy, there is no incentive for the use of BPD and no data are available on their effectiveness on

motorcycles in reducing neurological injuries and long-term disability.

Evidence of the effectiveness of motorcycle helmets in reducing the number and severity of brain injuries in crashes comes from biomechanical and epidemiological studies,¹³⁻¹⁵ but the effectiveness of BPD has not yet been proved. Up until now no studies have been published on the effectiveness of BPD. In fact, the only published study concerns protective clothing. Recently, however, an Australian study^{16,17} of 212 motorcyclists who had been involved in accidents demonstrated that when protective clothing included fitted body armour there was a reduced risk of injury to the upper body [risk ratio (RR)=0.77; 95% confidence interval (CI)=0.66-0.89]. Indeed, this study may be the first to evaluate the effectiveness of a device, i.e. the BPD, which has only recently appeared on the market.

BPD for snowboarders and skiers were analysed recently to determine their potential to prevent spinal injury^{18,19} but no evaluation of their effectiveness was made. It is, however, conceivable that back protection devices, including helmets to prevent traumatic brain injury (TBI), reduce both the frequency and the severity of spinal injuries resulting from RTAs. In fact, both devices operate as a mechanism to disperse kinetic energy. Although impact protectors cannot save a person from injury in a major impact, they can reduce injury severity. They slow down the rate of transfer of the forces in an impact to a less damaging or non-damaging level. Thanks to this impact ‘attenuation’ effect, it is more likely that the injury will be a simple fracture, which is easier to treat than a complex fracture, with less probability of spinal cord injury.

To fill this knowledge gap, the Italian National Institute of Health in collaboration with the National Traffic Police (NTP) implemented the ‘ST.E.P.’ (STudy of the Effectiveness of the back Protector) project to become familiar with the use and effectiveness of the BPD in a sample of motorcyclists and mopedists involved in road accidents.

Materials and Methods

A sample of 29 NTP departments fulfilled the territorial representation criteria.

Information about the use and types of BPD was collected by means of a short list developed by the Italian National Institute of Health (see [Appendix](#) available as Supplementary data at *IJE* online).

Diagnoses of spinal injuries were considered according to the International Classification of Diseases Clinical Modification, 9th revision (ICD9-CM). For the purposes of our study, spinal injuries included the following regions: cervical (from C1 to C7), thoracic (from T1 to T12) and lumbar (from L1 to L5). The specific diagnostic categories were fractures and dislocations. We took into account the following ICD9-CM diagnosis codes: 805 (fracture of vertebral column without mention of spinal cord injury); 806 (fracture of vertebral column with spinal cord injury); 839.0 (dislocation of cervical vertebra, closed); 839.1 (dislocation of cervical vertebra, open); 839.2 (dislocation of thoracic and lumbar vertebrae, closed); 839.3 (dislocation of thoracic and lumbar vertebrae, open); 839.4 (dislocation of other vertebra, closed); and 839.5 (dislocation of other vertebra, open). On the basis of this list of diagnostic codes, two spinal injury severity levels were mapped, i.e. serious and moderate ([Figure 1](#)).

Data were collected mainly in extra-urban areas and on major urban roads. These areas were identified based on the maximum speed permitted. According to Article 142 of the Italian Traffic Code, the maximum speed limit is 130 km/h on motorways and 110 km/h on main extra-urban roads. The speed limit is 90 km/h for secondary extra-urban roads and 50 km/h is the general limit on streets in urban areas (70 km/h on urban highways). Based on these criteria, extra-urban areas emerged as those with the highest speed limits (≥ 90 km/h).

A cross-sectional study design was adopted to assess the effectiveness of BPD in reducing the number and severity of spinal injuries. Data are presented as proportions, medians or means \pm standard deviation (SD), as appropriate. Differences in categorical variables between respective comparison groups were analysed using the chi square test or Fisher's exact test. The continuous variables were analysed using Student's t-test when applicable. Pearson's chi-square test for independence was performed to determine whether distributions of spinal injury in persons exposed to risk (i.e. not wearing protective devices) and in persons not exposed to risk (i.e. wearing protective devices) differed from one another. A predictive mathematical model was used to estimate the reduction of spinal injuries as a function of the protection factor and prevalence of use of

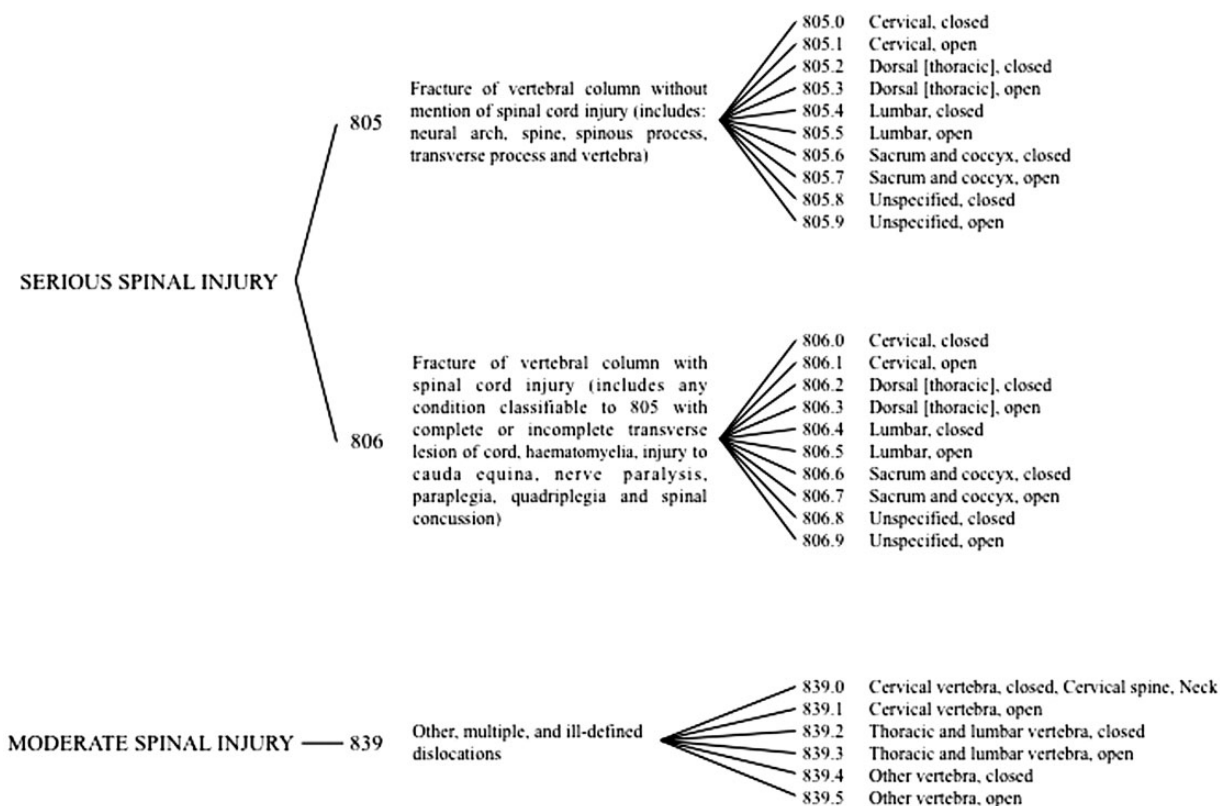


Figure 1. Paths of spinal injury and correspondent ICD-9-CM codes of diagnosis by the severity groups used in the study (serious or moderate spinal injury).



Figure 2. Hard-Shell Back Protector Device for the whole spinal column (cervical, thoracic, lumbar and sacral sections) worn on manikin. EN1621-2/12 Standard; CE2 certification.

BPD. Data analysis was carried out using Stata/SE 12.1 (StataCorp, College Station, TX, USA).

Results

We analysed accident cases collected from 1 December 2011 to 25 October 2013.

Overall, data from 2104 accidents involving 2319 injured subjects were analysed; 1821 (78.5%) of them were motorcyclists and 498 (21.5%) mopedists.

The distributions of the mechanisms of injury differed between the accidents of the two different vehicles ($\chi^2 = 14.5709$; $P = 0.002$). Mopeds were more involved in

crashes with vehicles than motorcycles (78.0% vs 69.8%) because of their predominant use in urban areas. By contrast, the number of accidents due to loss of control was higher in motorcycles (23.4% vs 18.5%).

The mean age of the injured moped drivers was 30.8 years (95% CI=29.2–32.5) and of motorcyclists 39.5 years (95% CI=38.8–40.1; t test = -11.4960 ; $P = 0.000$). Among moped drivers the proportion of females was three times higher than among motorcycle drivers (19.8% vs 6.4%; $\chi^2 = 76.7653$; $P = 0.000$).

For the purposes of this analysis, three decreasing levels of protection were identified:

- i. high-level protection provided by the use of the hard-shell BPD and/or the jacket or vest with an airbag;
- ii. low-level protection given by the use of protective clothing;
- iii. zero-level protection, when none of the above-mentioned protective devices was used.

Hard-shell BPD or jackets with airbags were used mostly by motorcyclists (16.2%); indeed, only 1.3% of moped drivers used them ($\chi^2 = 163.5062$; $P = 0.000$) (see Table 1). There were, however, no differences between drivers and passengers as to the level of protection (see Table 1), i.e. drivers with hard-shell BPD were accompanied by passengers with the same kind of BPD, etc. (Lin's concordance correlation coefficient $\rho_c = 0.886$; $P = 0.000$).

Finally, BPD use is not the same on all types of roads. For example, regardless of the type of vehicle, the BPD is not widely used in urban areas, especially not the one with the highest level of protection (5.9%); by contrast, in extra-urban areas its use has more than tripled (19.3%). Data analysis showed differences between motorcyclists and mopedists regarding the type of BPD used and the place of occurrence of the accident (Table 1; $\chi^2 = 123.0920$; $P = 0.000$). In extra-urban areas, where average speeds tend to be higher, the consequences of accidents are on average more severe; in fact, 32.2% of accidents had severe outcomes in extra-urban areas compared with 22.5% in urban areas ($\chi^2 = 27.2874$; $P = 0.000$).

As expected, drivers and passengers did not differ as to the consequences of the accidents ($\chi^2 = 0.9442$; $P = 0.331$) and the body parts injured ($\chi^2 = 2.5005$; $P = 0.475$). In the group of subjects with severe outcomes (hospitalized or deceased motorcyclists and mopedists), the percentage of injuries to the spine was lower (13.6%) among those who used a high-level safety device (hard-shell BPD and/or airbags) and increased up to 27.3% among those who were only wearing protective clothing (Table 2; $\chi^2 = 7.6745$; $P = 0.022$).

We classed spine fracture or spinal cord injury as serious spinal injury, and use of the hard-shell / airbag BPD as 'not

Table 1. Accidents by vehicle, role, environment and level of protection

	Hard-shell or airbag		Protective clothing		None		Test
Moped	6	1.3%	6	1.3%	447	97.4%	Pearson's $\chi^2 = 163.51$; $P = 0.000$
Motorcycle	267	16.2%	261	15.9%	1117	67.9%	
Drivers	273	13.0%	267	12.7%	1564	74.3%	Pearson's $\chi^2 = 0.60$; $P = 0.740$
Passengers	24	11.2%	27	12.6%	164	76.2%	
Extra-urban	230	19.3%	183	15.4%	777	65.3%	Pearson's $\chi^2 = 123.09$; $P = 0.000$
Urban	67	5.9%	111	9.8%	951	84.3%	

Table 2. Accidents by type of injury and level of protection

	Hard-shell or airbag		Protective clothing		None		Test
Spinal injury	12	13.6%	24	27.3%	52	59.1%	Pearson's $\chi^2 = 7.67$; $P = 0.022$
No spinal injury	80	18.2%	67	15.2%	293	66.6%	

Table 3. Mantel-Haenszel estimate of the odds ratio of spine fracture / spinal cord injury according to the level of protection (controlling for place of occurrence, vehicle, age of victim and severity of trauma)

	Odds ratio	χ^2	P-value	95% CI
Protective clothing/not protected v hard-shell or airbag	2.72	3.84	$P = 0.049$	1.00–7.74

exposed to risk' or 'protected'. When we controlled for place of occurrence, type of vehicle, age of victims and outcome, we found a Mantel-Haenszel pooled odds ratio between the unprotected and protected groups equal to 2.72 (Table 3). Thus the percentage of people with serious spinal injury in the exposed group, attributable then to the risk of not using hard-shell / airbag BPDs (being unprotected), was 63.2% (percentage attributable risk fraction in the exposed).

The potential impact fraction (PIF) of an increase in the prevalence of use of BPD in the population can be calculated as a function of the size of the modification as follows.^{20,21} In formal terms:

$$PIF = \frac{(P - P^*) \times (RR - 1)}{P \times (RR - 1) + 1} \times 100$$

Where:

P = prevalence of non-use of BPD before modification of two-wheelers' habits;

P^* = prevalence of non-use of BPD after modification of two-wheelers' habits;

RR = relative risk of serious spinal injuries in non-BPD users (unprotected group) vs BPD users (protected group).

According to the above estimated odds ratio (OR) = 2.72 (assuming OR as a good proxy of RR because the spinal injuries are rare events), and hypothesizing an increase in the overall prevalence of use of BPD from 12.8%

(current use) to 100.0%, a PIF of 60.0% can be estimated. This is the measure of the potential reduction in the incidence of serious spinal injuries if all the population of motorized two wheelers used BPD.

Results of the multivariate analysis (ordered logistic regression) are shown in Table 4, where the proportional odds ratios for a one-unit increase in the independent variables (risk factors) over the dependent variable level (serious, moderate, no spinal injury) are calculated (scalar deviation reduction = -434.1; $\chi^2 = 20.75$; $P = 0.0229$). According to this model, when protective clothing (vs hard-shell BPD and/or airbags) is used, the odds of serious spinal cord injury vs the linearly combined moderate- and no-lesion categories are 2.81 times greater ($P = 0.012$), when the other variables are kept constant in the model. Likewise, for elderly people aged > 60 years, the odds are 3.67 times greater ($P = 0.035$) when the other variables are kept constant.

Discussion

The use of BPDs and their effectiveness are more difficult to evaluate than those of the helmets or seat belts because the BPDs are not easily observable on the road, especially the hard-shell BPD that is worn under clothing. Therefore, to detect whether a BPD is being used requires an observer-driver 'interaction', and opportunities for observation are

Table 4. Model of ordered logistic regression (serious spinal injury vs moderate or no spinal injury)

Risk factors	Baseline level	Odds ratio	95% CI	P-value
Autumn/winter	Spring/summer	1.07	0.66–1.73	0.794
Protective clothing	Hard-shell / airbag	2.81	1.25–6.27	0.012
No protection		1.37	0.66–2.85	0.396
Adult (30–59 years)	Young (<30 years)	1.90	0.64–5.69	0.250
Old (>60 years)		3.67	1.10–12.29	0.035
Collision with fixed obstacle	Loss of control	1.25	0.53–2.96	0.617
Collision with vehicle		0.74	0.46–1.20	0.226
Motorcycle	Moped	0.87	0.46–1.63	0.662
Extra-urban area	Urban area	1.43	0.90–2.25	0.130
Male	Female	1.31	0.67–2.58	0.430

Parameters of the ordered logistic regression model: scalar deviation reduction = -434.1 , $\chi^2 = 20.75$, $P = 0.0229$.

limited. The register of traffic police interventions at the scene accidents was modified for this study. Information about the use of protective devices was added to the standard police registrations.

Indeed, thanks to the efforts of the traffic police it was possible to follow the outcomes of the injured until they were hospitalized. Thus, we were able to obtain valuable information about the types of injury sustained. This method has the advantage of allowing an analytical description of the accident and, at the same time, characterizing the injured person according to diagnosis or the type of injury reported. The drawback is that the complexity of this procedure limits the number of cases that can be observed to those that occur primarily in extra-urban areas, where the NTP are active, and also restricts the sample size.

One limitation of our investigation is the lack of information about kinetic energy (i.e. speed of the vehicle) at the time of the accident. Use of a BPD or protective clothing is associated particularly with high-performance motorcycles, where the energy of the impact might be so high as to reduce the effectiveness of the device in terms of dissipating kinetic energy. On the other hand, drivers of mopeds tend not to use BPDs, especially not in urban areas where speeds are generally low. Low speed also means that there is less kinetic energy and thus a lower probability of serious injury. To control for the hidden effect of speed in the evaluation of BPD effectiveness, a specific analysis of drivers was carried out to control for variables associated with speed, i.e. place of occurrence (urban or extra-urban area), type of vehicle (motorcycle or moped), age of victims and overall severity of trauma (death/hospitalization or

first aid/unharmed), assuming that the kinetic energy of the accidents was sufficiently homogeneous when adjusting for these variables (see Table 3).

This study on the use and effectiveness of back protector devices in motorbike and moped drivers highlighted some important results: drivers and passengers had similar levels of protection (25.7% and 23.8%, respectively, had some protection); the consequences of accidents (i.e. 27.8% and 24.7%, respectively, of those involved were hospitalized or died); and the main body part injured (i.e. 19.3% and 19.1%, respectively, showed spinal injury). Motorcycle and moped users are very different. Mopedists are on average younger and a higher percentage of women than men use the vehicle primarily in urban areas. Women are also the users who do not use the most effective BPD (hard-shell BPD and jacket/vest with airbags). The habit of protecting the back has, however, increased among motorcyclists, especially in the summer when high-powered motorcycles are probably used more as an alternative vehicle to the car for long trips because of the favourable weather conditions (higher temperatures and rare rainy days). For this reason, use of BPDs is much higher in extra-urban areas where motorcycles are used more than mopeds. This does not, however, prevent the occurrence of accidents that, on average, are more serious in extra-urban areas regardless of the vehicle used.

Regarding the effectiveness of BPDs in preventing or reducing injuries to the spine, the highly protective device (i.e. the hard-shell BPD or jacket/vest with airbags) reduces the probability of serious spinal injury (i.e. spinal fracture or spinal cord injury), similarly to helmets for motorcyclists and seat belts for car users. The use of seat belts and

helmets has been shown to be protective against fatalities and severity of injury after RTAs^{22–27} and has been reported as able to reduce health care costs associated with accident victims.^{28–31} A study carried out in the USA in a sample of 184 992 patients between 1988 and 2004 found that compared with the no-device group, the seat-belt group had a 51% mortality reduction and the injury severity scores showed a similar pattern.²³ According to the Third Report to the US Congress, carried out in 1996 by the National Highway Traffic Safety Administration,²⁶ fatality risk was reduced by 45% when seat belts were used. This was confirmed in a recent study²⁵ carried out in Japan which reported a decrease in the rate of killed or seriously injured casualties estimated as 49% for drivers and 42% for front seat passengers, when wearing seat belts. In a multivariate analysis of all restraint systems,³¹ seat belt use without airbag deployment was found to be the most protective restraint system (OR = 0.29; 95% CI = 0.16–0.50).

The finding that more serious injury patterns and adverse outcomes after motorcycle crashes are found in unhelmeted riders is not surprising. A comparison of TBI incidences in the Romagna region of Italy²⁷ showed a significant reduction of TBI admissions for motorcycle-moped crashes (–66%) in 2000, that is before and after the introduction in Italy of the mandatory use of helmets on mopeds also. This intervention increased the use of helmets in the population from 19% to 97%. According to a retrospective cohort study on the severity of TBI carried out in the state of Washington in 1989,³¹ unhelmeted motorcyclists are nearly three times more likely to be hospitalized with a head injury (RR = 2.9; 95% CI = 2.0–4.4) and almost four times more likely to have suffered a severe or critical head injury (RR = 3.7; 95% CI = 1.9–7.3). A large difference was found for total hospital costs. In a study carried out in the USA in patients admitted between 2005 and 2010 to a level 1 trauma centre subsequent to an RTA, the average total hospital cost for helmeted patients was found to be 43% lower than that for unhelmeted patients.³² A Cochrane systematic review on the use of helmets to prevent injury in motorcycle riders³³ identified 53 observational studies and found that, despite methodological differences between studies, motorcycle helmets reduced the risk of head injury (–69%; OR = 0.31; 95% CI = 0.25–0.38) and mortality (–42%; OR = 0.58; 95% CI = 0.50–0.68) after a motorcycle crash.

One limitation of this study is that the analysis of the effectiveness of BPDs was carried out on subjects with the most severe outcomes (i.e. hospitalized or deceased) and considering only the large groups of ICD-9-CM diagnoses (805, 806 vs 839), because of the overall low percentage of spinal injuries. However, the ST.E.P. project on

monitoring the use and effectiveness of BPDs is going forward and in a larger sample it should be possible to evaluate the effectiveness of BPDs according to a more specific description of the type of injury and the part of the spinal column involved (cervical, thoracic, lumbar or sacral). Further research is needed to explore other factors that might better explain the effectiveness of BPD, such as the role of kinetic energy. Keeping in mind the limitations of the study, particularly the lack of information on kinetic energy at the time of impact, the effectiveness of BPDs seems to be comparable to that estimated for seat belts or helmets.

Conclusions

In Italy, substantial attempts to reduce RTAs have been made through legislation, law enforcement and ongoing public education campaigns to increase awareness of the risks and penalties associated with not respecting traffic laws. Nevertheless, the number of casualties among motorcyclists and moped riders has not sharply decreased despite the high prevalence of safety helmet use, because of the increasing use of motorized two-wheeled vehicles. Using safety devices while driving is the most effective prevention for reducing the traumatic consequences of an RTA; but, unlike helmets, BPDs are not mandatory and this has slowed their uptake. This study reveals low use of BPDs, particularly among mopedists. On the other hand, it shows that BPDs are highly effective in reducing the probability of serious spinal injury. Thus, greater use of BPDs could reduce the number of injuries to the spinal column due to RTAs involving motorized two-wheeled vehicles.

Supplementary Data

Supplementary data are available at *IJE* online.

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