

Airbag vest effectiveness in reducing thoracic injuries among PTW riders in road crashes: An epidemiological study

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I. INTRODUCTION

Powered two-wheeler (PTW) user crashes, including motorcycles and mopeds, represent a major road safety concern in Europe. In 2023, they accounted for 19% of road fatalities, despite representing less than 2% of road traffic [1-2]. When accounting for exposure, PTW users have a 20–32 times higher risk of death than car occupants, and a 120 times higher risk of serious injury [3]. While extremities are the most commonly injured body region in PTW crashes, the head and the thorax are associated with the highest burden in terms of morbidity and mortality [4]. Helmets have substantially reduced the risk of serious and fatal head injuries, but protective devices designed specifically to mitigate thoracic injuries remain limited [5]. In this context, airbags integrated into motorcycle garments have been developed to protect the torso by deploying inflatable bags that absorb impact energy and redistribute loads. Experimental and numerical studies have shown that airbag vests mitigate thoracic loadings and contribute to lowering the risk and severity of rib fractures and internal organ injuries by reducing chest deflection and Viscous Criterion [6-7]. However, evidence of their effectiveness in real-world crashes remains scarce. A recent epidemiological analysis reported a non-significant trend toward a 20% reduction in mortality associated with airbag vest use [8]. However, this outcome is not specific to the primary protective target of these devices. A focus on the body region that is expected to be protected by the airbag vest would provide a more accurate evaluation of its effectiveness. Therefore, the objective of this study was to assess the effectiveness of airbag vests in reducing thoracic injuries among PTW users involved in real-world crashes.

II. METHODS

Data were collected as part of the EDAIR project, through an online survey conducted between October 2024 and February 2025 among users of In&motion motorcycle airbag vests. The questionnaire collected information on socio-demographic characteristics, PTW use, protective equipment, crash circumstances, airbag use and deployment, injuries, and medical care. After applying exclusion criteria (<18 years old, passenger, off-road or track crash, unspecified injuries or airbag deployment) and data validation techniques, eligible PTW riders were included in the study. Among them, those whose airbag vest inflated during the crash were considered exposed, while those who were not wearing an airbag vest or whose vest did not inflate were considered non-exposed. These two groups were compared using the chi-square test for categorical variables and the Wilcoxon–Mann–Whitney test for continuous variables. Categorical variables were summarised using frequencies and percentages, and continuous variables using the median and interquartile range (IQR). Casualties with thoracic injuries (TI) were defined as those sustaining a thorax injury according to the Abbreviated Injury Scale (AIS) body regions. The association between inflated airbag vest and thoracic injury risk was assessed using inverse probability of treatment weighting based on the propensity score, followed by weighted log-binomial regression to estimate relative risks (RR) with 95% confidence intervals (95% CI). Statistical significance threshold was set at 0.05.

III. INITIAL FINDINGS

A total of 943 PTW riders involved in a road crash were included in this study, including 480 (51%) with an inflated airbag vest and 463 (49%) without (Table I). The population was predominantly comprised of men (90.5%), with a median age of 45 years (IQR: 35–56) and a high overall level of protective equipment use (82.6%). PTW riders with an inflated airbag vest reported higher pre-crash speeds than those not wearing an airbag or without inflation (median: 45 km/h vs 40 km/h; $p = 0.013$) and were more frequently riding PTWs with an engine capacity ≥ 125 cc (96.4% vs 92.1%; $p = 0.005$). After weighting, inflated airbag vest was associated with a significant reduction in thoracic injury risk among casualties (RR [95% IC] = 0.48 [0.35–0.65]).

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TABLE I

CHARACTERISTICS OF PTW RIDERS ACCORDING TO AIRBAG VEST USE AND WEIGHTED RELATIVE RISKS (RR) OF THORACIC INJURIES –
EDAIR SURVEY

Characteristic	Inflated airbag vest				RR	95%CI
	Total n=943 ¹	No n=463 ¹	Yes n=480 ¹	p-value ²		
Thoracic injury	83 (8.8)	54 (11.7)	29 (6.0)	0.001	0.48	0.35–0.65
Age (in years)	45 [35–56]	44 [35–55]	45 [34–57]	0.7		
Men	817 (90.5)	400 (90.7)	417 (90.26)	0.8		
High protection level (helmet + ≥3 additional protective devices)	779 (82.6)	374 (80.8)	405 (84.4)	0.15		
PTW engine capacity ≥125 cc	874 (94.3)	419 (92.1)	455 (96.4)	0.005		
Self-reported pre-crash speed (km/h)	45 [30–60]	40 [25–55]	45 [30–60]	0.013		

¹N (%) or Median [IQR]. ²Wilcoxon test or χ^2 test.

Covariates included in the propensity score weighting were age, gender, socio-professional category, obesity, protection level, PTW engine capacity category, crash location, other vehicle involvement, object struck, and self-reported pre-crash speed.

IV. DISCUSSION

This observational study relied on survey data from PTW riders involved in road crashes, and aimed to evaluate the effect of airbag vests on thoracic injury occurrence. The airbag vest was associated with a 52% reduction in the risk of thoracic injuries. To our knowledge, this is the first epidemiological study assessing this effect in real-world crash conditions based on detailed injury data. The originality of this work lies in the use of propensity score-based causal inference methods, which reduces confounding from measured covariates by balancing baseline characteristics between exposed and non-exposed groups. The protective benefit of the airbag was evaluated for those for whom deployment occurred, as its capacity to absorb and redistribute impact energy is contingent upon inflation. Riders wearing an airbag vest that did not inflate (n=131) were therefore classified as non-exposed to avoid diluting the effect of the device. However, the timing of airbag triggering (before vs after the first body impact) was not assessed, and inflation occurring after thoracic impact would not provide effective protection. Notably, 37% of riders reported unknown (34%) or inflation after the first body impact (3%), which may have introduced exposure misclassification and led to an underestimation of the protective effect.

The analysis relied on adults who had purchased an airbag vest at the time of the survey. Previous studies suggest that these riders may differ from the broader PTW population, particularly in terms of riding behaviour, risk exposure, and safety equipment use [8]. Yet, this representativity bias is likely to have a limited effect on the validity of the estimated associations. Non-users were recruited among current airbag-vest users, some of whom could have adopted the device following a thoracic injury due to a previous crash, i.e., the event analysed in the present study. This could introduce a selection bias that could lead to effect overestimation. Future research should investigate the airbag vest effectiveness by selecting a population of non-users of airbag who are not current airbag users. In addition, the self-administered survey relied on participants' memory of events, which may introduce recall bias, due to the delay between the crash and filling in the questionnaire. However, any resulting misclassification would likely affect both groups similarly and would tend to attenuate the observed associations.

Our findings are consistent with the expected protective effect of airbag devices, and with evidence from both previous epidemiological and biomechanical studies [6-8]. They suggest that promoting and expanding the use of wearable airbags could contribute to public health and road safety benefits. However, caution is warranted in interpreting these results, as the protective effect may be overestimated. Future research could further investigate severe thoracic injury to better characterise the effect of airbag vests on the most critical injuries.

V. REFERENCES

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