Descriptive analysis of the effect of back protector on the prevention of vertebral and thoracolumbar injuries in serious motorcycle accident

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ABSTRACT:

Context and objective:

Among the different products and protective gear used by riders of two-wheeled motorized vehicles, back protectors that are designed to prevent damage to the spinal column are widely used today compared other protections. However, few studies measure their effectiveness. Can their effectiveness be measured? How do they help decrease or change the nature of thoracolumbar traumas that occur?

To address these questions and remedy the lack of objective data regarding these products, an epidemiological, clinical, and biomechanical analysis of motorcycle riders who were admitted to a French trauma center after an accident was performed.

Method:

A questionnaire was administered to victims of accidents involving two-wheeled motorized vehicles who were admitted to the trauma room at the Marseille trauma center over the course of 2016. Collect data are related to the victim, the accident scenario, and a detailed description of the observed injuries using AIS (Abbreviated Injury Scale) coding and Magerl classification. Univariate analyses and Fisher tests were performed for victims who were or were not wearing back protectors.

Results:

This study collected data from 124 victims. Almost half of the victims were wearing a back protector at the time of the accident (53 victims, thus 43% of riders). Collectively, twenty-nine victims who were wearing back protectors had 57 thoracolumbar injuries, and twenty eight victims who were not wearing back protectors had 75 thoracolumbar lesions. The results from this study show that there is no significant difference in the nature and mechanism of thoracolumbar injuries as a function of back protection. The majority of the thoracolumbar injuries were not severe. They were primarily bone injuries, essentially compression fractures, regardless of whether a back protector was worn.

Conclusion:

This study shows that the use of back protection does not decrease the number, type, or mechanism of thoracolumbar injuries associated with accidents involving two-wheeled motorized vehicles. However, it suggests that lumbar vertebral injuries are deflected towards the thoracic vertebrae when back protectors are worn. Finally, it suggests that the design of back protectors should be reconsidered to better protect riders from what are referred to as compression fractures (craniocaudal force), which remain the primary form of fracture regardless of the rider's characteristics, based on the data analyzed.

Keywords: accident, two-wheeled motorized vehicle, severity, mechanism of injury, back protection, thoracolumbar spine.

1. Introduction

In 2016, 22% of users of two-wheeled motor vehicles (TWMVs) were the victim of an accident on public roads (Observatoire national et al., 2017), even though they only represent 2% of road traffic (Van Elslande et al., 2014). Even more concerning, Blaizot et al. showed that riders of TWMVs have the highest rates of hospitalizations, serious injuries, and fatal injuries (Blaizot et al., 2013). Their vulnerability is explained in part by instability due to very limited contact with the ground (only two points of support), being difficult to see because of their small size, and of course the absence of a car body, which exacerbates their vulnerability. In 2016, results from the Rhône register revealed that 13% of victims of TWMV accidents in the Rhône region sustained at least one spinal injury (Observatoire national et al., 2017). Spinal trauma can be serious due to neurological consequences, which can be life-threatening or have a profound effect on the patient's functional prognosis, and their long-term complications.

To prevent this type of injury, back protectors have been designed to alleviate shocks to the thoracic and lumbar regions by covering the spine with a single plate or multiple articulated plates. As of 2003, back protectors must conform with norm EN 1621-2 entitled "Motorcyclists' Protective Clothing against mechanical impact – Part 2: Requirements and test methods for motorcyclists back protectors", which evaluates the ergonomics and the reduction in impact forces. These protectors must be able to withstand five impacts of 50 joules each, two of which are delivered to points that are deliberately chosen for their apparent weakness (joints…) (*NF EN 1621-2 Vêtements de protection contre les chocs mécaniques pour motocyclistes - Partie 2 : protecteurs dorsaux - Exigences et méthodes d'essai*, 2014).

In France, the use of back protectors is not required, and there are no figures available regarding the rate of back protector use. An analysis performed in Australia highlighted an increase in the use of back protectors from 19% in 2001 to 44% in 2006 (de Rome, 2006). Despite an *a priori* increase in the rate of the use of back protectors, however, very few studies have been published that assess their effectiveness in TWMV accidents. Recently, a comparison of De Rome's article "Motorcycle protective clothing: Protection from injury or just the weather?" and Guistini's article "Use of back protector device on motorcycles and mopeds in Italy" showed that there is a lack of evidence regarding the effectiveness of back protectors with regards to spinal injuries (Ekmejian et al., 2016). According to Ekmejian, additional analysis is needed regarding the mechanisms of injuries to determine whether back protectors are more useful in specific circumstances. These results and analyses highlight the necessity of making precise clinical data available to complement biomechanical and epidemiological analyses.

AIS coding enables each injury to be coded by body region, anatomical structure, the type of injury, and the severity of the injury, with a predefined measure of the immediately associated severity. However, it does not indicate the mechanism of injury. At the level of the thoracic and lumbar spine, the Magerl classification system (Magerl et al., 1994) provides a classification of the lesions linked to the mechanisms of the injuries. This classification system covers three types of fracture: A, B, or C, each of which contains groups and subgroups. Type A corresponds to a compression mechanism. Type B corresponds to a mechanism involving distraction of posterior or anterior elements. Type C corresponds to a rotation mechanism in addition to the mechanisms already described. This type of classification system is very useful for studying the etiology of spinal lesions.

Given the lack of scientific evidence, it seemed timely to us to investigate the effectiveness of back protectors, including their ability to prevent specific mechanisms of thoracic and lumbar spinal injuries related to TWMV accidents. Thus, the objective of this study was to combine epidemiological and biomechanical analyses of injury mechanisms to identify the effectiveness of back protectors in preventing vertebro-medullary injuries at the thoracolumbar level in TWMV users.

2. Materials and methods

In order to provide a wider view of the problem, this study combined information on the victims and their TWMV accidents, as well as detailed clinical data using AIS coding and the Magerl classification system. These data provide additional information regarding protective gear, the accident scenario, and vertebro-medullary injuries.

2.1 A specific questionnaire

A specific, anonymous, two-part questionnaire was distributed in the North Marseille Hospital trauma center. This questionnaire is dedicated to treating severe trauma patients, often with life-threatening injuries. Between 900 and 1000 patients per year are treated in this unit, of which between 400 and 500 are seen for trauma.

The first part of the questionnaire was filled out by the patients when conscious, or by an accident witness in the case of a loss of consciousness. This part collected information about the patient: age, sex, type of TWMV, level of experience, and protective equipment worn. This information enabled us to identify the characteristics of the severely injured TWMV user. This part also contained information regarding the accident: type of accident, estimated speed, and accident causes. This information enabled us to formulate an overall accident scenario type. Only one response was allowed per question, except for the question regarding the protective gear used.

The second part was filled out by the doctor and involved the medical evaluation, paying specific attention to injuries. The injuries were coded based on the “AIS 2005” injury scale

(AAAM, 2005), from level 1 to 6. In order to identify the mechanisms of thoracolumbar injury, each vertebral injury was classified according to the Magerl classification system. This enabled us to determine the stability of thoracolumbar spinal fractures and identify neurological risks, and was used to guide therapeutic decision-making. According to Amoretti et al., 55% of initial neurological problems are associated with type C fractures, 30% with type B, and 15% with type A (AMORETTI et al., 2013).

2.2 Data collection

During 2016, all individuals who were in a road traffic accident involving a TWMV and who were treated in the emergency department at the Marseille trauma center were invited to fill out the specific two-part questionnaire. Consent for use of the collected data was requested at the end of each questionnaire. These data were used to construct a database containing 94 variables that provided information about the victim and the accident and 20 variables for coding the lesions.

2.3 Study population

Based on the study objectives, the victims were classified into two groups: victims who were wearing back protectors (group I), and victims who were not wearing back protectors (group II). Each of these groups was then divided into subgroups based on whether or not they sustained thoracolumbar injuries (vertebro-medullary trauma): victims with thoracolumbar injuries (groups I.1 and II.1) and victims without thoracolumbar injuries (groups I.2 and II.2). The subgroups of individuals with thoracolumbar injuries were created based on the following criterion: each individual had at least one thoracolumbar injury with an AIS score of 1+. The subgroup of individuals without thoracolumbar injuries was created based on the following criterion: the individual did not have any thoracolumbar injuries. The group selection process is summarized in Fig. 1.

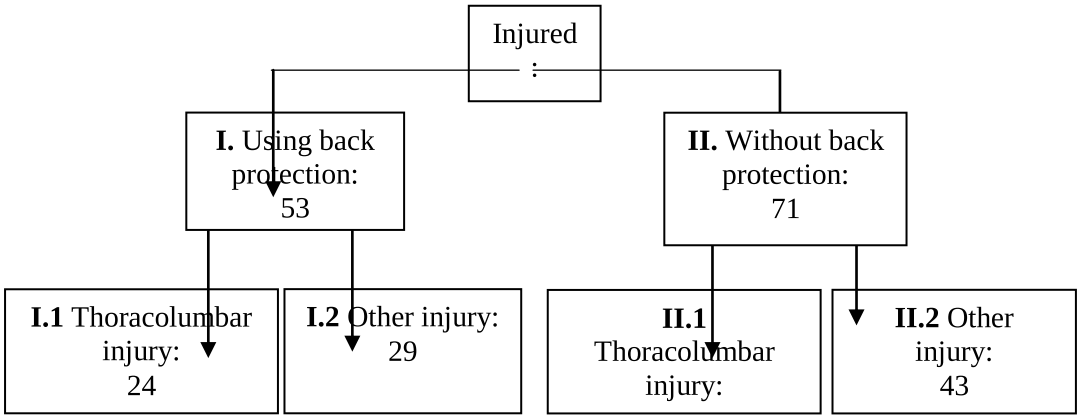

Fig. 1 Flow diagram of groups selection according to the use of back protection and trauma

3. Statistical analysis

This was a prospective, descriptive study whose goal was to collect information regarding risk exposure and health events in the studied population. The analyses were performed in two steps.

First, univariate analyses and Fisher tests ($p < 0.1$) were used to extract the individuals' characteristics. This first step consisted of comparing the groups of individuals with and without back protection (group I compared to group II) and the subgroups of individuals who had at least one thoracolumbar injury as a function of whether or not they were wearing back protectors (group I.1 to group II.1). The Fisher test assessed the equality of two distributions that were observed, without making any assumptions about the underlying reasons. The Fisher tests assessed the association between the following qualitative variables: sex, age, level of experience, cylinder size, type of road, protection used, type of accident, estimated speed prior to the accident, and death; and quantitative variables: thoracolumbar lesion and use of a back protector. These tests were performed for individuals who were wearing back protectors, and then individuals who had at least one thoracolumbar injury, respectively.

The second step focused on individuals who had at least one thoracolumbar injury (group I.1 and II.1). The injuries suffered by each of the victims in these groups were coded using the AIS 2005 injury severity classification system and were then classified according to the Magerl AO classification system to determine the severity and injury mechanisms. The univariate analyses and Fisher statistical tests were performed using R Studio software.

3.1 Parameters studied:

The parameters studied were: sex, age, level of experience, TWMV cylinder size (<50 m^3, between 50 and 125 m^3, more than 125 m^3), type of road (highway, avenue/boulevard/city street, country road), protective gear worn (helmet, jacket, neck protection, elbow pads, certified pants, gloves), type of accident, estimated speed, and finally consequences of the injury including death, as well as the injuries sustained according to the AIS 2005 injury severity scale and according to the Magerl classification.

For this analysis, three age groups (15-25, 26-39, 40-80) were defined based on the ages of individuals at risk of being involved in a TWMV accident ("ATSB. Monograph 12 – Motorcycle rider age and risk of fatal injury," 2002). A comparison of accident victims and a reference population indicated that riders with less than 6 months of experience riding a TWMV of any type are more likely to be involved in an accident (7.8% compared to 5.2% for the reference group) ("MAIDS Étude approfondie sur les accidents en motocycles. Rapport final 1.3," 2005). The level of the riders' experience was therefore defined based on three levels: less then 6 months, between 6 months and 2 years, and more than 2 years. For helmet use, we distinguished between wearing a full-face helmet and wearing an open-face helmet. Two types of back protection were taken into account with no distinction: back protectors inserted into the jacket (integrated) and back protectors directly in contact with the back (separate). The types of accidents were grouped into five categories: single vehicle, with an obstacle, with a car, with a heavy vehicle, or with a motorcycle. Accidents "with obstacles" included the following types: “safety barriers”, “building, wall, low wall, barrier”, or “narrow object (tree, post…)”. We defined three possibilities for estimated speed: fast, moderate, and slow. The “fast” group included speeds that were estimated to be “fast” and “too fast”, and the “slow” group included speeds that were estimated to be “stopped” and “slow”. The injury coding according to the Magerl classification system was obtained through two separate readings of computed tomography and/or MRI scans by radiologists and then spinal neurosurgeons. The thoracic vertebrae were classified into three groups depending on their positions in the spinal column: high thoracic vertebrae (from T1 to T4), middle thoracic vertebrae (from T5 to T8), and lower thoracic vertebrae (from T9 to T12).

4. Results

4.1 Characteristics of the injured subjects

In 2016, 124 individuals who were victims of a TWMV accident and who were admitted to the emergency department of the Marseille trauma center agreed to fill out a questionnaire. Most of these individuals were men (90% of victims), with a relatively large number of individuals aged 26 to 60 (59% of victims), riding at moderate speed (44% of victims), and with more than 2 years of experience (55% of victims). These users were well-equipped, with 60% wearing a full-face helmet and 43% wearing back protection. The primary types of accidents were collision with a vehicle (48% of accidents) and falling off of the motorcycle (23% of accidents). There were 12 cases of fatal accidents (10% of victims) (Table 1).

Table 1: Characteristics of injured TWMV users. Dorso-lumbar injuries, sex, age, level of experience, displacement, type of road, protection, type of accident, estimated speed, death.

	I.Using back protection		II.Without back protection		Total	Test Exact Fisher	
	I1.Dorso-lumbar injury (n=24) n (%)	**I2.Other injury** (n=29) n (%)	**II1.Dorso-lumbar injury** (n=28) n (%)	**II2.Other injury** (n=43) n (%)	(n=124) n (%)	**Dorso-lumbar Injury** (n=52)	**Back protection** (n=124)
Dorso-lumbar injuries	57		75		132		
Sex						1	0,3591
Female	2 (8,3%)	5 (17,2%)	2 (7,1%)	3 (7%)	12 (9,7%)		
Male	22 (91,7%)	24 (82,8%)	26 (92,9%)	40 (93%)	112 (90,3%)		
Age						0,213	0,468
15-25	12 (50%)	6 (20,7%)	7 (25%)	16 (37,2%)	41 (33,1%)		
26-60	5 (20,8%)	14 (48,3%)	8 (28,6%)	11 (25,6%)	38 (30,6%)		
>60	7 (29,2%)	9 (31,0%)	13 (46,4%)	15 (34,9%)	44 (35,5%)		
Level of experience						0,205	0,674
Less than 6 months	1 (4,2%)	5 (17,2%)	4 (25%)	4 (11,4%)	14 (11,3%)		
Between 6 months and 2 years	5 (20,8%)	5 (17,2%)	3 (18,8%)	9 (25,7%)	22 (17,7%)		
More than 2 years	18 (75%)	19 (65,5%)	9 (56,3%)	22 (62,9%)	68 (54,8%)		
Displacement						0,004	0,001
< 50m3	2 (8,3%)	3 (10,3%)	4 (25%)	7 (16,3%)	16 (12,9%)		
Betwen 50 and 125 m3	2 (8,3%)	4 (13,8%)	7 (25%)	10 (23,2%)	23 (18,5%)		
> 125m3	20 (83,3%)	22 (75,9%)	5 (17,9%)	17 (39,5%)	64 (51,6%)		
Type of road						0,404	0,684
Highway	3 (12,5%)	2 (6,9%)	1 (3,6%)	5 (11,6%)	11 (8,9%)		
City street	10 (41,7%)	15 (51,7%)	11 (39,3%)	17 (39,5%)	53 (42,7%)		
Country road	10 (41,7%)	11 (37,9%)	4 (25%)	12 (27,9%)	37 (29,8%)		
Protection						0,000	0,004
Full-face helmet	19 (79,2%)	27 (93,1%)	10 (35,7%)	18 (41,9%)	74 (59,7%)		
No full-face helmet	5 (20,8%)	1 (3,4%)	9 (32,1%)	18 (41,9%)	33 (26,6%)		
Jacket	17 (70,8%)	28 (96,5%)	0 (0%)	4 (13,8%)	49 (39,5%)		
Cervical protection	2 (8,3%)	0 (0%)	0 (0%)	0 (0%)	2 (1,6%)		
Elbow support	16 (66,7%)	28 (96,5%)	0 (0%)	8 (27,6%)	52 (41,9%)		
Motorcyclist's pants	6 (25%)	13 (44,8%)	1 (3,6%)	1 (3,4%)	21 (16,9%)		
Glove	9 (37,5%)	17 (58,6%)	6 (21,4%)	11 (37,9%)	40 (32,2%)		
Collision						0,157	0,521
No	6 (28%)	7 (24,1%)	6 (21,4%)	9 (20,9%)	28 (22,6%)		
Obstacle	2 (8,3%)	4 (13,8%)	3 (10,7%)	7 (16,3%)	15 (12,1%)		
Vehicle	11 (44%)	17 (58,6%)	13 (46,4%)	18 (41,9%)	60 (48,4%)		
Heavy vehicle	5 (20%)	1 (3,4%)	0 (0%)	3 (7%)	9 (7,3%)		
Motor	0 (0%)	0 (0%)	0 (0%)	2 (4,7%)	2 (1,6%)		
Estimated speed before crash						0,066	0,119
High	9 (37,5%)	10 (34,5%)	13 (46,4%)	19 (44,2%)	51 (41,1%)		
Average	15 (62,5%)	15 (51,7%)	9 (32,1%)	16 (37,2%)	55 (44,4%)		
Low	0 (0%)	2 (6,9%)	3 (10,7%)	5 (11,6%)	10 (8,1%)		
Death						0,199	0,674
No	23 (95,8%)	27 (93,1%)	23 (82,1%)	39 (90,7%)	112 (90,3%)		
Yes	1 (4,2%)	2 (6,9%)	5 (17,9%)	4 (9,3%)	12 (9,7%)		

4.1.1 Characteristics of injured individuals as a function of back protection

The Fisher test did not show any significant difference in the number of riders who sustained a thoracolumbar spinal injury based on the use or non-use of back protection. Therefore, we cannot confirm that these two variables are dependent. The Fisher tests performed on the other qualitative variables listed showed that there was no confounding effect linked to use of back protection and sustaining a thoracolumbar spinal injury in this analysis.

Individuals who used back protection were more likely to ride a large-cylinder TWMV (79.2% of victims with back protection; $p < 0.001$) and had a high rate of protective equipment use: 98% wore a helmet, 84% wore a jacket, 84% wore elbow pads, 36% wore certified pants, and 49% wore gloves ($p < 0.004$); these riders also tended to be traveling at a “moderate” estimated speed just before the accident (57% of victims with back protection) and had a relatively low rate of fatality (6% of victims with back protection).

In contrast, individuals who did not use back protection exhibited a low level of protective equipment use: 24% of victims without back protection were not wearing any type of helmet, only 6% were wearing a jacket, 11% elbow pads, 3% certified pants, and 24% gloves; and tended to be traveling at a “fast” estimated speed just prior to the accident (45%).

The Fisher tests did not show any significant difference based of back protection for the following variables: sex, age, level of experience, type of road, type of accident, and death.

4.1.2 Characteristics of individuals who sustained thoracolumbar injuries as a function of back protection

Groups I.1 and II.1 (I.1: individuals who sustained at least one thoracolumbar injury and who were wearing a back protector; II.1: individuals who sustained at least one thoracolumbar injury and who were not wearing a back protector) were distinguished by the rate of helmet use and the estimated speed. There was no significant different depending on the type of accident.

Group I.1 was composed of 24 individuals who had 57 injuries, for a rate of 2.4 injuries per individual. All of these individuals were wearing a helmet at the time of the accident ($p < 0.01$), and 63% estimated their speed just before the accident as “moderate” ($p < 0.07$).

Group II.1 was composed of 28 individuals who had 75 injuries, for a rate of 2.7 injuries per individual. In total, 32% of these riders were not wearing a helmet at the time of the accident, and 46% estimated their speed as “fast” ($p < 0.07$).

4.2 Nature and severity of thoracolumbar injuries

4.2.1 Nature of the injuries

Table 2 shows the nature of the thoracolumbar injuries as a function of wearing back protection. The majority of thoracolumbar injuries were strictly bone injuries. Among all injuries thoracolumbar, the transverse apophysis are the most affected. Out of the injuries sustained by victims who were wearing back protection, two were contusions of the spinal bone marrow. In contrast, no medullary lesions were found in victims who were not wearing a back protector. There are more burst injuries for victims without back protection. There is no significant difference between the number of injuries sustained by those who use back protection and those who do not use it (p-value = 7%).

Table 2: Description of the thoraco-lumbar injuries by the AIS 2005 coding according to the wearing of the back protector for the victims of a TWMV accident having had at least one thoraco-lumbar injury

Injury	I.Using back protection	II.Without back protection	**Fisher**
Transverse apophysis fracture	24	36	
Burst fracture	6	13	
Spinous process fracture	10	6	
Vertebrale body fracture	6	4	

Multiple fractures of the same vertebra	5	5	
Vertebral facet fracture	0	7	
Fracture with or without dislocation, without involvement of the spinal cord	2	2	
Spinal cord contusion	2	0	
Pedicle fracture	1	1	
Vertebral blade fracture	1	0	
Unilateral dislocation of the facet joints	0	1	
Total	**57**	**75**	**0 ,0688**

4.2.2 AIS lesion severity and location

Table 3 shows the thoracolumbar injuries by location and AIS1+ and AIS3+ lesion severity as a function of wearing a back protector. The majority of the thoracolumbar injuries were classified as AIS2. Only six individuals who wore back protectors and six individuals without back protection had at least one injury classified as AIS3+.

In victims who had been wearing a back protector, there were proportionally more injuries in the high and medium thoracic regions (T1 to T8). Without back protection, there were proportionally more lesions in the lower thoracic (T9 to T12) and lumbar (L1 to L5) regions.

Among the individuals who had at least one thoracolumbar injury and had been wearing a back protector (group I.1), two individuals had both thoracic and lumbar spinal injuries. Among the individuals who had at least one thoracolumbar injury and were not wearing back protection (group II.1), five individuals had both thoracic and lumbar spinal injuries.

Table 3 : Number of victims with at least one lesion by thoraco-lumbar location and by AIS score (AIS1 + and AIS3 +) according to the back protection wear: number and percentage.

	I. Using back protection		II. Without back protection	
	AIS1+	AIS3+	AIS1+	AIS3+
T1-T4	8 (33,33%)	1 (4,17%)	8 (28,57%)	0 (0%)
T5-T8	10 (41,67%)	1 (4,17%)	10 (35,71%)	1 (3,57%)
T9-T12	6 (25%)	1 (4,17%)	9 (32,14%)	2 (7,14%)
L1-L5	6 (25%)	3 (12,5%)	15 (53,57%)	3 (10,71)

Legend: Among those who were wearing back protection and injured in the thoraco-lumbar region, 33.33% had at least one lesion in the T1-T4 region.

4.2.3 Mechanisms of thoracolumbar injuries according to the Magerl classification system

Table 4 shows the victims who had at least one thoracolumbar lesion by location and Magerl classification as a function of wearing back protection. The majority of the victims sustained at least one type A injury, which corresponds to axial compression. There were only slightly more victims without back protection than with back protection who sustained at least one type B or type C thoracic injury, corresponding to distraction or rotation, respectively: without protection, five victims had at least one distraction injury and two victims had at least one rotation injury; with back protection, two victims had at least one distraction injury and one victim had at least one rotation injury. This difference was not significant.

Table 4: Number of victims with at least one AIS1+ lesion per thoraco-lumbar location in function to the Magerl classification and back protection port: number and percentage.

	I.1 Using back protection			II.1 Without back protection		
	A	B	C	A	B	C
T1-T4	8 (33,33%)	1 (4,17%)	0 (0%)	8 (28,57%)	0 (0%)	1 (3,57%)
T5-T8	10 (41,67%)	0 (0%)	0 (0%)	7 (25%)	3 (10,71%)	0 (0%)
T9-T12	6 (25%)	0 (0%)	0 (0%)	6 (21,43%)	2 (7,14%)	1 (3,57%)
L1-L5	4 (16,67%)	1 (4,17%)	1 (4,17%)	14 (50%)	0 (0%)	0 (0%)

Legend: Among those who were wearing back protection and injured in the thoracolumbar region, 33.33% had at least one lesion in the T1-T4 region of type A (compression).

5. Discussion and limitations

The originality of this study is that it combines an epidemiological analysis with a clinical and biomechanical analysis to associate the nature of the injury with the mechanism that is likely to have produced it. This study provided a description of severe injuries sustained after a TWMV accident and allowed us to quantify the severity and mechanisms of the thoracolumbar injuries as a function of using back protection.

5.1 Data collection:

For this study, we chose to recruit victims of TWMV accidents who were admitted to the emergency department between January 1, 2016 and December 31, 2016 and who agreed to fill out a questionnaire. Thus, a sample size calculation was not performed. The inconclusive Fisher tests could therefore be because of the lack of statistical significance due to including too few subjects. Thus, there could be a small significant difference that the small sample size did not allow us to detect.

Even though it was based on a relatively small sample, the objective of this study was to provide an exhaustive database. It did not take into account individuals who were involved in a TWMV accident but who were not injured or who only sustained non-severe injuries that did not require treatment in the trauma room. This could include individuals for whom protective gear, including back protection, was effective. In 2015, according to the Rhône register, 9.2% of victims of TWMV accidents were treated in the trauma room (161 out of 1771 cases), and 17% of these individuals had at least one thoracolumbar injury (27 out of 162 cases).

Given the nature of the traumatic injuries that we encountered, the responses to the first part of the questionnaire (information about the victim and how the accident happened) are most likely somewhat imprecise with regard to the trauma encountered. The patients were victims of a serious accidents, which are sometimes associated with memory problems, and this almost certainly led to a reduced response quality. In addition, this part of the questionnaire was filled out by the patients when they were able to, or by a witness to the accident when the patient was unconscious or disoriented. According to the doctors who participated in the study, the questionnaire was most often filled out by the patient, but we do not know the exact number of questionnaires that were filled out by witnesses. This could have affected the speed estimate or the type of accident that was reported. The victims' perception of their own behavior could differ from that of a witness. However, this difference would not have had any effect on the responses to questions that were not open to interpretation, such as information about the patient (sex, age), the type of TWMV used, the protective gear used, and the place where the accident occurred. The second part, which was filled out by the doctor and provided information about the medical evaluation, was not subject to this type of problem. This enabled us to obtain a robust estimate of the mechanisms of injuries that occurred during the accidents.

5.2 The use of back protection

No figures regarding the rate of wearing back protection have been published for France. In this study, 43% of victims of TWMV accidents who were seriously injured were wearing back protection. This is a relatively high rate, but is very similar to the rate of back protector use among TWMV riders reported in a study from New South Wales in Australia that was published in 2006 (44%).

In this study, participants were specifically asked "were you wearing a back protector at the time of the accident" at the beginning of the interview, but no distinction was made between the different types of back protectors: those that are integrated into riding jackets or separate back protectors, and level 1 or 2 according to the norm. Integrated and separate back protectors are intended to protect the thoracic and lumbar vertebrae. However, separate back protectors can be adjusted to fit better than integrated back protectors and are sometimes large enough to cover the shoulder blades. When the data were collected, a specific description of the type of back protector used could have been requested. However, given the sample size, it was difficult to explore this level of detail.

5.3 Characteristics of injured individuals

The results from the univariate analyses show that the severely injured patients had a tendency to be injured following a collision with a vehicle (48%) or following a solitary fall (23%) on an avenue, boulevard, or city road (43%). These victims were, for the most part, experienced young men. Nevertheless, there was a difference in the level of protection used, the cylinder size, and the estimated speed at the time of the accident. Two characteristic rider profiles emerged from the analysis.

The first profile was primarily composed of riders of large cylinder vehicles (> 125 m^3) who were attentive to their protective equipment (back protector, full-face helmet, elbow pads, jacket, certified pants, gloves) and riding at a speed that they considered to be moderate at the time of the accident. The second profile was composed of riders of small cylinder vehicles (< 125 m^3) who were much less attentive to their protective equipment. They were not wearing back protection or neck protection. Only rarely were these riders wearing a jacket, gloves, elbow pads, or certified pants. In addition, they estimated their speed as fast at the time of the accident (Table 1). The identification of these two profiles will allow preventive campaigns to better target to this population to encourage them to use protective equipment or even advise them regarding the limitations of this type of equipment when it comes to protection from injury.

5.4 Thoracolumbar lesions:

According to the data, the riders who were not wearing back protectors were involved in accident scenarios that were potentially more serious than those faced by riders who were wearing back protectors. High speeds, which are known increase traumatic injuries, and very limited use of protective gear at the time of the accident confirm this greater exposure to the risk of more severe injuries. Nevertheless, the severity was not confirmed by the nature and number of thoracolumbar injuries observed in this study (only three AIS+3 injuries were observed in victims who were not wearing back protectors). Despite these relatively opposite rider profiles, the study did not show any difference significant in injuries between these two groups (table 2). Even if the number of burst injury is slightly higher for individuals without back protection than individuals with back protection, fisher's test did not highlight it. Thus, we can say that the two profiles overall had the same number and type of injuries. The injury mechanisms did not differ depending on the use of back protection. The axial compression characteristic of type A lesions according to the Magerl classification system is the most common mechanism of thoracolumbar injuries. It occurs due to an impact in the craniocaudal direction. Multiple injury mechanisms with potentially multidirectional force loads can occur during TWMV accidents. Back protectors, which are designed to protect users from impacts in a posterior-anterior direction, do not protect riders from the axial forces that cause compression injuries. Among the injury data collected from the riders who were not wearing back protectors, very few injuries linked to posterior-anterior impacts could have been avoided by the use of back protection. Thus, it is difficult to draw any conclusions regarding the effectiveness of back protection given that this type of protector is designed to prevent posterior injuries, which did not appear in the study population.

Other studies suggest that the majority of spinal injuries that occur during TWMV accidents are caused by flexion and torsion forces, and not by direct impacts on the vertebral column (de Rome, 2006). Thus, this study highlights the necessity of preventing compression injuries, which, instead of being prevented by wearing a back protector, are deflected to the thoracic spine (lumbar vertebra-medullary lesions are deflected to the thoracic vertebrae), and the medical implications of these injuries are known to be potentially much more significant. This finding clearly defines the challenge of developing new back protectors that prevent these injuries instead of deflecting them to the adjacent spinal segment.

Studies have identified the thoracic region as the region that is most commonly affected in TWMV users who are involved in accidents (Ankarath et al., 2002). Our results show that, among victims of serious TWMV accidents, 27% had thoracic injuries and 17% had lumbar injuries. The greater number of injuries at the level of the thoracic vertebrae reveals that the thoracic spine is overexposed. In addition, this is the area of the spine that is most curved, and is thus likely to by more sensitive to structural buckling. The smaller size of the thoracic vertebrae could also explain why their fragility is increased by the presence of the back protector, which, by restraining spinal mobility, increases the risk of a local break. Here again, a detailed biomechanical analysis based on digital simulation could confirm the hypotheses generated in this study.

6. Conclusion

This multidisciplinary study, which combined epidemiological data with a clinical and biomechanical analysis, allowed us to identify the mechanisms of thoracolumbar injuries sustained during TWMV accidents as a function of wearing back protection.

The results from this study show that the use of back protectors is widespread, as 43% of individuals who sustained serious injuries were wearing a back protector at the time of the accident. This study does not aim to question the effectiveness of back protectors in protecting users from impacts in a posterior-anterior direction. Currently available back protectors are not appropriate for protecting against impacts in a craniocaudal direction. It is therefore important to clarify messages regarding the effectiveness of this type of gear and determine how to develop back protectors that better protect the spine.

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AMORETTI, M.E., BRONSARD, N., AMORETTI, N., 2013. Fractures récentes du rachis thoracolombaire: De la classification au traitement.
Ankarath, S., Giannoudis, P.V., Barlow, I., Bellamy, M.C., Matthews, S.J., Smith, R.M., 2002. Injury patterns associated with mortality following motorcycle crashes. Injury 33 6 , 473–477.
ATSB. Monograph 12 – Motorcycle rider age and risk of fatal injury [WWW Document], 2002. URL https://infrastructure.gov.au/roads/safety/publications/2002/Mcycle_Age_1.aspx (accessed 11.28.17).
Blaizot, S., Papon, F., Haddak, M.M., Amoros, E., 2013. Injury incidence rates of cyclists compared to pedestrians, car occupants and powered two-wheeler riders, using a medical registry and mobility data, Rhone County, France. Accid Anal Prev 58, 35–45. doi:10.1016/j.aap.2013.04.018
Carroll, C.P., Cochran, J.A., Price, J.P., Guse, C.E., Wang, M.C., 2010. The AIS-2005 Revision in Severe Traumatic Brain Injury: Mission Accomplished or Problems for Future Research? Ann. Adv. Automot. Med. Annu. Sci. Conf. 54, 233–238.
de Rome, L., 2006. Planning for motorcycle safety: measures of success, in: Australasian Road Safety Research Policing Education Conference.
Ekmejian, R., Sarrami, P., Naylor, J.M., Harris, I.A., 2016. A systematic review on the effectiveness of back protectors for motorcyclists. Scand. J. Trauma Resusc. Emerg. Med. 24, 115. doi:10.1186/s13049-016-0307-3
Magerl, F., Aebi, M., Gertzbein, S.D., Harms, J., Nazarian, S., 1994. A comprehensive classification of thoracic and lumbar injuries. Eur. Spine J. 3 4 , 184–201. doi:10.1007/BF02221591
MAIDS Étude approfondie sur les accidents en motocycles. Rapport final 1.3 [WWW Document], 2005. URL http://www.maids-study.eu/pdf/MAIDSreport1.3_FR.pdf (accessed 9.26.17).
Ministère des affaires sociales et de la santé, 2017. Classification statistique internationale des maladies et des problèmes de sante connexes cim-10 fr a usage pmsi, 2017th ed, Atih.
NF EN 1621-2 Vêtements de protection contre les chocs mécaniques pour motocyclistes - Partie 2 : protecteurs dorsaux - Exigences et méthodes d’essai, 2014. . afnor.
Observatoire national, Interministériel, de la sécurité routière, 2017. La sécurité routière en France - Bilan de l’accidentalité de l’année 2016. Paris.
Van Elslande, P., Fournier, J.-Y., Parraud, C., 2014. Accidentalité des deux-roues motorisés à usage urbain [WWW Document]. URL https://hal.archives-ouvertes.fr/hal-01006561/document (accessed 11.24.17).