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Tractor rollover fatalities, analyzing accident scenario

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Keywords:

Accidents database
Tractor safety, driver restraint system
Fatal accidents
ROPS
Work-related deaths

A B S T R A C T

Introduction: In many countries, traditional data sources for collecting injuries of workers covered by compulsory accident insurance have recently been integrated by new observatories whose results may differ. A comparative analysis of the Italian data collection systems related to fatal tractor accidents in agriculture was performed focusing on tractor rollover fatalities with the aim of analyzing the accident scenario. *Method:* Data from the Operational Archives of the Italian Workers Compensation Authority (INAIL), which collects injuries of workers covered by compulsory accident insurance and those of the National Surveillance System (INAIL-ASL), which provides narrative text reports of work-related fatal accidents have been analyzed and compared to the information collected by the INAIL Observatory. The INAIL Observatory was recently set up to complement the collection of fatal accidents involving agricultural machinery. Italian data were then compared to data available at an international level. Fatal tractor accidents vary considerably with respect to fatal accidents in agriculture, being 10.6% and 43.7% for the Operational Archives and Surveillance System, respectively. National Surveillance System records, implemented with narrative texts allowed the accident scenario to be defined. *Results:* 71.7% of fatal tractor-related accidents refer to non-ROPS equipped vehicles and of these, 26.5% involved machines originally mounted with a ROPS that had been removed or was inoperative in the folded-down position during the rollover event. Just one fatal event from a collapsed ROPS on the overturned tractor was recorded. It is interesting that 16.6% of fatal accidents involved a clear environmental factor. *Practical application:* A campaign to train tractor drivers on the correct use of the combination ROPS and seatbelt can contribute to decreasing rollover events with fatal outcomes. Contemporarily a strict requirement to install ROPS and a seatbelt on tractors, combined to an official inspection at the farm level, can increase the chance of survival in a rollover accident.

1. Introduction

Tractors are considered the leading cause of agricultural work-related fatalities in many industrialized countries (Day, Rechner, & Lough, 2004; Myers, 2010; Reynolds & Groves, 2000; Sanderson et al., 2006) and rollovers frequently account for more than 50% of tractor deaths (Jawa et al., 2013; Marshall, Clarke, Langley, & Cryer, 1996; Myers et al., 1998; Springfeldt, 1996; Springfeldt, Thorson, & Lee, 1998). Indeed tractors are particularly subject to rollover because of their high center of gravity, exposure to considerable external loads, large torque outputs, sloping or uneven ground (Guzzomi, Rondelli, Guarnieri, Molari, & Molari, 2009).

Over the years, research studies on tractor rollover have been well-documented (Arndt, 1971; Myers, 2000; Springfeldt et al., 1998; Tinc, Ayers, May, Purschwitz, & Sorensen, 2015). After the pioneer work of using safety education to preventing tractor rollover, the innovative tractor design approach in the 1950s was the mounting of a passive

Rollover Protective Structure (ROPS), to provide the driver with a clearance zone during a rollover accident (Fig. 1). The ROPS solution has since been adopted worldwide and ROPS testing procedures have been issued (Harald & Moberg, 1973). The effectiveness of ROPS in preventing rollover fatalities has been widely demonstrated (Springfeldt, 1996; Reynolds & Groves, 2000) and since 1974 official rules have made ROPS compulsory for the type-approval of wheeled agricultural and forestry tractors in Europe (European Commission, EC Directive 1974/150).

A clear safety complement to ROPS in injury prevention during a tractor rollover event was demonstrated to be the fitment of a driver restraint system, such as a seatbelt (Reynolds & Groves, 2000; Myers & Pana-Cryan, 2000; Molari & Rondelli, 2007). In Europe, it has been compulsory to fit new tractors with seatbelts since 2005 (European Commission, EC Directive 1974/150, EC Directive 2005/67); while the requirement for the in use tractors in Italy has been in force since 2008 (Legislative Decree 81/2008). Nonetheless, even if the introduction of ROPS and driver seatbelts is now well consolidated all around the world, fatalities associated with farm tractors continue to be a serious occupational hazard (Reynolds & Groves, 2000; Bunn, Slavova, & Hall, 2008; Mayrhofer, Quendler, & Boxberger, 2014).

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Fig. 1. Tractor ROPSs; (a) four post frame, (b) cab, (c) rear two post, (d) front foldable two post.

An analysis of the circumstances leading to tractor accidents could help in defining appropriate measures to prevent injuries and fatalities, and would provide information on the incidence of rollover and effectiveness of the ROPS protection. A statistical evaluation of tractor accident data is essential to develop prevention policies in agriculture. In many European countries, the reporting systems for work-related accidents insufficiently describe circumstances and causes of accidents, due mainly to the delay in acquiring information and lack of specific details. As a consequence, comparing data from different countries is rather difficult and often inappropriate because of the different approach in accident survey methods. In 1990, to harmonize countries data, the European Statistics on Accidents at Work (ESAW) was launched. However, tractor rollover accidents are not clearly specified in the ESAW approach; similarly, the additional circumstances that help in understanding the details of the accident, such as the presence of safety systems as ROPS and seatbelts, are not specified. To obtain more information on accident scenarios, Kogler, Quendler, and Boxberger (2015) suggested adopting the narrative text analysis approach as an accident reporting system.

In many countries, workers compensation archives include all types of injuries in agriculture if related to workers covered by compulsory accident insurance, but exclude the many self-employed workers, unpaid family members, or retirees who frequently work on farms. To overcome this limitation, national surveillance systems have been organized in many countries, together with report systems, based on information obtained from farm surveys, collection of news clippings, hospital and clinic-based surveillance, medical reports, or death certificate data (O'Connor, Gordon, & Barnett, 1993; Gross, Peek-Asa, Ramirez, & Gerr, 2012; Rissanen & Taattola, 2003). A modern approach for accident information is from news clippings by searching in national and local newspapers (Ozegovic & Voaklander, 2011; Pessina & Facchinetti, 2017).

In the current analysis, Italian agriculture has been considered an interesting case study for tractor accidents due to the widespread use of tractors, the presence of many hilly lands, and the large number of arable crops, orchards, and vineyards. Injury data are traditionally provided by the Operational Archives of the Italian Workers Compensation Authority (INAIL), which collect injury reports of workers covered by compulsory accident insurance. They also include less severe injuries, so these records represent the wider source of non-fatal accident data. However, in June 1993, with Italian law 243/1993, self-employed people were excluded from compulsory insurance. Thereafter, INAIL considered only professional workers and there was a sharp decline of recorded data in the historical series. Indeed, between 1992 and 1994, a 40% reduction of injuries was recorded in agriculture together with 53% fewer fatalities (INAIL, historical statistics). INAIL injury coding was then aligned to the ESAW approach. Nonetheless, given the variables describing causes and circumstances of accidents, obtaining detailed information about accident scenarios is rather difficult.

In 2002, an additional accident recording system was issued in Italy: the INAIL_ASL Surveillance System for fatal and severe work-related injuries. The database is managed by INAIL in cooperation with the Local Health Authorities (ASL), involving regions and autonomous provinces, with the coordination of the Ministry of Health. In archiving the accidents, a backward reconstruction process used in legal procedures is

adopted. Factors leading to the accident and those influencing its severity are identified. Short narrative text reports describing fatalities and some severe injuries are available online by consulting the Infor.MO web tool. Even so, the main reconstructive descriptors of the accident are sometimes lacking (Lombardi & Rossi, 2013).

An INAIL Observatory project to add data and information on fatalities in agriculture covering workers, even those not INAIL insured, was then instituted in 2008. The Observatory collects accident data associated with the use of agricultural machinery; operational archives, INAIL_ASL Surveillance System, newspapers and websites are the information sources. Data from online newspapers and websites can reveal injuries not detected by the traditional data reporting systems; however, technical safety details are often omitted in news articles and, moreover, the correctness of the information is not always ascertainable.

The aim of the analysis in this article was to compare the tractor-related fatalities data provided by the three official Italian reporting systems. This was done to characterize the rollover accidents scenario by assessing the fitment on the tractor of the mandatory safety systems (ROPS and driver seatbelts) and their correct use, the age of the victims, and the contribution of environmental risk factors. The Italian data were then compared with data available at an international level.

2. Materials and methods

Data of INAIL Operational Archives were provided by the statistical service of INAIL (personal communication) and include 213 fatalities in agriculture from 2002 to 2014. The Infor.MO web tool of the INAIL_ASL Surveillance System was the second database analyzed for data on fatal and severe work-related injuries. The website provides short narrative text data for each recorded accident. Eight hundred and seventeen fatalities were reported in agriculture from 2002 to 2012. These reports were analyzed to define the tractor rollover accident scenario. To identify the main cause of tractor-related accidents, a text search method based on specific keywords (tractor, rollover, overturn, ROPS, vehicle) was adopted. Fatalities due to tractor rollovers were identified. The second step was studying additional elements influencing the accident severity and its dynamics to identify the presence of ROPS and seatbelts, and specifying if these were mounted on the tractor at the time of the accident, had been removed or were in the folded-down position (Fig. 2).

However, given that the ROPS fitment was not always clearly stated, in the current analysis the not specified ROPS rollover events were identified as "undefined." Therefore, a separate group of rollover accidents related to the accident narrative texts lacking information regarding the ROPS was considered. Concerning the driver restraint system as a complement of the ROPS safety provision, most of the narrative reports were absolutely vague on the fitment of a seatbelt system on the tractor. Taking into consideration that, unfortunately, the requirement of the seatbelt anchorage on the tractor is quite recent with respect to the time period evaluated in the analysis, to show clear safety evidence it was considered advisable to check if the driver was restrained by the seatbelt.

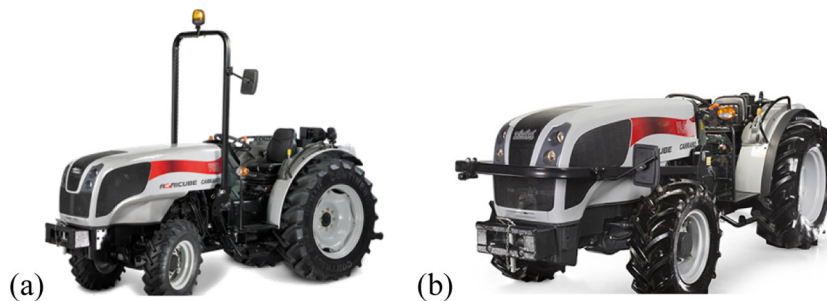


Fig. 2. Tractor fitted with a front foldable two post ROPS: (a) upright position of the ROPS providing for driver clearance zone, (b) inoperative ROPS in the folded-down position.

188 Since driver age is considered an important risk factor (Arana et al.,
189 2010; Gross et al., 2012; O'Connor et al., 1993) tractor rollover fatalities
190 were also divided between tractor drivers over 65 years old and those
191 under 65 based on the driver age recorded by Surveillance System.

192 Lastly, environmental factors considered as relevant to the accident
193 and reported by the Surveillance System were evaluated to better ana-
194 lyze the accident scenario. Main environmental factors in the database
195 were: slippery soil (even for heavy rain or ice), steep embankment,
196 steep slope, collapsed embankment, and deep ditches covered by
197 thick vegetation.

198 The third accident database evaluated in the comparison was the
199 INAIL Observatory from the period 2009–2014. Data were obtained by
200 personal communications and official publications (INAIL, 2014, 2015)
201 and were analyzed to distinguish tractor-related fatalities. However,
202 the records did not allow details to be added on the definition of acci-
203 dent scenario.

204 3. Results

205 3.1. Tractor-related fatalities overview

206 INAIL Operational Archives for the period 2002–2014 reported 2007
207 fatalities in agriculture (on average, 154 per year), 213 were tractor-
208 related (10.6%, 16 per year); however rollover events were not
209 identifiable.

210 According to the data of the INAIL_ASLSurveillance System, in 2002–
211 2012 there were 817 fatalities in agriculture (on average 74 per year)
212 with 357 tractor-related (32 per year) and 205 tractor rollover fatalities
213 (18 per year). Therefore, in this database tractor-related fatalities were
214 43.7% of total fatalities in agriculture, while rollover fatalities were
215 57.4% of tractor-related fatalities.

216 According to the INAIL Observatory, tractor-related fatalities for the
217 period 2009–2014 were 766 (on average 128 per year), with 594 roll-
218 over fatalities (99 per year) representing 77.5% of tractor-related fatali-
219 ties. Clearly the time considered for the three reporting systems
220 differed. Nonetheless, a comparison of the yearly average of fatal inju-
221 ries as recorded by the three reporting systems in the same observation
222 time period (2009–2012) is shown in Fig. 3. There is an obvious differ-
223 ence in the data. The Surveillance System recorded a much lower num-
224 ber of fatalities in agriculture with respect to the Operational Archives
225 (74 and 171, respectively). A possible explanation could be that the
226 Operational Archives are compulsory and the notification of the acci-
227 dent is to obtain the insurance payment for the insured worker while
228 the Surveillance System is based on data collected at regional level
229 and the database could be affected by local procedures in providing ac-
230 cident details.

231 Considering the tractor effect on fatalities, according to the Surveil-
232 lance System 43.7% of fatalities in agriculture were tractor-related
233 (2002–2012), while the Operational Archives recorded only 10.6%
234 (2002–2014). The Observatory gave many more tractor-related fatali-
235 ties than the other two data sources; moreover, 43% of the victims
236 were over 65 years old, a category of workers neglected by the

Operational Archives statistics. The crucial contribution of news clip- 237
pings for a more reliable evaluation of tractor fatalities is thus evident. 238

Data analyzed showed how the actual number of accidents in the 239
different reporting systems is clearly influenced by the database origin. 240
Without case matching, it could be totally inappropriate to mix data 241
from different sources to overcome the incompleteness of each data 242
set. Nevertheless, a thorough analysis of the different systems could 243
allow information from the various databases to be used as a stand- 244
alone source. The Operational Archives approach could be suitable for 245
comparing injuries and fatalities of professional workers to obtain in- 246
dexes representing farm workers, whereas poor information is provided 247
on accident dynamics and the vehicle involved. The Surveillance System 248
would be appropriate for investigating the causes and aggravating fac- 249
tors of fatalities because the short narrative text recording the accident 250
scenario allows the circumstances of the event to be defined, which may 251
allow appropriate measures to prevent accidents and/or their severity 252
to be identified. Indeed the added value of the database approach is re- 253
lated to the ASL staff inspecting the accidents, who are properly trained 254
to draft the accident text reports detailing the surrounding conditions, 255
aggravating factors, and incorrect behavior. However, a clear limitation 256
in the INAIL_ASLSurveillance System is the fewer accidents recorded 257
with respect to the INAIL Operational Archives. To improve the effi- 258
ciency of the system, a higher number of assigned operators would be 259
advisable. The INAIL Observatory system appears to be the most effec- 260
tive data source due to its ability to collect the largest number of tractor 261
fatalities, but the approach adopted made it difficult to compare their 262
data with the other sources and did not allow the event and surround- 263
ing conditions to be described in detail. 264

265 3.2. Accident scenario evaluation

266 Analysis of the narrative text recorded for tractor rollovers by the
267 INAIL_ASLSurveillance System allowed the dynamics of the accident

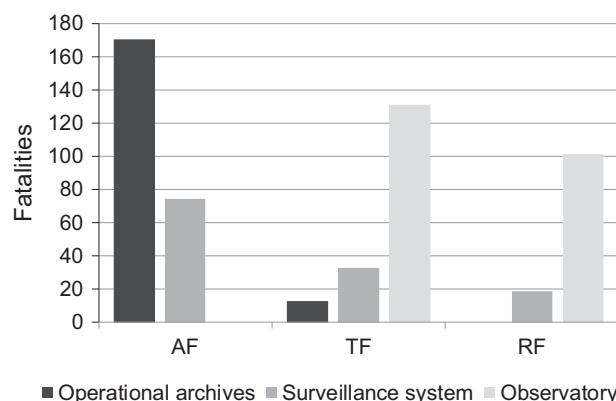


Fig. 3. Work-related fatalities in agriculture, yearly average (2009–2012), in the three Italian reporting systems. Total fatalities in agriculture (AF), tractor-related fatalities (TF), tractor rollover fatalities (RF).

t1.1 **Table 1**
t1.2 Fatalities in Italian agriculture between 2002 and 2012, source Infor.MO web tool.

Fatalities	Frequency	%
t1.4 Tractor rollover	205	25.1
t1.5 Fall from height	124	15.2
t1.6 Hit by falling object	88	10.8
t1.7 Change in the vehicle direction (rollover excluded)	79	9.7
t1.8 Contact with objects, equipment or vehicles in motion	78	9.5
t1.9 Accidental starting of the vehicle	63	7.7
t1.10 Contact with moving parts	69	8.4
t1.11 Projections of solids	21	2.6
t1.12 Direct electrical contact	19	2.3
t1.13 Other fatalities	71	8.7
t1.14 Total	817	100

268 to be characterized, even though it should be noted that the information
269 in the short reports was not homogeneous. Indeed, reports with a very
270 detailed description of the accident scenario were available and narra-
271 tive texts with very few details on the accident circumstances also
272 existed.

273 **Table 1** shows the main causes of fatalities in agriculture recorded
274 for the period 2002–2012. Two hundred and five tractor rollovers fatal-
275 ities were recorded. An evaluation of the accident text reports was done
276 concerning the safety systems mounted on the tractors at the time of
277 the accident.

278 Concerning the driver seatbelts, few narrative texts highlighted the
279 fitment of the seatbelt anchorage on the driver seat. Very few reports
280 did note that the driver was not restrained during the rollover event
281 but there were no reports that referred to the driver being restrained
282 at the time of the accident. Consequently, it was assumed that in the
283 205 rollover fatalities, the drivers were not fastened in during the
284 event, and therefore the information on seatbelt was not included in ta-
285 bles and figures. This approach was also supported by the fact that it is
286 estimated that only 23% of the 1.5 million tractors in use in Italy are
287 mounted with a driver restraint system ([Italian Senato Resolution,](#)
288 [2015](#)).

289 ROPS fitment on the tractors involved in fatal rollover accidents with
290 respect to the activity performed, for example, in field operations or
291 in transport on farm or public roads, for workers under and over
292 65 years old is depicted in **Table 2**. The results showed that ROPS fitment
293 is a discriminant factor on the outcome of the overturning: 71.7% ($n =$
294 147) of the fatal accidents were related to tractors without ROPS, 18%
295 ($n = 37$) to ROPS equipped tractors and 10.2% ($n = 21$) to the not-
296 specified category. Nevertheless, by assuming this category as part of
297 the ROPS equipped tractors the percentage would increase to 28.2% of
298 fatalities.

299 Analyzing data for both driver age and ROPS fitment, 42.4% of fatal
300 accidents involved workers over 65, and these were driving tractors
301 without ROPS in 78.2% of the rollover events. Only 12.6% of the accidents
302 pertained to ROPS equipped tractors (**Fig. 4**). The percentage of over 65
303 driving non-ROPS equipped tractors (78.2%) was, as expected, higher
304 than the percentage of other workers (66.9%).

305 52.2% of fatalities occurred in normal field operations while 42.9% re-
306ferred to the tractor in operation or while being driven on the farm or on

t2.1 **Table 2**
t2.2 Fatal tractor rollovers with respect to ROPS fitment, tractor activity and driver age (205 accidents, from 2002 to 2012).

	Total			Over 65 years			Under 65 years		
	In field	In transfer	Undefined	In field	In transfer	Undefined	In field	In transfer	Undefined
t2.5 ROPS	21	15	1	5	6	0	16	9	1
t2.6 No ROPS	77	63	7	34	29	5	43	34	2
t2.7 Undefined	9	10	2	4	4	0	5	6	2
t2.8 Total	107	88	10	43	39	5	64	49	5

t2.9 ROPS, fatalities involving tractors with ROPS; No ROPS, fatalities involving tractors without ROPS; Undefined, fatalities involving tractors for which the ROPS fitment was not defined in the records.

a public road. The ROPS fitment in field and road accidents were sub- 307
stantially equivalent, 71.9% of tractors were non-ROPS equipped in 308
field operations with respect to the 71.6% on the road 309

The fatalities attributed to no ROPS tractors ($n = 147$) were evalu- 310
ated to verify if the tractors were manufactured without ROPS or if the 311
ROPS was originally installed but had been removed or was in the 312
folded-down position (**Fig. 2**) at the time of the accident, as frequently 313
observed when narrow track tractors are used in the field ([Khorsandi,](#) 314
[Ayers, Jackson, & Wilkerson, 2016](#)). The data were recorded according 315
to the activity performed for both worker groups (**Table 3**). 316

73.5% of fatalities involved tractors without a ROPS protection origi- 317
nally installed by the manufacturer, 21.8% of fatalities were related to 318
tractors with foldable ROPS with the ROPS in the folded-down position 319
(equivalent to no ROPS protection for the driver), and lastly, 4.8% of fatal 320
accidents concerned tractors with foldable ROPS but the ROPS had been 321
removed at the time of the event (**Fig. 5**) 322

Considering the fatalities related to worker age, the percentage of 323
tractors without ROPS involved in fatal rollovers was 25.2% higher for 324
the over 65 age group (82.4 and 65.8% for the over and under 65 years 325
old workers, respectively). Taking into consideration the tractors 326
equipped with foldable ROPS in the folded-down position at the time 327
of rollover, the percentage of fatalities for drivers under 65 years old is 328
almost double that involving drivers over 65 (27.8% and 14.7%, 329
respectively). 330

Considering activities, for the tractor in field operations the fatalities 331
involving no ROPS tractors were 66.2% while they were 82.5% for the 332
tractor in operation or while being driven on the farm or on a public 333
road. The ROPS was in the folded-down position in 28.6% of field events 334
and in 12.7% of those on the road. This is consistent with the fact that 335
when working in the field, the upright position of the ROPS could affect 336
performing the operation correctly; that is why narrow track tractors 337
are mounted with front foldable, two post ROPS allowing a folded- 338
down position when the space for the tractor is restricted by the crop, 339
as in orchard or vineyard inter-rows. Nevertheless, the fatalities re- 340
corded during road operation clearly do not involve this need and de- 341
note an incorrect use of the tractor. 342

Analyzing the fatal rollovers to ROPS equipped tractors ($n = 37$), for 343
which an acceptable level of protection for the driver could be expected, 344
the fatal outcome was due to the lack of retention of the driver inside 345
the clearance zone. It was clearly stated in the narrative report that 346
the driver was thrown out of the driver seat and/or repeatedly bumped 347
into the ROPS frame. More precisely, 37.8% of deaths ($n = 14$) were be- 348
cause the driver was crushed by the tractor on impact with the ground, 349
while in 24.3% ($n = 9$) of the cases, the driver hit the ROPS. One fatal 350
event (2.7%) was because the driver drowned while trapped inside 351
the ROPS cab, and in one case (2.7%) the driver was crushed in the col- 352
lapsed ROPS cab. In the remaining rollover events, 32.4% ($n = 12$), the 353
accident narrative texts did not detail the cause of the fatalities. The lit- 354
erature suggest a collapsed ROPS is very rare in agricultural operations 355
([Reynolds & Groves, 2000](#); [Pessina & Facchinetti, 2017](#)) and our analysis 356
supports this. 357

Tractor rollover fatalities where environmental factors clearly con- 358
tributed to the accident were 16.6% of the recorded accidents ($n =$ 359
34). The most frequent causes of overturning were due to the presence 360

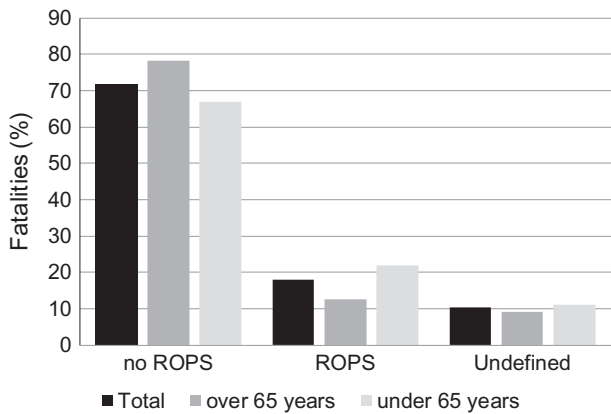


Fig. 4. Tractor fatalities (%) related to worker age (over and under 65 years) and ROPS installation. Tractors non-ROPS equipped (no ROPS); Tractors with ROPS (ROPS); ROPS not assessed (Undefined).

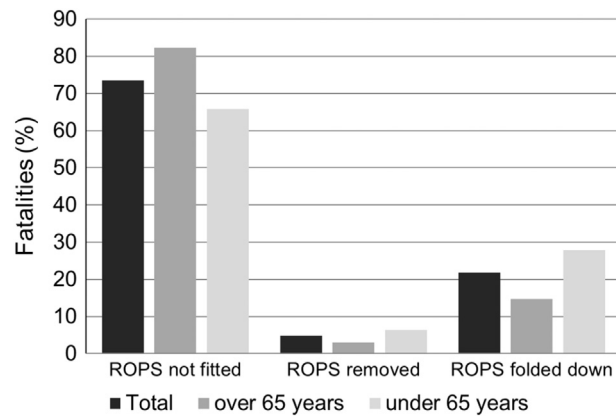


Fig. 5. Fatalities related to tractor rollovers without ROPS protection with respect to driver age. Tractors non-ROPS equipped (ROPS not fitted); tractors manufactured with foldable ROPS but ROPS was removed (ROPS removed); tractors manufactured with foldable ROPS and the ROPS was in the inoperative folded-down position (ROPS folded down).

of slopes, ditches, or embankments (27%), an excessive or unbalanced load on the tractor (16.2%) and mechanical problems (8.1%). In field operations the main environmental contributions were tractors sliding into ditches or bumping against obstacles, sometimes not visible, and tractors working on slopes or slippery ground. In tractors driving on roadways, the main environmental factors involved were the lack of road maintenance and steep slopes adjacent to the tractor path. As already reported, the tractor rollover accident occurrence is frequently affected by environmental risk factors (Arana et al., 2010; Degroot, Isaacs, Pickett, and Brison, 2011).

4. Discussion

Fatal and non-fatal tractor injury are often difficult to compare among different countries because the injury rates are related to the approach and the objective of the data source. Traditional reporting systems often refer only to insured workers, thus accounting for just a proportion of the actual victims of accidents in agriculture (Franklin, Mitchell, Driscoll, & Fragar, 2000; Mayrhofer, Quendler, & Boxberger, 2013). The underestimation of fatal accidents by data sources related to occupational injuries is quite common in the reporting systems of many countries (Arana et al., 2010; Murphy & Yoder, 1998). In the current data analysis the average annual number of tractor-related fatal accidents recorded by the INAIL Operational Archives was only 41% of that recorded by the INAIL_ASJ Surveillance System, while the value reported by the INAIL Observatory is, respectively, 4 and 10 times higher than the Surveillance System and Operational Archives data.

In the literature, tractor-related fatalities recorded in agriculture are quite consistent with the data of the Italian Surveillance System: 43.7% of total farm fatalities were tractor fatalities, as depicted in Table 4 that shows an international overview of the tractor accident rate. Day (1999) refers to a higher percentage (72% from 1985 to 1996) based on data obtained by the Workcover Authority Health and Safety

Division of the state of Victoria, Australia; while Jones, Day, and Staines (2013), based on the same data source, propose a lower percentage (56.5%) because a longer period of time was considered, including more recent data (1985–2010) denoting a significant decrease of the recorded tractor fatalities in the more recent years; this may be due to the increase of ROPS equipped tractors. For the period 2000–2010, tractor fatalities were 46% of farm fatalities, a result consistent with data shown in the present study (Table 4).

Based on the INAIL_ASJ Surveillance System, 25.1% of fatalities in agriculture and 57.4% of tractor fatalities were due to a rollover event, which is data consistent with the international literature (Table 4). According to Bunn et al. (2008), data from the Kentucky Fatality Assessment and Control Evaluation (FACE), rollover fatalities were about half of total tractor fatalities, a value similar to the 57.4% reported in the present study. Arana et al. (2010) showed a higher value (70.1%) for Spanish agriculture in 2004–2008, basing their analysis on 388 fatal accidents recorded in newspaper articles and from an internet search.

The performance of the ROPS protection in tractor rollover is widely documented in the literature (Browning, Westneat, Truszczynska, Reed, & McKnight, 1995; Kelsey, May, & Jenkins, 1996; Reynolds & Groves, 2000; Myers, Cole, & Westneat, 2008; Jones et al., 2013). Springfieldt et al. (1998) verified a 93% reduction of rollover fatalities in Sweden, from 12 to 0.2 fatalities per 100,000 tractors over 30 years, with ROPS equipped tractors increasing from 6 to 93% in the period 1957–1990. The incidence of non-ROPS equipped tractors in many countries is estimated (NIHOSH, 2010; INSHT, 2009; MAPA, 2006; Cole, 2003; Hoy, 2009; Loring & Myers, 2008); this is not the case for Italy because official data are not available. Nonetheless, tractor ROPS fitment has the aim of minimizing the risks for the driver; therefore the potential fatal outcome in the case of a rollover event is not excluded. In the current study, the fatalities with ROPS equipped tractors were 18% of total rollover fatalities; in just one case the ROPS collapsed; in almost all these

Table 3
Fatal tractor rollovers with respect to ROPS fitment, tractor activity and driver age (147 accidents, 2002–2012).

	Total			Over 65 years			Under 65 years	
	In field	In transfer	Undefined	In field	In transfer	Undefined	In transfer	Undefined
Not fitted	51	52	5	26	26	4	26	1
Uninstalled	4	3	0	1	1	0	2	0
Folded down	22	8	2	7	2	1	6	1
Total	77	63	7	34	29	5	34	2

Not fitted, fatalities involving non-ROPS equipped tractors. Uninstalled, fatalities involving tractors with ROPS removed. Folded down, fatalities involving tractors with the ROPS in the inoperative folded-down position.

t4.1 **Table 4**
t4.2 Tractor accidents rate, an international overview.

t4.3	Reference	Rate	Country	Data source years
t4.4	Tractor fatalities with respect to total fatalities in agriculture (%)			
t4.5	Bunn et al., 2008	48	Kentucky, USA	1994–2005
t4.6	Day, 1999	72	Victoria, Australia	1985–1996
t4.7	Jones et al., 2013	56.5	Victoria, Australia	1985–2010
t4.8	Murphy and Yoder, 1998	32.1	USA	1992–1995
t4.9	NHIOS, 2010	36	USA	2003–2007
t4.10	Pickett, Hartling, Brison, and Guernsey, 1999	47.5	Canada	1991–1995
t4.11	Present study ^a	10.6	Italy	2002–2014
t4.12	Present study ^b	43.7	Italy	2000–2012
t4.13	Tractor rollover fatalities with respect to total fatalities in agriculture (%)			
t4.14	DeGroot et al., 2011	20.4	Canada	1990–2005
t4.15	Jones et al., 2013	23.7	Victoria, Australia	1985–2010
t4.16	NHIOSH, 2010	16.4	USA	2003–2007
t4.17	Present study ^b	25.1	Italy	2002–2012
t4.18	Tractor rollover fatalities with respect to total tractor fatalities (%)			
t4.19	Arana et al., 2010	70.1	Spain	2004–2008
t4.20	Bunn et al., 2008	52.2	Kentucky, USA	1994–2004
t4.21	Day, 1999	61	Victoria, Australia	1985–1996
t4.22	Dogan et al., 2010	37.2	Turkey, Konya	2000–2007
t4.23	Jones et al., 2013	42.0	Victoria, Australia	1985–2010
t4.24	NHIOSH, 2010	45.2	USA	2003–2007
t4.25	Present study ^b	57.4	Italy	2002–2012
t4.26	Rollover fatalities referred to ROPS equipped tractors with respect to total rollover fatalities (%)			
t4.27	Arana et al., 2010	0.4	Spain	2004–2008
t4.28	Day, 1999	17	Victoria, Australia	1985–1996
t4.29	Myers et al., 2009	4	Kentucky, USA	2002
t4.30	Present study ^b	18	Italy	2002–2012
t4.31	Authors' elaboration based on			
t4.32	^a INAIL, Operational Archives			
t4.33	^b INAIL_ASLSurveillance System			

426 cases the driver not wearing the seatbelt did not remain protected in-
427 side the ROPS clearance zone.

428 The percentage of fatalities with ROPS equipped tractors is signifi-
429 cantly higher than the values reported by other authors. Myers et al.
430 (2009) noted 4% of fatalities in rollover accidents involving ROPS fitted
431 tractors; Arana et al. (2010) evaluated 272 fatal overturns and only one
432 involved a ROPS equipped tractor; Day (1999) showed a higher per-
433 centage, 17%, close to the value obtained from the Italian Surveillance
434 System (Table 4).

435 In relation to the age of the driver involved in fatalities the interna-
436 tional literature shows that in agriculture the frequency of the elderly
437 is higher than in the other fatalities (Table 5). The percentage of elderly
438 victims ranged between 20 and 40% in agriculture while the data of the
439 Italian INAIL Operational Archives showed a percentage of 17%. As al-
440 ready mentioned, the gap could be due to the fact that the elderly pop-
441 ulation is generally not insured and is therefore not recorded in the
442 archives. Concerning tractor fatalities, the percentage of elderly victims
443 in the literature is generally higher than those of the INAIL Operational
444 Archives while the INAIL_ASLSurveillance System refers to data more in
445 line with the international statistics. The low rate documented by Dogan
446 et al. (2010) could be related to the fewer ROPS equipped tractors in
447 Turkey, as evidenced by Cavallo et al. (2014), which aligns the risk con-
448 ditions of all drivers independently of age and working operations.
449 Arana et al. (2010) explained the higher risk of death, increasing with
450 driver age, by hypothesizing that elderly people drive older, non-ROPS
451 equipped tractors.

5. Conclusions

452

In Italy, as in many European countries, complete workers compen- 453
sation archives and complementary monitoring systems are the refer- 454
ence databases for workplace injuries and fatalities. Considerable 455
differences emerge in the accident data according to the reporting sys- 456
tem considered. Many official accident archives consider only insured 457
workers. As a consequence, injuries involving categories such as self- 458
employed, retired, and part-time workers or unpaid family members, 459
are in many instances not recorded causing a huge lack of information 460
in agriculture. 461

Tractor-related fatalities in Italian agriculture range from 10.6 to 462
43.7%, depending on the data source. Total average number of tractor 463
fatalities per year ranged from 16 to 128 for the INAIL Operational 464
Archives and INAIL Observatory, respectively. The INAIL Observatory 465
data source probably provides the most reliable number of tractor- 466
related fatalities with respect to the other two Italian data sources. Nev- 467
ertheless, despite its incompleteness, data of the INAIL_ASLSurveillance 468
System, which has short narrative text reports, provides information on 469
accident scenarios. 470

Regarding the tractors involved in fatalities, 71.7% of the fatal 471
tractor-related accidents involved non-ROPS equipped vehicles. 472
Concerning tractors manufactured with a ROPS protection, a result 473
worth highlighting is the high number of tractor rollover fatalities asso- 474
ciated with tractors equipped with front foldable ROPS in the inopera- 475
tive folded-down position (21.8%) or even removed (4.8%) during the 476
rollover event. 477

Nonetheless, the ROPS fitment did not guarantee the protection of 478
the driver in all overturning situations; indeed 18% of rollover fatalities 479
concerned ROPS equipped tractors. In this respect, it should be 480
underlined that an additional 10.2% of tractor-related fatalities was un- 481
certain because the ROPS fitment was not clearly stated in the reports, 482
so that percentage was not categorized. Data recorded for ROPS 483
equipped vehicles included just one fatality associated with the ROPS 484
collapsing on impact with the ground, confirming the very positive per- 485
formance of the ROPS in rollovers. In ROPS equipped tractors, the main 486
cause of fatalities was the driver being thrown outside the clearance 487
zone, crushed beneath the tractor, or colliding with the ROPS mount- 488
ings, because the victim was not restrained in the seat. As already stated 489
in the international literature (Day, 1999; Molari & Rondelli, 2007; 490
Myers & Pana-Cryan, 2000) the seatbelt is confirmed as a necessary 491
safety component for effective ROPS performance. No records denoted 492
the use of the driver restraint system at the time of the accident. Fatal 493
accidents were often associated with an inadequate perception of the 494
rollover risk, mainly on sloping or slippery areas and/or in the presence 495

t5.1 **Table 5**
t5.2 Elderly fatalities rate, an international overview.

t5.3	Reference	Rate	Country	Data source years
t5.4	Fatalities for elderly workers with respect to total agriculture fatalities (%)			
t5.5	Gross et al., 2012	30.7	USA	2011
t5.6	NHIOS, 2010	40	USA	2003–2007
t5.7	Pickett et al., 1999	36	Canada	1991–1995
t5.8	Present study ^a	17	Italy	2002–2014
t5.9	Rissanen & Taattola, 2003	>20	Finland	1988–2000
t5.10	Tractor fatalities for elderly workers with respect to total tractor fatalities (%)			
t5.11	Arana et al., 2010	44.6	Spain	2004–2008
t5.12	DeGroot et al., 2011	43.6	Canada	1990–2005
t5.13	Gross et al., 2012	40	USA	2011
t5.14	Pickett et al., 1999	46.7	Canada	1991–1995
t5.15	Present study ^a	22	Italy	2002–2014
t5.16	Present study ^b	42.4	Italy	2002–2012
t5.17	Rissanen & Taattola, 2003	36	Finland	1988–2000

t5.18 Authors' elaboration based on

t5.19 ^a INAIL Operational Archives and

t5.20 ^b INAIL_ASLSurveillance System

t5.21

of obstacles. Concerning the age of the victims in tractor rollovers, the percentage of elderly was higher for the non-ROPS equipped tractors.

As a general conclusion it should be highlighted that the approach adopted by the INAIL_AS_L Surveillance System based on data with short narrative text was shown to be highly advantageous for characterizing the accident scenario. Although the recorded events underestimated the number of tractor-associated fatalities, its value is due to the rigorous method adopted in accident reporting. Unfortunately, the data source did not record non-fatal cases nor information deriving from farmer's surveys or hospital reports. Nevertheless, this costly and time-consuming approach could allow public prevention policies to be defined, such as massive training campaigns among farmers on the correct use of ROPS equipped tractors. This approach could also help researchers and tractor manufacturers enhance the effectiveness of ROPS on modern tractors. Additionally, a strict requirement to retrofit ROPS on all tractors could increase the survival chances of drivers in rollover accidents.

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