Farm staff wrong movements affects PRRSv prevalence and viremia

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Abstract

Background Biosecurity is known as the implementation of measures to reduce the risk of introduction (external biosecurity) and spread (internal biosecurity) of disease agents. One of the most common diseases in the porcine industry is the porcine reproductive and respiratory syndrome (PRRS), which has a huge negative impact on the well-being of the animals and consequently, on their productivity. Nonetheless, most of the biosecurity evaluation tools are based on scored systems. A new digital biosecurity system was designed to help control PRRS virus (PRRSv) infection status throughout an objective tool for the evaluation of internal biosecurity based on a system of control of the flow of internal movement of personnel in commercial farms. Movements, routes and health data were combined to classify the staff movements into three categories including “Risky” (From PCR(+) to PCR(-) barns), “Unsafe” (between PCR(+) barns) and “Safe” (From PCR(-)). Therefore, the main aims of the present work were to evaluate the efficacy of this new tool, its relationship with PRRSv incidence as well as to demonstrate the importance of biosecurity education to help farm workers to adopt safer daily practices.

Results The observed results showed an overall smaller number of monthly movements ($p < 0.05$) and a significant increase in the Safe movements percentage ($p < 0.05$), concomitant with a decrease in the Risky movements percentage ($p < 0.05$) after the training session. In regards the relationship between staff movements and PRRSv presence, neither the percentage nor the total amount of both Safe and Unsafe movements were significantly different between the PCR(+) and PCR(-) groups of PRRSv status ($p > 0.05$). Nonetheless, both the total number and the percentage of Risky movements were significantly lower in the PCR(-) group ($p < 0.05$) compared with PCR(+) group. These results show a clear relationship between the total amount of Risky movements and the probability of a PRRSv outbreak in the farms.

Conclusions Our results support the notion that staff movement patterns within the different farm areas are a major factor in its internal biosecurity. The new tool described in the current work showed a significant relationship between staff movements and the probability of PRRSv outbreak and demonstrate the importance of biosecurity training to help farm workers adopt safer daily practices.

Background

Biosecurity is known as the implementation of measures to reduce the risk of introduction and spread of disease agents [1] and can thus be divided into two aspects. External biosecurity relates to the prevention of pathogens entering a herd, while internal biosecurity prevents the spread of disease within a herd, mainly from older to younger animals [1]. In this regard, biosecurity is an important aspect of preventing the transmission of diseases, thus improving health and reducing the need for antimicrobials [2]. Moreover, most diseases have a negative impact on the well-being of the animals and consequently, on their productivity. Thereby higher levels of biosecurity lead to also improved the economy of the farmer.

One of the most common diseases in the porcine industry is the porcine reproductive and respiratory syndrome (PRRS). This disease impairs swine health and is responsible for huge economic losses in the swine industry worldwide [3]. Infection with PRRS virus (PRRSv) is characterized by reproductive failures in pregnant sows, high pre-weaning mortality in piglets infected in utero and respiratory signs in both growers and finishers pigs [4–6].

Numerous studies [7–16] have described the routes which are involved in PRRSv transmission between and within herds, including the introduction of positive animals or semen, management of the quarantine for the newly introduced animals, as well as vehicles, aerosols, insects or contaminated fomites. Moreover, the marked genetic and antigenic heterogeneity of the virus, combined with its immune evasion strategies, inhibit the full efficacy of current commercial PRRS vaccines [17]. Therefore, PRRS control based only on the use of vaccination has often provided limited efficacy under field conditions [18]. Hence, it is of paramount importance the implementation of good biosecurity measures to prevent the introduction of the virus into a farm but also to slow down its transmission within a herd once infected.

Nonetheless, most of the developed programs of biosecurity measures are based on scoring systems or survey forms. For instance, researchers from Ghent University developed a scoring system called Biocheck.UGent™ [2, 19] as a risk-based scoring tool to evaluate the biosecurity quality of pig herds. Another scoring system has been developed by the University of California-Davis (Disease Bioportal®) for the dynamic risk assessment and farms benchmarking also based on surveys [20]. In this line, Sternberg-Lewerin et al. [21] developed a risk assessment tool for Brachyspira hyodysenteriae and Mycoplasma hyopneumoniae considering the frequency of contacts, but it was only focused on external biosecurity. All these tools are based on values obtained through expert opinion panels; however, the perception of experts may vary depending on different circumstances, therefore, scoring systems based on perceptions should be adapted to each situation.

The aim of the current study was to evaluate the efficacy of a new digital biosecurity system, an objective tool for the evaluation of internal biosecurity based on a system of control of the flow of internal movement of personnel on pig farms as well as its relationship with PRRSv incidence.

Material And Methods

In order to evaluate the relationship between PRRSv viremia and risk level of farm staff movements in several commercial farm scenarios, eight Spanish farms with different PRRS disease status, facilities, ratio sows per person, size and biosecurity (internal and external) score were chosen.

PRRS status was defined by barn (either Positive or Negative) in all farms. After this health evaluation, digital biosecurity system (Biorisk®, PigCHAMP Pro Europa, Segovia, Spain) system was installed, and workers started using the personal tracking devices and behaved as they usually did in order to measure the real workflow and risk level of movements on the farm. This period was considered as the control period.

After the first control period of one month, the collected data were used to develop a customized internal biosecurity training for farm staff based on their movements and their PRRSV situation, setting up the main goals to reach and steps to follow to control the disease.

Experimental farms

Main inclusion criteria:

Each farm was included based on two main inclusion criteria: PRRS classification and biosecurity score.

1.
PRRS classification. It defines the initial PRRSv status according to shedding and exposure conditions [22] (Table 1).
2.
Biosecurity score. Every selected farm was initially evaluated based on both internal and external biosecurity using a standard questionnaire which gives a score from 0 (the lowest risk) to 100 (the highest risk) as Table 2 shows.

Table 1
Breeding-herd classification for porcine reproductive and respiratory syndrome virus according to shedding and exposure status [22].

Herd category	Shedding status	Exposure status
Positive Unstable (I)	Positive	Positive
Positive Stable (II-A)	Uncertain	Positive
Positive Stable (II-B) (Undergoing Elimination)	Uncertain – undergoing elimination	Positive
Provisional Negative (III)	Negative	Positive
Negative (IV)	Negative	Negative
Positive Unstable (I)	Positive	Positive

Table 2
Farm classification according to their biosecurity score (internal and external biosecurity) made by using a standard questionnaire.

Score[1]	0–25	26–50	51–75	76–100
Risk level	Safe or low risk	Caution	Corrective actions	Failure
Recommendation	Keep the status	Review certain improvements	Improvements needed	Immediate improvements

[1]Biosecurity score: from 0 (the lowest risk) to 100 (the highest risk).

Selected farms characteristics:

Table 3 shows the characteristics of the eight selected farms including the type of farm management, the number of sows, ratio sows/person, biosecurity score and historical PRRS herd category.

Table 3
Characteristics of the eight chosen farms.

Evaluation	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Management	Farrow to finish	Farrow to finish	Farrow to finish	Site II	Farrow to finish	Farrow to finish	Site II	Farrow to finish
Sows	281	660	614	588	340	340	1100	1000
Ratio sows/person	93	94	153	117	85	85	157	142
Biosecurity score (global)	57	60	67	41	55	54	37	45
External biosecurity score	53	49	61	43	49	47	43	23
Internal biosecurity score	63	76	76	38	63	63	30	76
Historical PRRS Herd category	I	I	II-A	II-B	I	I	II-B *	II-A *

*: Status I in selection moment due to new outbreak.

Evaluation of PRRSv status

Before the implementation of this new system, some of the farms used their own diseases status evaluation system, while other farms even had not health evaluation methods. Nonetheless, taking into account this scenario, the implementation of a digital biosecurity system is also linked to health assessments to determine the disease status, being PRRS evaluation one of the most relevant in this procedure. This process had two steps which included the initial evaluation and the disease monitoring. The number of samples depended on farm size and virus prevalence.

Initial evaluation. PCR (pools of 5 samples) and ELISA (individual samples) tests were run on each group of age on the farm to understand the infection dynamics. Defined groups of age were suckling piglets, weaned piglets, middle and ending nursery piglets, early and ending fattening pigs.
PRRSv infection monitoring. Every two months, a basic PCR profile (pools of 5 samples) was developed to ensure the PRRS status. Samples from suckling piglets, nursery and fattening pigs were taken. Every two-monitoring sampling, an initial profile was done to deepen the PRRS situation.

Farm barns classification

Based on laboratory results, every barn of the farm was defined at the beginning and during the process as:

1.
Hazardous area. Laboratory results from PRRSv PCR (+).
2.
Sensitive area. Laboratory results PRRSv PCR (-).
3.
Sanitary area. Every changing clothes/boots or shower facilities.

This barn/building classification was used to define the risk level of every movement on the farm.

Movements and routes description.

Movements, routes and health data were combined to classify the staff movements into three categories, including “Risky”, “Unsafe” and “Safe”. Both “Risky” and “Unsafe” routes were those movements that could potentially spread the virus within the farm.

“Risky” movements corresponded to the most dangerous routes.
Movements going from a hazardous barn into a sensitive one.
Movements between two different kinds of hazardous areas. For instance, from infected fattening to the infected nursery.
“Unsafe” movements corresponded to those movements between two different hazardous areas barns inside the same kind of area — for instance, movements between two different fattening infected buildings.
“Safe” movements. All the movements between sensitive areas and from sensitive to hazardous areas.
Risky and Unsafe movements could be changed into Safe ones by taking a shower or changing clothes in

the lockers. If the system detected the minimum time spent in locker rooms (defined farm by farm regarding the specific characteristics) in this route, the movement was classified as “Safe”.

Hardware used

The new digital biosecurity system was based on two on-farm hardware pieces including beacons and readers. Each farm worker was given small Bluetooth™ transmitters called beacons, which were required to wear all the time while they were within the farm facilities. Readers were installed and fixed at every access of every barn, including lockers and showers. These devices can detect beacon signals by proximity. Whenever a beacon was within a device’s detection range, the device registered the beacon identity as well as the detection time and uploads the record to a database.

Data collection and processing records from readers were sent to the cloud and processed, so the movements and routes of the farm’s workers were computed. Each movement represented a route made by a farm worker from an origin zone to a destination zone. Thus, the system allowed the real-time monitoring of the farms’ staff movements patterns.

Datasets

Data collected during this project was processed into two datasets:

1.
Dataset 1 contained the monthly amounts of Safe, Unsafe and Risky movements at each of the eight farms. As it has been commented, the first monthly record for each farm corresponded to the movement pattern before the biosecurity training. This dataset was used to compare the safety of the movements’ pattern before and after the training across all farms.
2.
Dataset 2 contained the results of the bi-monthly PCR analytics at the three age groups for each farm, as well as the percentages of Risky and Safe movements observed on the farms during the two months preceding the analytics. The PCR records were classified into two groups: PCR(+), for those analytics with at least one age group PCR positive, and PCR(-), for those records with all three age groups PCR negative. This dataset was used to compare the percentage of Risky movements between the PCR(+) and PCR(-) groups.

Statistical and data analysis

Movements comparison before and after training

To assess the effect the biosecurity training on the farm staff movements pattern, the percentages and totals of movements of each type at each of the eight farms were compared before and after the training session. Farms started the project at different times, and the latest farm which was included had only five months’ worth of post-training data by the end of the project. Hence, in order to compare identically defined quantities, five months as the post-training period to study were picked. Total movements were analyzed by comparing the total amount of Safe, Unsafe and Risky movements during the month preceding the training with the corresponding average of the total movements (monthly measured) during the next five months after the training session. Wilcoxon test was used to test differences in paired datasets.

For comparing movement percentages, the percentage of movements of each kind during the previous month and the next five months of the training session were compared. Equal proportions test was used to test differences in paired percentages.

Relationship between “Risky” movements and PRRSv status

To understand the relationship between movements and PRRSv status, the amount and percentages of movements of each kind (Safe, Unsafe and Risky) were compared with the bi-monthly analytics. The analytics registers from Dataset 2 were grouped into a Positive and Negative group, containing registers with at least one age group PCR positive and registers with all age groups PCR negative, respectively. For each movement category, the movement type percentage across positive and negative groups were compared by means of an analysis of variance. Noticeably, the data were not normally distributed, due to typical movement percentage values vary greatly across farms. Hence, despite the well-known robustness of the ANOVA test to non-normal data, the results were backed by means of a non-parametric Kruskal-Wallis test. All statistical analyses were conducted using Python Software (Python Software Foundation, Wilmington, DE, USA).

Results

The numerical results of the comparison of staff movements between farms are shown in Table 4. The Wilcoxon test determined a statistically significant decrease ($W = 2$; $p = 0.025$) in the total amount of movements after the training session in 7 out of the eight farms. After the examination of the total amounts of movements of each type, a significant decrease in total Safe (7 out of 8 farms, $W = 3$, $p = 0.036$) and Risky movements (7 out of 8 farms, $W = 2$, $p = 0.025$) was observed, while Unsafe movements tended to be lower after the training session (6 out of 8 farms, $W = 6$, $p = 0.093$).

Table 4
Total number and percentage of monthly movements before and after the training session.

Farms		Safe	Unsafe	Risky	Total
		total	total	total	
1	Pre[1]	1679	749	146	2574
	Post[2]	1421.0 (279.0)	590.8 (136.7)	114.5 (43.7)	2126.3 (410.9)
2	Pre	4533	24	703	5260
	Post	4706.7 (679.5)	46.7 (15.0)	701.8 (194.6)	5455.2 (795.5)
3	Pre	1951	55	113	2119
	Post	1326.0 (423.1)	36.3 (14.1)	100.3 (50.5)	1462.7 (450.6)
4	Pre	1743	405	4	2152
	Post	1626.5 (281.4)	315.5 (93.6)	1.8 (2.1)	1943.8 (369.7)
5	Pre	2000	27	136	2163
	Post	1261.7 (440.0)	11.8 (9.1)	48.5 (43.3)	1322.0 (482.7)
6	Pre	2424	3	120	2547
	Post	1413.5 (581.4)	0.5 (1.2)	38.2 (42.0)	1452.2 (621.5)
7	Pre	742	79	8	829
	Post	618.0 (80.4)	33.0 (35.6)	10.0 (12.9)	661.0 (108.2)
8	Pre	2216	177	1544	3937
	Post	1581.5 (816.7)	179.2 (123.0)	611.7 (484.9)	2372.3 (1151.5)
Wilcoxon test		W = 3 p = 0.036	W = 6 p = 0.093	W = 2 p = 0.025	W = 2 p = 0.025

[1]Pre-training values are the registered movements. [2]Post-training values are the average (standard deviation) of the five months following the training.

Figure 1. Average of percentages of Safe (green), Unsafe (orange) and Risky (red) movements before (■) and after (□) the training session considering the eight farms in which the system control movement was installed.

The results of the relationship between Risky movements and PRRSv status are shown in Fig. 2. Neither the percentage nor the total amount of both Safe and Unsafe movements were significantly different between the PCR Positive and Negative groups by either the ANOVA and Kruskal-Wallis tests. It is important to notice that the percentage of Safe movements was always above 80% in the Negative PCR group. Typical values of the Unsafe movement, both totals and percentage, did not vary greatly across groups. However, the percentage of Risky movements was significantly smaller in the PCR negative group as determined by both the Kruskal-Wallis ($K = 9.08$, $p < 0.005$) and the ANOVA ($F = 4.94$, $p < 0.05$) tests. The group difference was more evident when comparing the total amount of Risky movements as determined by the Kruskal-Wallis total amount ($K = 10.7$, $p < 0.005$) as well as the ANOVA ($F = 4.94$, $p < 0.05$) tests. These results show a clear relationship between the total amount of Risky movements and the probability of a PRRSv outbreak on the farms.

Discussion

The present work tries to demonstrate the effectivity of a new digital biosecurity system based on objective data to control internal biosecurity in commercial pig farms. With this purpose, the system based on the control of the flow of internal movements of farm workers was implemented in different farms.

In contrast with tools previously developed, the system described in the present work is based only on objective parameters. In other words, the real movements that workers do in farms are recorded.

As it has been mentioned, all tools previously developed regarding biosecurity (both external and internal) are based on values obtained through expert opinion panels (farmers themselves and veterinarians) [2, 19–21]. For instance, Biocheck.UGent™ test, originally developed by Laanen et al. [2, 23], consists of a total of 109 questions grouped in different subcategories for external and internal biosecurity. Subcategories related to internal biosecurity are: “Disease management”; “The farrowing and suckling period”; “The nursery unit”; “The fattening unit”; “Biosecurity measures between compartments and the use of equipment”; and “Cleaning and disinfection”, and questions have to be completed by the experts.

Nevertheless, it is important to keep in mind that the perception is a subjective aspect, and therefore, expert opinion will always introduce some bias that might be influenced by different factors, such as knowledge, previous experiences or personality. For this reason, scoring systems used as a tool to control biosecurity are not the best option.

Allepuz et al. [24] recently pointed the desire for the development of more complex models to providing quantitative risk assessment. Emphasizing that this kind of model could be more precise in mimicking the reality and might provide a more accurate estimation of the probability of virus spread within the herds by the different routes. The same authors noted that these quantitative models could not be developed easily because of the lack of relevant long-term data series. Moreover, according to Sternberg-Lewering et al. [21] is extremely difficult to obtain quantitative data from field studies. Nonetheless, as it has been presented, the development of this new tool allows the collection of a huge data series and their real-time processing. At the time in which the present study was carried out, other 19 companies have installed the system and are working with it worldwide.

It is already known that compliance with biosecurity measures varies depending on personality traits, such as responsibility, work experience and education [25]. Furthermore, in this sense, veterinarians play a key role in training and educating farmers with the final purpose that they carry out the application of the correct biosecurity measures on their farms [26]. Hence, the system developed in the current research allow both veterinarian and consultants acting at three different levels: 1) Follow-up of the health plans recommended and its degree of compliance 2) Customized training to the workers that need more support, coaching or time dedicated 3) Provide easy remote monitoring and consultancy.

As McCaw [27] already described, adequate management practices help to control mortality rates in both suckling and nursery pigs during acute outbreaks of PRRS. In this sense, McREBEL (management changes to reduce exposure to bacteria to eliminate losses) management has demonstrated an improvement in preweaning and nursery mortality related to PRRS. The McREBEL management must achieve the following four steps: 1) Cross-fostering of piglets between litters will not occur after 24 hours of age. 2) Suckling piglets and nursery pigs will be moved strictly all-in-all out by room. 3) Piglets will not be moved among different rooms to "nurse sow" (especially poor-doing piglets to younger age groups attempting to save them). 4) Piglets without a prognosis for recovery will be euthanized to minimize the exposure of other pigs in the litter or room to secondary bacteria and PRRS.

In that regard, and has already demonstrated McREBEL management, thanks to the installation of the new tool to control personal flow inside a farm as is describing in the current work, it has been proved that little variations of farm management, can reduce the spread of diseases and improve the global sanitary status of farms.

One of the most important conclusions obtained in the current work was that after training, farm workers were more conscious of the risks associated with movements and they usually avoid unnecessary routes within the farm. This observation is directly associated with a lower probability of spread any disease, and consequently an increase of productivity of farms.

Conclusions

According to the results, it can be concluded that the present work supports the notion that staff movements patterns within the different farm areas are a major factor of its internal biosecurity. This new digital biosecurity system confirmed a significant relationship between staff movements and the probability of PRRSv outbreak incidence. Moreover, the movements observed before and after training demonstrated the importance of biosecurity knowledge and training to help farm workers adopt safer daily practices. This system opens new possibilities to make objective those factors that were impossible to detect or quantify so far. Furthermore, it allows focusing the efforts on those areas or people that show more important deviation from the recommendations. This new digital tool allows for collected data which combined with classic tools enable to generate information helping decision making.

Declarations

Abbreviations

PRRS: porcine reproductive and respiratory syndrome.

PRRSv: porcine reproductive and respiratory syndrome virus.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on request.

Authors' contributions

ID was investigator of the study; ID and CE was Clinical Research Manager and participated in animal manipulations and data collection; MJM performed the statistical study; ID, MR and MJM wrote the manuscript; JM, CP and MA participated in the experimental design, the discussion of results and contributed in writing the manuscript. All authors read and approved the final manuscript.

Ethics approval

Owner consents were completed by the farmers prior to the enrolment of their animals in the study. This study was conducted in compliance with the Good Clinical Practice Guidance Document #85, May 9, 2001 (VICH GL9) and was approved by PigCHAMP Pro Europa animal welfare committee. Animals were handled in compliance with both Spanish regulations and guidelines for the protection of animals used for scientific research (Real Decreto Español 223/88 BOE 67: 8509-8511) and applicable European regulation.

Consent for publication

Not applicable.

Competing interests

The authors are employees of PigCHAMP Pro Europa, and Biorisk® is a digital biosecurity system offered by this company.

References

1.
FAO. Food and Agriculture Organization of the United Nations/World Organization for Animal Health/World Bank. Good practices for biosecurity in the pig sector – Issues and options in developing and transition countries. Rome: FAO Animal Production and Health; 2010. Paper No. 169.
2.
Laanen M, Persoons D, Ribbens S, de Jong E, Callens B, Strubbe M, Maes D, Dewulf J. Relationship between biosecurity and production/antimicrobial treatment characteristics in pig herds. Vet J. 2013;198:508–12.
3.
Neumann EJ, Kliebenstein JB, Johnson CD, Mabry JW, Bush EJ, Seitzinger AH, Green AL, Zimmerman JJ. Assessment of the economic impact of porcine reproductive and respiratory syndrome on swine production in the United States. J Am Vet Med Assoc. 2005;227:385–92.
4.
Done SH, Paton DJ, White MEG. Porcine reproductive and respiratory syndrome (PRRS): a review, with emphasis on pathological, virological and diagnostic aspects. Br Vet J. 1996;152:153–74.
5.
Kranker S, Nielsen J, Bille-Hansen V, Bøtner A. Experimental inoculation of swine at various stages of gestation with a Danish isolate of porcine reproductive and respiratory syndrome virus (PRRSV). Vet Microbiol. 1998;61:21–31.
6.
Rossow KD. Porcine reproductive and respiratory syndrome. Vet Pathol. 1998;35:1–20.
7.
Baysinger AK, Dewey CE, Straw BE, Brumm MC, Schmitz J, Doster A, Kelling C. Risk factors associated with endemic reproductive deficiencies caused by PRRSV infection. J Swine Health Prod. 1997;5:179–87.
8.
Weigel RM, Firkins LD, Scherba G. Prevalence and risk factors for infection with Porcine Reproductive and Respiratory Syndrome Virus (PRRSV) in swine herds in Illinois (USA). Vet Res. 2000;31:87–8.
9.

Mortensen S, Stryhn H, Søgaard R, Boklund A, Stärk KDC, Christensen J, Willeberg P. Risk factors for infection of sow herds with porcine reproductive and respiratory syndrome (PRRS) virus. Prev Vet Med. 2002;53:83–101.
10.
Otake S, Dee SA, Jacobson L, Pijoan C, Torremorell M. Evaluation of aerosol transmission of porcine reproductive and respiratory syndrome virus under controlled field conditions. Vet Rec. 2002;150:804–8.
11.
Otake S, Dee SA, Rossow KD, Deen J, Joo HS, Molitor TW, Pijoan C. Transmission of porcine reproductive and respiratory syndrome virus by fomites (boots and coveralls). J Swine Health Prod. 2002;10:59–65.
12.
Otake S, Dee SA, Rossow KD, Trincado C, Pijoan C. Studies on the carriage and transmission of porcine reproductive and respiratory syndrome virus by individual houseflies (Musca domestica). Vet Rec. 2004;154:80–5.
13.
Firkins LD, Weigel RM. A retrospective study of risk factors for porcine reproductive and respiratory syndrome virus infection and clinical disease in swine herds in Illinois during the early years of the pandemic. J Swine Health Prod. 2004;12:23–8.
14.
Evans C, Medley G, Green L. Porcine reproductive and respiratory syndrome virus (PRRSV) in GB pig herds: farm characteristics associated with heterogeneity in seroprevalence. BMC Vet Res. 2008;4:48.
15.
Dee S, Otake S, Oliveira S, Deen J. Evidence of long-distance airborne transport of porcine reproductive and respiratory syndrome virus and Mycoplasma hyopneumoniae. Vet Res. 2009;40:39.
16.
Lambert ME, Arsenault J, Poljak Z, D'Allaire S. Epidemiological investigations in regard to porcine reproductive and respiratory syndrome (PRRS) in Quebec, Canada. Part 2. Prevalence and risk factors in breeding sites. Prev Vet Med. 2012;104:84–93.
17.
Hu J, Zhang C. Porcine reproductive and respiratory syndrome virus vaccines: current status and strategies to a universal vaccine. Transbound Emerg Dis. 2014;61:109–20.
18.
Geldhof MF, Van Breedam W, De Jong E, Lopez Rodriguez A, Karniychuk UU, Vanhee M, Van Doorsselaere J, Maes D, Nauwynck HJ. Antibody response and maternal immunity upon boosting PRRSV-immune sows with experimental farm-specific and commercial PRRSV vaccines. Vet Microbiol. 2013;167:260–71.
19.
Postma M, Backhans A, Collineau L, Loesken S, Sjölund M, Belloc C, Emanuelson U, Grosse-Beilage E, Stärk KD, Dewulf J. MINAPIG consortium: the biosecurity status and its associations with production and management characteristics in farrow-to-finish pig herds. Animal. 2016;10:478–89.
20.

Holtkamp DJ, Kliebenstein JB, Neumann EJ, Zimmerman JJ, Rotto HF, Yoder TK, Wang C, Yeske PE, Mowrer CL, Haley CA. Assessment of the economic impact of porcine reproductive and respiratory syndrome virus on United States pork producers. J Swine Health Prod. 2013;21:72–84.
21.
Sternberg-Lewerin S, Österberg J, Alenius S, Elvander M, Fellström C, Tråvén M, Wallgren P, Waller KP, Jacobson M. Risk assessment as a tool for improving external biosecurity at farm level. BMC Vet Res. 2015;11:171.
22.
Holtkamp DJ, Yeske PE, Polson DD, Melody JL, Philips RC. A prospective study evaluating duration of swine breeding herd PRRS virus-free status and its relationship with measured risk. Prev Vet Med. 2010;96:186–93.
23.
Laanen M, Beek J, Ribbens S, Vangroenweghe F, Maes D, Dewulf J. Biosecurity on pig herds: Development of an on-line scoring system and the results of the first 99 participating herds. Vlaams Diergen Tijds. 2010;79:302–6.
24.
Allepuz A, Martín-Valls GE, Casal J, Mateu E. Development of a risk assessment tool for improving biosecurity on pig farms. Prev Vet Med. 2018;153:56–63.
25.
Racicot M, Venne D, Durivage A, Vaillancourt JP. Evaluation of the relationship between personality traits, experience, education and biosecurity compliance on poultry farms in Québec, Canada. Prev Vet Med. 2012;103:201–7.
26.
Gunn GJ, Heffernan C, Hall M, McLeod A, Hovi M. Measuring and comparing constraints to improved biosecurity amongst GB farmers, veterinarians and the auxiliary industries. Prev Vet Med. 2008;84:310–23.
27.
McCaw MB. Effect of reducing crossfostering at birth on piglet mortality and performance during an acute outbreak of porcine reproductive and respiratory syndrome. J Swine Health Prod. 2000;8:15–21.

Figures

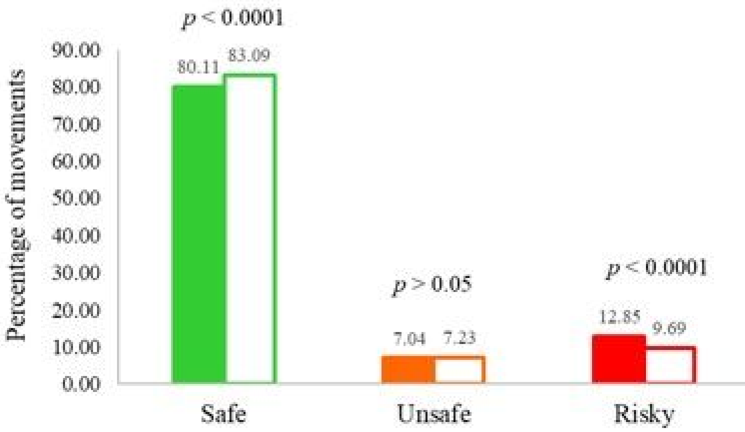

Figure 1

Average of percentages of Safe (green), Unsafe (orange) and Risky (red) movements before (■) and after (□) the training session considering the eight farms in which the system control movement was installed.

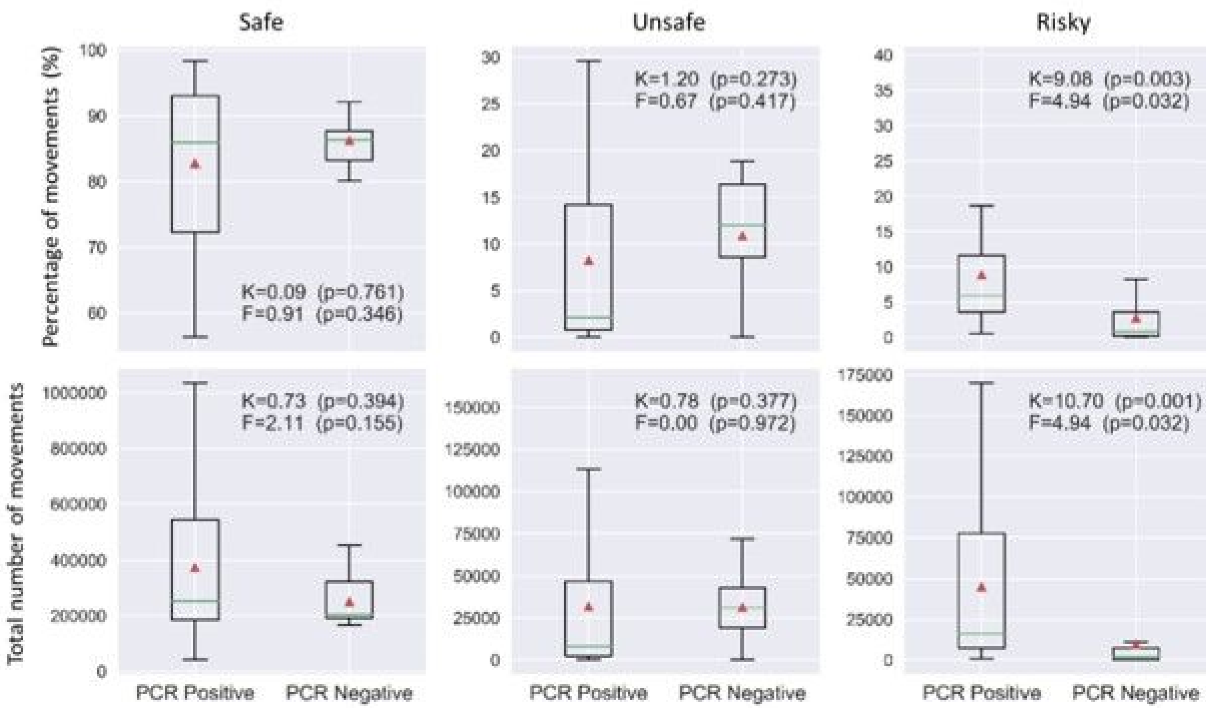

Figure 2

Comparison of percentages and totals of Safe, Unsafe and Risky movements between the PCR analytics positive and negative groups. The boxes extend between the first and third quartiles of the data for each group, and the whiskers extend between the minimum and maximum values. Group average is shown by the red triangles, while median lines are shown with solid green lines.