

1 **It does not occur by chance: a mediation model of the influence of workers'**
2 **characteristics, work environment factors, and near misses on agricultural**
3 **machinery-related accidents**

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Abstract

24

Agriculture is among the most hazardous productive sectors, and farm machinery is a major source of injury. In the present study, a mediated model was used to test the role played by workers' characteristics, work environment factors, and near misses in predicting agricultural machinery-related accidents in a sample of Italian users (n = 290). Hours worked per week (via the mediation of an adverse work environment) showed a positive association and years of work experience (via the mediation of risk perception) showed a negative association with the probability of being involved in a near miss, which in turn showed a positive association with the probability of being involved in a machinery-related accident. Implications for tailored preventive interventions are discussed.

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Keywords: agriculture; near miss; occupational accident; risk perception; mediation model

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Introduction

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With the mining and construction industries, agriculture is one of the three most hazardous productive sectors both in developing and industrialized countries [1], with an incidence rate of fatal accidents that is double the average of all other industries [2]. Based on data collected by the International Labour Organization (ILO) [3], in the EU-15, the incidence of fatal accidents in agriculture in 2005 was 0.8 per 10,000 farm workers. The corresponding incidence rate for the mining and construction industries was 0.5. For the US, the National Safety Council [4] reported that the mean fatality rate for the US agricultural industry from 1992 to 2002 was 2.23 deaths per 10,000 farm workers, whereas it was 0.39 per 10,000 workers for all US industries. Farm machinery is a major source of injury [5], and the highest number of fatalities involves tractors, mainly because of tractor rollover [6]. In the United States, Carlson et al.[7] reported 9.6 tractor-related injuries/1000 persons/year. A similar picture emerges in European Union countries [8] and particularly in Italy, where approximately 2,000 of 31,000 injuries that occurred in the agricultural sector in 2013 involved machinery, and 1,000 were tractor-related injuries [9].

49 The literature about occupational accidents shows that the occurrence of an accident involves
50 multiple variables related to the individuals and their environment [10]. The same holds true
51 regarding accidents in agriculture [11]. Two different classes of elements have been identified as
52 the main predictors of being a victim of a farm accident: workers' characteristics and work
53 environment factors. In addition to these two classes of risk factors, another powerful predictor of
54 accidents is the so-called *near misses*, i.e., unplanned events that do not result in any injury, illness
55 or damage only because of a fortunate break in the chain of events [12].

56 ***Workers' characteristics***

57 The main workers' characteristics are socio-demographic variables and those accounting for
58 workers' relation with work [13]. Being an older farmer, working long hours, working alone, and
59 operating on a large farm were found to foster the probability of being involved in farm injuries and
60 fatal tractor overturns [14]. Furthermore, having a low risk perception has been shown to increase
61 operators' exposure to occupational risks and accidents [15]. However, inconsistent results have
62 been found in the literature with regard to the factors affecting risk perception, in particular relating
63 to work experience and familiarity with tasks, machinery and equipment. In some studies,
64 experience and familiarity were shown to reduce risk perception [16]. According to these studies,
65 this occurs because familiarity may lead to overconfidence in the use of the devices: the lack of
66 accidents in the person's history with the device contributes to the idea that 'I could do this with my
67 eyes shut', thus reducing risk perception and the attention rate and increasing the probability of
68 performing an unsafe behavior that may lead to an accident. For instance, a driver's accurate
69 perception of the lateral tilt angle of a vehicle is an important factor in avoiding situations that may
70 potentially lead to a side overturn. Görücü et al. [17], in their study addressing the perception of the
71 lateral tilt angle of agricultural tractors, reported that older and more experienced participants
72 disclosed higher limits of the lateral angle at which they felt uncomfortable and would not have
73 driven the tractor. The result of this perception is depicted by the fatality statistics, which show that

74 older male operators usually represent a large percentage of tractor overturn victims [18]. Other
75 studies, however, noted the opposite result [19]. According to them, individuals in familiar
76 situations might be more likely to perceive the risks because they are more frequently exposed to
77 the risky situation. This may increase compliance with safety practices and reduce the actual risk of
78 accidents. Consistent with this, the results of an investigation of farmers' attitudes toward
79 agricultural tractor innovations showed that the older the tractor users and the longer they had
80 worked in agriculture, the higher their commitment to safe working conditions [20].

81 ***Work environment factors***

82 Work environment factors represent the second group of predictors of accidents. They account for
83 workload and work organization [11]. Farm work exposes operators to a high workload due to a
84 combination of different factors. Indeed, farmers usually work longer hours, and mostly alone, than
85 workers in other occupations, and they must perform complex and varied tasks. They also handle
86 different machinery that they must care for and maintain; furthermore, their work may be frequently
87 interrupted by mechanical malfunctions – which occur especially in the case of old machinery – and
88 visitors [13]. These adverse working conditions put high external pressure on farmers, increasing
89 their fatigue and probability of being involved in an accident and being injured [21].

90 ***The near misses***

91 Near misses are at the lowest level of the safety pyramid model [22]. they occur more frequently
92 and are smaller in scale than serious accidents, and each major accident is usually preceded by a
93 number of near misses [23]. Near misses have been investigated in different sectors: road and rail
94 traffic [24], plant engineering [25], building safety [26], home safety [27], and healthcare systems
95 [28]. Less is known in the literature about near misses and their determinants in the agricultural and
96 forestry sector than about other safety issues. Some exceptions are represented by the study by
97 Lilley et al. [29], who showed that accidents among forestry workers in New Zealand were
98 associated with having had near-miss injury events, and the literature review on accident prevention

99 by Lundqvist et al. [30], which included studies investigating near misses as a useful source of
100 information about farm accidents. However, both the abovementioned studies considered near
101 misses for their effects (accidents) rather than their determinants. Wright and Schaaf [24] showed
102 that near misses and accidents substantially share the same determinants, confirming the idea that
103 near misses may be considered a proxy of being exposed to the risk of suffering a more serious
104 accident.

105 *Motivations and aims of the present study*

106 Many statistics are available worldwide about accidents in the agricultural sector, their incidence,
107 and the characteristics of the injured workers [1]. Less is known, however, about the processes and
108 the relationships between the critical variables leading to an accident. The two different classes of
109 risk elements identified in the literature (workers' characteristics and work environment factors) and
110 their role in predicting the probability of being involved in an accident have systematically been
111 investigated by analyzing survey data with multiple regression models [11,13]. Such models are
112 undoubtedly fruitful. However, they force the researcher to consider all the predictors considered in
113 the study at the same hierarchical level without taking into account that some variables may
114 simultaneously be predictors of some and outcomes of other variables.

115 Regarding this aspect, the review of the literature showed that many variables are involved
116 at different levels in the onset of a farm accident. Experience has an influence on risk perception
117 (though previous results are not consistent regarding the direction of such influence: see
118 McLaughlin et al. [16]; Rogers et al. [19]), and risk perception in turn affects the probability of
119 being involved in occupational accidents [15]. In addition, working for longer hours, alone, and on
120 a large farm has been shown to increase workers' exposure to adverse work environment factors
121 [14]. These are conditions that can trigger near misses [31] and accidents [18]. Therefore, we
122 assumed that the processes leading to farm accidents may be more suitably investigated by adopting
123 a mediation model instead of a multiple regression model. In addition, we assumed that the model

124 tested should include the near misses, which have been reported as important predictors of accidents
125 [12] but nonetheless have been under-investigated in previous studies of accidents in agriculture.

126 Based on these considerations, the present study aimed to investigate the risk factors for
127 agricultural machinery-related accidents in a sample of Italian users, examining the role played by
128 a) workers' characteristics, b) work environment factors, and c) near misses and adopting a
129 mediated model to test the seven different hypotheses (Hs) described hereafter.

130 Based on Myers and Hendricks [13] and on Hwang et al. [14], we expected working alone
131 (H1), farm size (H2) and working hours (H3) to show a positive association with the exposure to
132 adverse work environment factors. Concerning the relation between years of work experience and
133 risk perception, because of the inconsistent results available in the literature, we made two
134 alternative competing hypotheses. If—as in McLaughlin et al. [16]—work experience leads mainly
135 to overconfidence in the use of devices, it should show a negative association with risk perception
136 (H4a); in contrast, if work experience—as in Rogers et al. [19]—leads mainly to an increased
137 situational awareness, it should show a positive association with risk perception (H4b).

138 Furthermore, based on Kogler et al. [31] and on Elkind [15], we postulated that exposure to
139 adverse work environment factors would show a positive association (H5) and risk perception
140 would show a negative association (H6) with near misses. Finally, based on Phimister et al. [23],
141 we expected near misses to show a positive association with being involved in an accident (H7). We
142 analyzed such relations via a mediated model rather than a standard regression to account for the
143 complexity of the associations we hypothesized, with accidents being the outcome of the model;
144 working alone, farm size, hours worked, and years of experience being the predictors (i.e., the
145 exogenous variables); and adverse work environment, risk perception, and near misses being
146 mediators (i.e., outcomes of working alone, farm size, hours worked, and years of experience and at
147 the same time predictors of accidents).

148 **Method**

149 ***Participants and setting***

150 The study involved a sample of 290 users of agricultural machinery (272 men, $M_{\text{age}} = 45.46$ years,
151 $SD = 17.40$). The participants worked an average of 39.67 hours per week ($SD = 23.72$) and had
152 been working in agriculture for 26.45 years ($SD = 18.00$).¹ Participants' distributions of gender,
153 age, education, and occupation were in line with those of the Piedmont and Italian agricultural
154 population, as reported in the VI Agricultural Census of 2010 [32,33]. They were recruited from the
155 visitors to the 35th National Exhibition of Agricultural Mechanization in Savigliano, the largest
156 agricultural machinery exhibition in the Piedmont region (northwestern Italy). The 2016 edition of
157 the show (18-20 March) was attended by over 65,000 visitors. The Piedmont region, one of the
158 twenty Italian regions, covers 35% of the Po River catchment, with agriculture taking place on the
159 plain (41% of the utilized agricultural area – UAA), mainly maize-based systems, and on the hills
160 (31% of the UAA), mainly vineyards and winter cereals [34]. The Piedmont region is a good
161 representation of the Italian farming system and rural population since it includes approximately
162 10% of the total Italian UAA. Moreover, over 61,000 of the 1,620,884 Italian agricultural holdings
163 operate in this region [32].

164 Since the agricultural population is spread across the country and has varying operating
165 schedules, agricultural machinery exhibitions are one of the few occasions at which a large and
166 wide-ranging group of agricultural workers comes together. Such events therefore provide a
167 suitable location for appropriate surveys and other data-collection activities [17,35].

168 ***Instrument***

¹ As shown in Table 1 (see below), in our dataset, participants' age and years of experience in agriculture showed a very strong correlation. To avoid an excessive conceptual overlap and problems of empirical collinearity, both in the theoretical and in the empirical sections of the paper, we reasoned in terms of years of experience rather than in terms of age.

169 A 27-item self-administered paper-and-pencil questionnaire was used to gather information about
170 participants' work environment, risk perception, near misses, and accidents. The different sections
171 and items of the questionnaire were designed based on previous instruments [11,29] and on the
172 evidence from a preliminary qualitative study [36]. Risky machinery-related tasks and types of
173 accidents and near misses were selected after an analysis of the statistics regarding the most
174 frequent and serious machinery-related accidents and injuries in Italian agriculture [9]. The
175 questionnaire was pilot-tested with a group of 8 operators before being submitted to the sample of
176 the present investigation.

177 The questionnaire was composed of 3 sections. In the first section, participants were
178 administered a list of 4 adverse work environment factors: sufficient manpower (con-trait),
179 interruptions by machinery malfunctions, interruptions by on-farm visits, and work delay due to the
180 adoption of safety measures. Participants were asked to rate on a 4-point scale (1 = never, 4 =
181 always) how often these 4 situations occurred on their farm. The 3 items related to manpower and
182 interruptions came from Glasscock et al. [11], whereas the adoption of safety measures was
183 indicated by farmers as often causing work delays and thus increasing time pressure in agricultural
184 tasks in a preliminary qualitative study [36]. A confirmatory factor analysis (CFA), performed after
185 reversing the first item, showed that the scale was unidimensional, $CFI = 1.00$, $IFI = 1.00$, $RMSEA$
186 $= .00$ (90% $CI = .00, .08$).²

187 In the second section, participants had to report on a 4-point scale (ranging from 1 = not
188 risky at all to 4 = very risky) how risky they considered the following tasks in machinery
189 operations: moving equipment near power lines, manually feeding a wood chipper, using a wood-
190 splitting machine/circular saw, using the tractor on a field without a seatbelt, handling round bales

² We tested the unidimensionality of this and the next scale using CFA instead of Cronbach α because the strength of the latter depends, beyond their mean correlation, on the number of items, and our first battery was composed of only 4 items.

191 with a front-end loader, working with machinery near ponds or ditches, cleaning a manure spreader
192 while it is in motion, and descending from the tractor without turning the engine off. Items about
193 power lines and working near ponds were taken from Whitman and Field [37], whereas the other
194 items were operations or tasks that are more likely to lead to an accident according to Italian
195 national safety statistics [9]. A CFA showed that the scale was unidimensional, $CFI = .93$, $IFI = .93$,
196 $RMSEA = .05$ (90% $CI = .00, .09$). Participants' scores on these scales were computed as
197 standardized factorial scores.

198 In the third section, participants had to indicate how often in the 12 months preceding the
199 survey they had been involved in 5 different types of events involving agricultural machinery, using
200 a 3-category format (0 = never; 1 = once; 2 = twice or more): fall/thrown from a vehicle; run
201 over/crushed by a vehicle; struck by flying objects, broken parts, or hydraulic fluid; side/rear
202 rollover; and road accident with tractor/equipment. Participants were asked to answer the battery
203 twice, reporting for each event how often they had been involved with (i.e., accident) and without
204 (i.e., near miss) suffering an injury. The list of events was created based on the most common types
205 of accidents involving agricultural machinery according to the statistics from the Italian Workers'
206 Compensation Authority [9]. After dichotomizing participants' answers (contrasting the 0 and the
207 other responses), we computed two scores as sums of their responses to the first and to the second
208 version of the batteries that were used as operationalization of the number of accidents and of near
209 misses occurring in the 12 months preceding the survey. A standard socio-demographic form
210 assessing participants' relation with work (hours worked per week, years of experience in the
211 agricultural sector, farm size and whether they were a sole farmer) ended the questionnaire.

212 ***Procedure***

213 Trained research assistants handed out the questionnaire to people walking through the exhibition.
214 They approached visitors and asked whether farming was their primary or secondary occupation
215 (i.e., being a part-time farmer) and whether they used agricultural machinery at least once a week.

216 In the case of a positive answer, the assistants explained the aims of the study and informed the
217 participants that the questionnaire was anonymous. The questionnaire was in Italian, and its
218 completion took approximately 6-7 min. No incentive was offered to induce visitors to participate
219 in the survey. The response rate was approximately 85%.

220 **Results**

221 Table 1 reports the descriptive statistics for the variables that the study investigated and the
222 correlations among them. Of the participants, 45.9% had been involved in at least an accident and
223 44.8% had been involved in at least a near miss in the 12 months preceding the survey.

224 ---Table 1 about here---

225 A first path analysis model showed that H1 and H2 were falsified. Indeed, being a sole
226 farmer ($b = .04$, $SE = .12$, $p = .74$) and the size of the farm where the participant worked ($b = .00$,
227 $SE = .00$, $p = .13$) showed no significant association with adverse work environment. Thus, we re-
228 ran the model after deleting those variables. All the paths of the resulting model were statistically
229 significant (see Figure 1: betas and standard errors are displayed). The hours worked showed a
230 positive association with working in an adverse environment ($R^2 = .06$), confirming H3. Consistent
231 with H4b and contrary to H4a, years of experience showed a positive association with risk
232 perception ($R^2 = .08$). Consistent with H5 and H6, working in an adverse environment and risk
233 perception, respectively, showed a positive and a negative association with near misses ($R^2 = .07$),
234 which in turn, consistent with H7, showed a positive association with accidents ($R^2 = .08$). Table 2
235 shows that all the indirect effects we tested, even the small ones, were significant. The fit of the
236 model was satisfactory, $\chi^2(9) = 16.44$, $p < .06$, $IFI = .92$, $CFI = .92$, $RMSEA = .05$ ($CI = .00, .09$).³

237 ---Figure 1 about here---

238 ---Table 2 about here---

³ Parallel analyses, performed by substituting participants' years of experience in agriculture for their age, showed analogous results (available upon request).

239 **Discussion**

240 The present study investigated, via a mediation model, the risk factors for machinery-related
241 accidents in the agricultural sector. The model showed that workers' characteristics are associated
242 with exposure to adverse work environment factors and risk perception, which in turn are associated
243 with the probability of being involved in near misses and accidents. Consistent with the literature
244 about occupational accidents [10], in the present study, different variables were shown to be
245 interwoven in the occurrence of an agricultural machinery-related accident.

246 Our mediation model noted the more critical variables and at what level they affect the chain
247 of events leading to accidents, suggesting that machinery-related safety issues be addressed by an
248 ergonomic approach (www.iea.cc) This approach considers the individuals in their interaction with
249 the proper tools and tasks of their work environment and allows interventions to be developed in
250 different dimensions (materials vs. practices) and at different levels (individual level vs. farm level)
251 [38] to find the best fit between the worker and the job in terms of health, safety, comfort, and
252 performance [21].

253 The results of the study showed that regarding workers' factors, working long hours
254 increased the exposure to accidents through the mediation of adverse working situations, such as
255 interruptions and time pressure. A positive association between hours worked and involvement in
256 accidents has already been noted by previous studies both in the agriculture/forestry sector [29] and
257 in other industries [39]. When an operator works long hours, he/she is likely to address many
258 different situations, which increases fatigue and reduces alertness, causing errors and thus
259 enhancing the possibility of being injured in an accident [40]. Interventions addressing this issue
260 may focus on redesigning the work process [41], for instance, by training workers to take
261 systematic rest breaks during their working hours [38] or assisting farmers in managing external
262 pressures [18].

263 The worker's experience is another critical workers' factor that, according to the results of
264 the model we tested, enhances risk perception. The outcome of the study contributes to the
265 discussion of the consequences of familiarity with tasks and machinery [16,19], strengthening the
266 assumption of the protective role of this variable. A lack of accidents or near misses in a person's
267 history with a device/machine has been reported to lead to overconfidence in its use and lower risk
268 perception [16]. Similarly, it is reasonable to assume that previous exposure to near misses and
269 accidents is responsible for the positive association between work experience and risk perception
270 found in the present study. In this light, the longer the operator has been working in the field, the
271 more accidents and near misses he/she may have encountered, learning from these events and thus
272 increasing his/her risk awareness and perception [42].

273 The study showed that higher risk perception predicts lower occurrence of near misses and
274 accidents. Risk perception is thus confirmed to play a crucial role in the occurrence of accidents
275 [15], suggesting further investigation, especially in such a hazardous sector as agriculture.
276 Identifying factors that lead to a higher risk perception in agricultural operators will allow the
277 development of training interventions and information campaigns tailored to maximize their
278 preventive effectiveness.

279 In the present study, near misses appeared to be a significant predictor of accidents. This
280 result confirms the importance of investigating near misses to prevent more serious accidents [12],
281 including in the agricultural sector, in which near misses have been largely neglected. Farmers may
282 be trained to recognize and annotate near misses to early identify critical aspects leading to
283 accidents and intervene to eliminate or reduce them. According to Kogler et al. [31], the main
284 preventive measures indicated by farmers to help them avoid near misses are, in order of
285 importance, increased training in agricultural operations, mechanical adaptations, and easy-to-
286 understand and short written operating instructions. Regarding the importance of training, the
287 evidence by Burke et al. [43] raises some considerations about the need to adopt not only such

288 conventional training methods as pamphlets, lectures, and videos but also more engaging behavioral
289 modeling techniques – such as hands-on demonstrations and behavioral simulations – to promote
290 the correct and safe use of machinery and therefore reduce accidents.

291 Clear and short operating instructions, such as use and maintenance manuals, and clear and
292 effective safety information about machinery, such as pictorial representations, are additional
293 important elements to promote the safe use of machinery. Operator manuals are supposed to be an
294 exhaustive source of information for the safe use and maintenance of agricultural machinery, but
295 previous studies have shown that they are often unread [44] due to poor document design, requiring
296 a non-negligible cognitive load to decipher pages packed with information that is mainly intended
297 for the legal protection of the manufacturer. Pictorial representations affixed to machinery are visual
298 tools to convey relevant safety information, but they are not as effective as they are supposed to be
299 [45,46]. A re-design of these sources of safety information must be considered to enhance safety in
300 machinery use.

301 Contrary to the findings of previous studies [13,14] no significant associations between
302 being a sole farmer and farm size on the one hand and exposure to accidents on the other hand
303 emerged. Accidents occur in all types of farms of any dimension and to all kinds of holders: safety
304 interventions and campaigns should therefore address all kinds of farms and farm operators without
305 considering some groups more at risk than others.

306 *Limitations of the present study and possible research developments*

307 Some limitations of the present study should be acknowledged. The survey was carried out in the
308 Piedmont region of northwestern Italy. On the one hand, the Piedmont farming system is a good
309 representation of Italian agriculture, and performing the study at a local level allowed us to test a
310 parsimonious model: participants in the study had a similar cultural background; thus, we could
311 manage comparable data without controlling for a plethora of socio-demographic variables [47].
312 Even though the socio-demographic characteristics of our participants were in line with those of the

313 Italian rural population reported in the last agricultural census, it is apparent that only the people
314 who attended the Exhibition of Agricultural Mechanization in Savigliano could participate in our
315 survey. More generalizable results would be available from a random sample of agricultural
316 workers.

317 Another limitation is that our data on near misses and accidents were based solely on self-
318 reports, and the recall covered quite a long period (12 months). Even though self-reporting is a quite
319 common strategy in this kind of investigation [29,48], and 12 months is the usually considered
320 period [11], it is possible that the participants' responses were affected by memory bias, thus
321 resulting in a gap between self-reported and actual involvement in the reported events [49]. To
322 obtain more accurate information about these variables, a possible direction of study would be to
323 register near misses and accidents weekly (as for the accidents studied in Glasscock et al. [11]).

324 Finally, it should be noted that the bivariate correlations between our variables were not
325 very strong, like the variance of the dependent variables we have explained. Moreover, consistent
326 with Chaplin [50], the indirect effects that we detected were small. The weakness of these effects
327 may likely be attributed, at least in part, to methodological rather than theoretical reasons. Indeed,
328 as we performed field research, we could measure our variables using short scales; thus, we had to
329 manage measures that were plausibly distorted, at least in part, by measurement error. Stronger
330 indirect effects will likely stem from new research performed using longer scales.

331 Possible future developments of the research could further explore the relationship between
332 adverse work environment factors and accidents, considering the safety behaviors [11] and coping
333 strategies adopted when dealing with adverse and stressful conditions [51] as mediators of the
334 relationship. Moreover, it would be interesting to increase our understanding of the factors
335 contributing to farm accidents in two ways: first, via more objective techniques of data collection,
336 such as the observation of farmers interacting with different machines, to identify risky behaviors
337 that can increase the probability of being involved in an accident (as in Mann et al., [52]), and

338 second, taking directly into account the issue of the age of agricultural machinery, which is known
339 to play a role in the onset of agricultural accidents [53]. The use of aging machines with inadequate
340 safety engineering represents a constant source of risk, as operations involving high numbers of
341 disturbances, e.g., machinery breakdowns, have a higher accident probability [54]; our
342 questionnaire item about frequent interruptions of farm work due to machinery malfunctions was
343 based on this evidence. However, the age of machinery could be explicitly assessed as a factor that
344 could affect the mediators or the outcomes of our model.

345 Furthermore, the reasons underlying the positive association found in the present study
346 between work experience and risk perception could be further investigated. For instance, a farmer's
347 previous history of near misses and accidents could be evaluated and added as a mediator in the
348 relationship between experience and risk perception, or expert and novice farmers could be
349 observed/interviewed when interacting with machinery to identify the ways in which they perform
350 their complex and varied tasks and the different strategies adopted to reduce risks (as in Mann et al.
351 [52]).

352 Furthermore, in future research, data collection on farm accidents and near misses could be
353 extended over a longer period. This would allow researchers to investigate the possible mediation
354 effects of previous exposure to such events on the relationship between work experience and risk
355 perception [42]. Finally, a mediation model such as the one used in the present study could be
356 adopted to investigate accidents related to livestock [55] and pesticides [56], which are other major
357 causes of accidents and health issues in the agricultural sector.

358 **Conclusions**

359 The chain of events leading to an occupational accident deserves particular attention in agriculture,
360 due to the high hazardousness of this sector. The results of the present study showed that different
361 critical variables intervene at different levels in determining an agricultural machinery-related
362 accident. Hours worked and work experience affected the probability of being involved in an

363 accident through the mediation of adverse work environment and risk perception and then of near
364 misses. These results suggest that different facets of the interaction between the operator and his/her
365 work environment should be considered when designing preventive interventions, ranging from a
366 re-design of the actual work processes to the development of strategies to enhance workers' risk
367 perception. Interventions should also focus on near misses, making the reporting and analysis of
368 these events a widespread and systematic practice among farmers and farm workers [12].
369 Furthermore, interventions should support the protective role played by work experience by
370 adopting engaging training methods as behavioral modeling in the use of machinery to optimize the
371 learning of safety practices and safe behaviors. Finally, it must be noted that, as found by Kogler et
372 al. [31] with regard to near misses, any solution and intervention aimed at improving the quality of
373 farmers' work life and reducing accidents must also be disseminated to the farming populations in
374 formats that are acceptable and understandable [21].

375

376 **Disclosure statement**

377 The authors have no competing interests to declare.

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Table 1. Descriptive statistics for the variables we used and correlation among them

	Mean	SD	1	2	3	4	5	6	7	8	9
1. Worked hours per week	39.67	23.76	-	-.15*	-.12*	.28***	-.19***	.24***	-.13*	-.07	-.03
2. Age	45.47	17.40		-	.82***	-.14*	.29***	-.18**	.23***	-.10	-.08
3. Years of experience in agriculture	26.45	18.00			-	-.10	.22***	-.11	.23***	-.12*	-.10
4. Farm size (ha)	33.83	53.40				-	-.18**	.15*	-.10	-.05	-.06
5. Sole farmer (0 = no, 1 = yes)	.37	.48					-	-.04	.12*	-.03	.01
6. Adverse work environment	0.00	1.00						-	.01	.13*	.15**
7. Risk perception	0.00	1.00							-	-.13*	.09
8. Near misses	1.11	1.71								-	.97***
9. Accidents	0.99	1.52									-

Note. The “mean” of being a sole farmer is the proportion, on a 0-1 scale, of the participants who reported to be a sole farmer. When being a sole farmer is involved, the point-biserial correlation coefficient is displayed. *** $p < .001$. ** $p < .01$. * $p < .05$.

1 Table 2. Indirect effects of the exogenous variables and of the mediators.

	Years of experience in agriculture	Worked hours per week	Risk perception	Adverse work environment
Risk perception				
Adverse work environment				
Near misses	-.00*	.01**		
Accidents	.00**	.00**	-.23**	.00**

2 *Note.* ** $p < .01$. * $p < .05$.

3 Figure caption

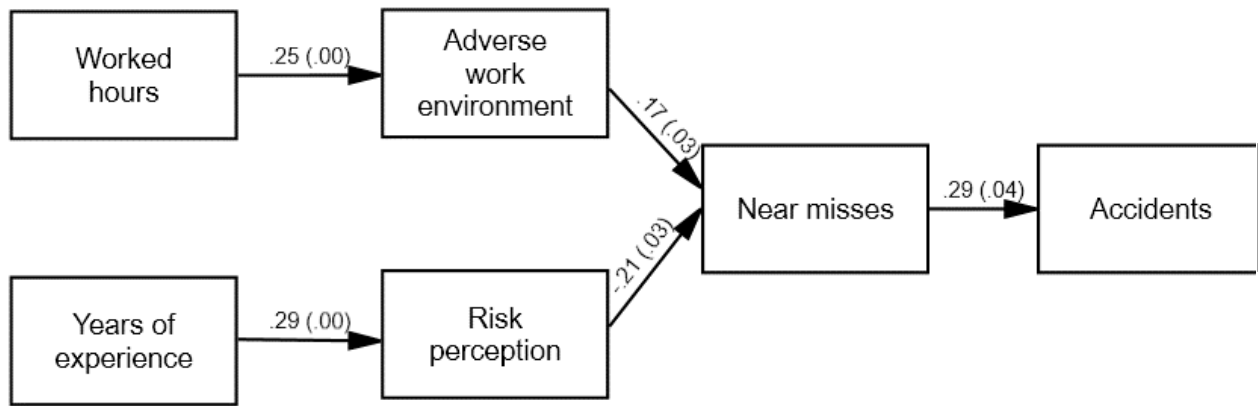
4 Figure 1. Workers' characteristics predict accidents through the mediation of adverse work
5 environment, risk perception, and near misses.

6

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8

9 Figure 1



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