Zoonoses in Veterinary Students: A Systematic Review of the Literature

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Abstract

Background
Veterinary students face diverse potential sources of zoonotic pathogens since the first years of their academic degree. Such sources include different animal species and pathologic materials which are used at university facilities as well as commercial clinics, farms and other external facilities.

Objectives
The present study utilizes a systematic review of the literature to identify zoonoses described in veterinary students.

Data sources
Web of Science and PubMed.

Results
Of the 1,254 titles produced by the bibliographic search, 62 were included in this review. Whereas 28 of these articles (45.2%) described individual cases or outbreaks, the remaining 34 (54.8%) reported serological results. The zoonotic etiological agents described were bacteria, in 39 studies (62.9%), parasites, in 12 works (19.4%), virus, in 9 studies (14.5%) and fungi, in 2 (3.2%) of the selected articles. The selected literature included references from 24 different countries and covered the time period of the last 55 years.

Limitations
The fact that common cases of disease or cases of little clinical importance without collective repercussions are not usually published in peer-reviewed journals limits the possibility to reach conclusions from a quantitative point of view. Furthermore, most of the selected works (66.1%) refer to European or North American countries, and thus, the number of cases due to pathogens which could appear more frequently in non-occidental countries might be underestimated.
Conclusions/implications

The results of the present systematic review highlight the need of including training in zoonotic diseases since the first years of Veterinary Science degrees, especially focusing on biosecurity measures (hygienic measures and the utilization of the personal protective equipment), as a way of protecting students, and on monitoring programs, so as to adequately advise affected students or students suspicious of enduring zoonoses.

Introduction

Zoonotic diseases are recognized as occupational risks to which veterinarians are subjected [1]. The frequency of veterinarians who acknowledge to have endured a zoonosis varies between 16.7% and 64% [2–4]. Moreover, in these studies the different transmission routes and associated factors occurred in each case are also described. Apart from the communication of clinical cases, the systematic revision of the available scientific literature about zoonoses affecting veterinarians reveals that the seroprevalence against different zoonotic pathogens is greater amongst veterinarians than between the general population, suggesting that veterinarians could act as sentinels to detect emergent diseases and also that they could potentially disseminate zoonotic pathogens to their relatives or the animals they are treating [2].

In general, the activities scheduled in the study plans of Veterinary Sciences are designed with regard to biosecurity guidelines, and additionally, students receive specific advice about the risks associated to animal handling, protective equipment and specific risks associated with pre-existing medical conditions such as immunosuppression or pregnancy [5]. Taking into account the variety of animal species of veterinary interest and the subsequent specialization of veterinary professionals, veterinary students are to face many different sources of zoonotic infections including distinct animal species and in a diversity of situations during their training. In this sense, in addition to the scheduled practices in laboratories, necropsy and dissection rooms, abattoirs and university farms and hospitals, internships in commercial farms, clinics, slaughterhouses or official health services, which are of great academic interest, multiply the chances of interaction between veterinary students and zoonotic pathogens. At the same time, teaching student groups of variable sizes might favor zoonotic outbreaks which in standard conditions would appear as isolated zoonosis cases. Hence, the teaching activity is going to be bound to a changing sanitary situation which will evolve according to the animal species affected and the area of reference. In this context, student’s mobility between educational centers of different regions or countries may expose them to less common pathogens which they are not familiar with, or against which the routinely applied protective measures are less effective.

The vocational character of the veterinary career means that veterinary students have a special relationship with animals, and show great interest in putting knowledge to practical use from the beginning of their education. In this sense, it has been described that the empathy veterinary students have with animals is greater in the first than in the last year of their degree, when they take a more instrumental attitude towards animals [6]. In general, there is a need to update the health risks associated to the teaching activity and also the available protective measures, with special regard to those who belong to any risk group.

The knowledge of zoonotic cases happening in veterinary students dates back a long way. In 1939, Morrill [7] described four cases of infections caused by *Erysipelothrix* spp. in students who got injured during the dissection of a horse. Afterwards, in 1964, Schnurrenberger...
proposed including the serological detection of different zoonotic pathogens in student’s health programs [8]. Notwithstanding, the global information available about zoonoses in veterinary students is scarce and to date, no systematic review addressing this subject has been published. In addition, the awareness of zoonoses affecting veterinary students could help to design programs aimed at the prevention of this diseases. Therefore, the aim of the present review is to examine and summarize the available scientific literature related to zoonoses in veterinary students.

Methods
A systematic scientific review, using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [9], of the available literature was performed in September 2016 in order to identify any scientific article documenting zoonotic cases in veterinary students.

Search Strategy and Selection Criteria
The databases included in the Web of Science™ (v5.22.3) and PubMed platforms were consulted. The search in the Web of Science (WOS) included the following databases: Web of Science™ Core Collection, Current Contents Connect®, KCI-Korean Journal Database, MEDLINE®, SciELO Citation Index and Russian Science Citation Index. On both platforms, we used the following Boolean search statements: (zoonoses OR zoonosis OR outbreak OR case OR prevalence OR infection OR antibody) AND (veterinary students).

No time limits were defined and all the articles published in English, French or Spanish with at least an English abstract were selected. Subsequently, the titles and abstracts of the selected articles were examined so as to detect clinical cases or serological evidences of zoonotic diseases in veterinary students. In the articles selected the following data were obtained: zoonosis/causative agent, year (when this information was not specified, the year of publication was considered for guidance), country, number of affected students or percentage of seropositive students, animal species involved, associated risk factors and/or circumstances relevant to each case.

According to the concept of zoonosis, cases of allergies happened during practice lessons, allergies due to vector bites, vaccinal reactions, psychosocial disorders and infections acquired elsewhere unrelated to the academic activity were not considered. Additionally, works of which no English abstracts could be found, although they described zoonoses in veterinary students, were also discarded (these studies were published before 1987).

Results
This exhaustive revision of the literature provided a total of 1,254 results (808 on WOS and 446 on PubMed), 281 of which were discarded as they were found to be duplicated using a reference manager software (EndNote™). These duplications were also confirmed manually. During the review process, 891 works were excluded because they did not confirm disease cases in veterinary students. The remaining 82 studies were analyzed, rejecting those which did not include abstracts in English or which did not provide information according to the established search criteria (Fig 1).

Eventually, a total of 62 articles were selected (Table 1). Fifty-eight of them were written in English, 3 in Spanish and 1 in French, and all of them included an English abstract. Whereas 28 of these articles (45.2%, 95%CI [33.4, 57.5]) described individual cases or outbreaks, the remaining 34 (54.8%, 95%CI [42.5, 66.6]) reported serological results. The zoonotic etiological agents described were bacteria, in 39 studies (62.9%, 95%CI [50.5, 73.8]), parasites, in 12
works (19.4% 95%CI [11.4, 30.9]), virus, in 9 studies (14.5%, 95%CI [7.8, 25.3]) and fungi, in 2 (3.2%, 95%CI [0.9, 11]) of the selected articles. The selected literature included references from 24 different countries and covered the time period of the last 55 years. Twenty-two articles (35.5%, 95%CI [24.7, 47.9]) described zoonoses in veterinary students in Europe, followed by 19 (30.6%, 95%CI [20.6, 43]) which reported cases occurred in the USA, 10 (16.1%, 95%CI [9, 27.2]) in Asia, 7 (11.3%, 95%CI [5.6, 21.5]) in South America and the Caribbean, 3 (4.8%, 95% CI [1.7, 13.3]) in Oceania and 1 case (1.6%, 95%CI [0.3, 8.6]) happened in Africa.

The analyzed studies described 21 diseases or infections caused by the same genus or family of pathogenic agents in veterinary students. Cryptosporidiosis was the most frequently described zoonosis (10 articles), followed by brucellosis (9 works), Q fever (7 works), leptospirosis (6 works), toxoplasmosis (5 works), infections by Poxvirus (4 works), methicillin-resistant staphilococci (3 works), Corynebacterium spp. (3 works), Bartonella henselae (2 works), dermatophytosis (2 works), psittacosis (2 works), rabies (2 works), Toxocara canis (2 works), hepatitis E (1 work), Lyme disease (1 work), Mycobacterium bovis (1 work), Streptococcus suis type 2 (1 work), Swine Influenza virus (1 work), vancomycin-resistant enterococci (1 work) and West Nile Virus (1 work). The outbreaks with a greater number of diseased students were due to cryptosporidiosis, which caused 26 clinical cases in a veterinary teaching hospital [45]. The accidental exposure to animals infected with rabies virus incurred an intervention on >200 alumni [65]. On the other hand, the greatest seroprevalence values obtained in student groups were reported for Lyme disease (47.5%) [28] and Q fever (30% seropositive students in the Netherlands) [39]. In addition, the serial historic seroprevalence values against brucellosis...
Table 1. Zoonoses reported in veterinary students identified by the systematic literature review according to the agent, country, year and main quantitative and qualitative information summarized from the selected studies.

| Zoonoses/agent          | Country     | Year            | Human clinical cases or seroprevalence (%)<sup>1</sup> | Animal or risk factors identified and comments                                                                 | Reference |
|-------------------------|-------------|-----------------|--------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----------|
| **Bacteria**            |             |                 |                                                        |                                                                                                               |           |
| *Bartonella henselae*   | Japan       | 1995–1999       | 11.7%                                                  | Cat contact has been suggested as a risk factor for cat scratch disease                                        | [10]      |
| *Bartonella henselae*   | Japan       | 1997–1998       | 2                                                      | The clinical cases had association with cat scratch and showed antibody elevation after clinical manifestation of Cat Scratch Disease | [11]      |
| Brucellosis             | USA         | 1959–1964       | 1, 3.7%                                               | Brucellosis infections were associated to the summer                                                          | [8]       |
| Brucellosis             | UK          | 1962–1968       | From 8.9% in the first course to 48.5% within five years of graduation | *Brucella abortus* detected by serial *Brucella* agglutination tests                                           | [12]      |
| Brucellosis             | France      | 1968–1982       | 15.6%–5.2%                                          | Authors discuss the reduction of the seroprevalence in veterinary students in relation with the seroprevalence of bovine brucellosis in France | [13]      |
| Brucellosis             | France      | 1984            | <2% and 5.9%                                         | In veterinary students in three first school years and in their last school year, respectively, % of positive skin test reactions to a phenol-soluble antigen of *Brucella abortus* | [14]      |
| Brucellosis             | USA         | 1984            | 1                                                      | Accidental Inoculation of *Brucella abortus* Strain 19                                                      | [15]      |
| Brucellosis             | USA         | 1997            | 4                                                      | The affected students participated in an attempted vaginal delivery, a caesarean delivery, and a necropsy on a stillborn calf that died because of *Brucella abortus* strain RB51 infection | [16]      |
| Brucellosis             | India       | 2005            | 1.14%                                                 | The seroprevalence in veterinary students was lower than in general population (2.45%)                         | [17]      |
| Brucellosis             | Iran        | 2010            | 42                                                    | Occupational risk was demonstrated                                                                            | [18]      |
| Brucellosis             | Colombia    | 2010            | 18.4%                                                 | Protective barriers are suggested during contact with animals carrying the organism during training as veterinary medical students | [19]      |
| *Corynebacterium*       | USA         | 1979            | 1                                                      | Affected by pneumonia                                                                                         | [20]      |
| *pseudotuberculosis*    | Norwegian   | 2007            | 1                                                      | Affected by pneumonia. Laboratory work (possibly due to the inhalation of bacteria when catalase reaction were performed) | [21]      |
| *Corynebacterium*       | UK          | 2010            | 1                                                      | Contact with lambing farm or domestic animals were considered to be the most likely sources                    | [22]      |
| *ulcerans*              | USA         | 1959–1963       | 0%                                                     | Seropositives were not detected for any of the 3 leptospiral serotypes in the 493 serums tested over the 4 year period studied | [8]       |
| Leptospirosis           | Spain       | 1994–1995       | 8.4% and 11.4% in each period, respectively           | Risk factors associated: taking the course specialising in food inspection and technology, on-farm work, contact with pets in general, and particularly carnivores, and contact with animal traders | [23]      |
| Leptospirosis           | Colombia    | 2003            | 17%                                                    | Occupational exposure was identified as a risk factor                                                        | [24]      |
| Leptospirosis           | Peru        | 2005            | 11.9%                                                 | Zoonotic origin was suggested                                                                               | [25]      |
| Leptospirosis           | Trinidad and Tobago | 2013 | 9.7%                                                 | Veterinary student was the only risk factor that was associated with *Leptospira* infection                  | [26]      |
| Leptospirosis           | New Zealand | 2010–2011       | 0%                                                     | Low risk, despite frequent exposure to animal urine                                                        | [27]      |

*Continued*)
| Zoonoses/agent | Country | Year       | Human clinical cases or seroprevalence (%) | Animal or risk factors identified and comments | Reference |
|----------------|---------|------------|---------------------------------------------|------------------------------------------------|-----------|
| Lyme disease   | Mexico  | 2016       | 47.5%                                       | Associated to tick exposure or bites          | [28]      |
| Methicillin-resistant *Staphylococcus aureus* (MRSA) | The Netherlands | 2006 | 2 students positives in a population with 3.9% of MRSA carriage | veterinary doctors and students caring for livestock have a high risk of being colonized by MRSA | [29] |
| Methicillin-resistant *Staphylococcus aureus* | USA | 2010 | 22% | Visiting contaminated pigs farms | [30] |
| Methicillin-resistant *Staphylococcus aureus* | Malasya | 2013 | 23.3% | Occupational exposure was proposed for MRSA | [31] |
| *Mycobacterium bovis* | Spain | 1986–1990 | 2 | The human cases of tuberculosis by *M. bovis* diagnosed in the hospital was the 0.9% of the total of tuberculosis in the period studied | [32] |
| Psittacosis | USA | 1959–1963 | 0.6% | Psittacosis infection was detected in the spring | [8] |
| Psittacosis | The Netherlands | 2005 | Students infected in a population with an infection frequency of 34% | An outbreak of psittacosis in a veterinary teaching hospital. Parrots, identified as the source of infection, were exposed to a group of cockatiels coming from outside the teaching facility | [33] |
| Psittacosis | Brazil | 2010 | 1 student seropositive in a population with 23.9% of seropositives | The population studied included veterinarians, biologists, animal scientists, veterinary students, animal keepers and others employees in 20 zoos | [34] |
| Q fever | USA | 1959–1963 | 5.1% | The higher percentage of seropositives (12.7%) was reached just prior to graduation | [8] |
| Q Fever | Spain | 1994–1995 | 10.02–11.01% | Coursing the speciality in Food Inspection and technology or the speciality of Animal Production, to practise with living animals (particularly with ruminants) and to contact frequently with persons who worked with animals | [35] |
| Q Fever | Turkey | 2000 | 0% in a population with a seroprevalence of 7.8% | Positive results were obtained in farmers, veterinarians and abattoir workers | [36] |
| Q Fever | Slovakia | 2011 | 16.8 and 58% for phase I and II, respectively | Occupational risk factors were suggested | [37] |
| Q Fever | The Netherlands | 2006 | 18.7% | Study direction “farm animals”, year of study, having had zoonosis, lived on a ruminant farm | [38] |
| Q Fever | The Netherlands | 2009 | 30% of veterinary students in a population of Dutch veterinaries with a seroprevalence of 65.1% | Practical rotations during their study | [39] |
| Q Fever | Iran | 2015 | 34.7% | Age and sex | [40] |
| *Streptococcus suis* type 2 | New Zealand | 1989 | 0% in a population with a seroprevalence ranged between 9% and 21% | The development of antibody to *S. suis* type 2 was associated with occupational contact with pigs or their meat products | [41] |
| Vancomycin-resistant *Enterococci* | Malasya | 2007–2009 | 4.3% | The populations in close contact with livestock are not at higher risk for the colonization of Vancomycin-resistant Enterococci | [42] |

**Parasite**

| Cryptosporidium spp. | Finland | 1986 | 5 | Associated with contact with experimentally infected calves | [43] |
| Cryptosporidium spp. | USA | 1988 | 10 | Associated with direct contact with infected calves and contact with contaminated materials | [44] |
| Cryptosporidium spp. | USA | 1987 | 26 | Outbreak in a veterinary teaching hospital after admission of calves from affected farm | [45] |
Table 1. (Continued)

| Zoonoses/agent | Country | Year   | Human clinical cases or seroprevalence (%) | Animal or risk factors identified and comments | Reference |
|----------------|---------|--------|---------------------------------------------|---------------------------------------------|-----------|
| Cryptosporidium parvum | USA     | 1997   | 2                                           | The index case was an infected dairy calf. Outbreak of cryptosporidiosis occurred at a veterinary hospital involving a pony, a llama and 2 students | [46]      |
| Cryptosporidium parvum | USA     | 2003   | 7                                           | Calves. Authors recommend considering Cryptosporidium spp. as a cause of gastroenteritis among farm-animal workers | [47]      |
| Cryptosporidium parvum | New Zealand | 2011 | 25 (attack rate 29%) | Contact with calves during a practical class | [48]      |
| Cryptosporidium parvum | UK      | 2007   | 6                                           | Associated to a lapse in handwashing procedures on a farm with enzootic C. parvum in calves | [49]      |
| Cryptosporidium parvum | Sweden  | 2013   | 13                                          | Entering pens of calves with diarrhoea and eating in clinic cars were identified as risk factors. Washing hands at least twice per farm visit was protective | [50]      |
| Cryptosporidium parvum | USA     | 2015   | 16                                          | Training session at the bovine obstetric laboratory with euthanized calves | [51]      |
| Cryptosporidium parvum | Italy   | 2013   | 6                                           | Outbreak associated to two foals hospitalized in an Equine Perinatology Unit | [52]      |
| Toxocara canis      | France  | 1988–1989 | 11.8% and 20.4% in each period, respectively | Hygiene errors and contamination by food were identified as a risk factors | [53]      |
| Toxocara canis      | Mexico  | 2008–2010 | 13%                                        | The seroprevalence in veterinary students were higher than in Graphic Design students in Mexico City (13% and 7.0% respectively) | [54]      |
| Toxoplasma gondii   | USA     | 1960–1961 | 17.8%                                      | The contact with animals and farm environment is discussed as possible risk factors | [55]      |
| Toxoplasma gondii   | USA     | 1975–1976 | 20.4%                                      | No relationships were established between the preseance of T. gondii antibodies and animal contact | [56]      |
| Toxoplasma gondii   | USA     | 2002–2006 | 5.6%                                       | There was no significant difference (P > 0.05) in the prevalence of T. gondii antibodies in veterinary versus undergraduate students | [57]      |
| Toxoplasma gondii   | Malasya | 2013–2014 | 14.9%                                      | The age group of > 30 years old and working or study duration of >10 years having close contact with animals were identified as significant risks | [58]      |
| Toxoplasma gondii   | Iran    | 2016   | 33.7%                                      | No statistically significant difference observed in the infection rate between the veterinary laboratory sciences students group and control group | [59]      |
| Virus              |         |        |                                             |                                             |           |
| Hepatitis E        | USA     | 1999   | 6% in a population with 23–26% of seropositives | Swine veterinarians (without difference between academic, practicing, student, and industry veterinarians) may be at somewhat higher risk of Hepatitis E virus infection than are normal blood donors | [60]      |
| Poxvirus. Bovine Papular Stomatitis | USA | 1979 | 5                                      | Contacted with cattle. Diagnosed by clinical and epidemiological data | [61]      |
| Poxvirus. Cowpox   | Austria | 2010   | 1                                         | The patient had ulcerated nodule in the skin and malaise and a painful pronounced cervical lymphadenopathy | [62]      |
| Poxvirus. Orf       | USA     | 2012   | 1                                         | Intubation of a goat without wearing gloves | [63]      |
| Poxvirus. Orthopoxvirus | Italy | 2005   | 1                                         | Scratched by a cat | [64]      |

(Continued)
in veterinary students from the École d’Alfort (France), which describe that the greatest values were obtained in fourth-year students during the school year 1970–71, reaching 37.4% of positive results, is also worth mentioning [13].

All the analyzed articles refer to domestic animals (including stray cats) or their environment, as zoonoses in veterinary students associated to wildlife or exotic animal species have not been reported. Regarding the animal species involved in the cases described in the analyzed literature, calves are held responsible for almost all the cases of cryptosporidiosis [43–51], except one outbreak which was caused by an asymptomatic foal hospitalized in an Equine Perinatology Unit [52]. More specifically, the works about *Bartonella henselae* associate seropositivity against this pathogen or clinical cases of cat-scratch disease with contact or injuries caused by cats, respectively [10, 11]. Porcine livestock has been related to infections such as hepatitis E [60] and swine influenza virus [67], and *Streptococcus suis* Type 2, although this pathogen was not detected in veterinary students which were included in a risk population group [41]. Concerning the animal species associated to infections by Poxviridae virus, ruminants were considered the main source of these agents [61–63], though one student became infected with Orthopoxvirus after being scratched by a cat [64]. Two of the articles that report cases of psittacosis associate this disease to the exposure to birds [33, 34], whereas student’s cases of dermatophytosis were related to contact with cats [69] and an infected horse [70]. In the studies which report the animal species involved in each zoonosis, transmission through direct contact prevails, although indirect infection through contaminated equipment is also described for cryptosporidiosis [50] and dermatophytosis [69].

The occupational nature of zoonotic diseases is clearly discernable considering the works which report cases of brucellosis [8, 12–19], methicillin-resistant staphylococci [29–31] and Q fever [8, 35–40]. Moreover, this relationship is also suggested in various works assessing seropositivity against *Leptospira* spp. in veterinary students [23–26]. One case of infection by *Corynebacterium pseudotuberculosis* of laboratory origin has been reported [21] and also one case of West Nile virus after performing a necropsy on an infected horse [68].

| Table 1. (Continued) |
|-----------------------|-----------------|-----------------|------------------------------------------------|------------------|
| Zoonoses/agent        | Country         | Year            | Human clinical cases or seroprevalence (%)¹ | Animal or risk factors identified and comments | Reference |
| Rabies                | USA             | 1970–1977       | > 200 exposed                                  | Accidental exposure to rabies with an accelerated preexposure rabies prophylaxis program coupled | [65]       |
| Rabies                | USA             | 1979            | Students in a group of 36 persons exposed to a rabid dog | Effects of the vaccine types are discussed | [66]       |
| Swine Influenza virus | USA             | 1981            | Students positives in a population with a 11% of seroprevalence | Veterinary students had lower seroprevalence than veterinarians, pork producers and swine abattoir employees | [67]       |
| West Nile Virus       | South Africa    | 2008            | 1                                             | Transmission during horse autopsy. Handle the brain without mask or eye protection | [68]       |
| Fungus                |                 |                 |                                               |                                               |            |
| Dermatophytosis by *Microsporum canis* | Spain          | 2010            | 4                                             | Originated in a litter of stray cats | [69]       |
| Dermatophytosis by *Arthroderma vanbreuseghemii* | Switzerland | 2015            | 20                                            | Inadequate immune response of the affected horse and the high number of people in contact with it at the equine clinic were associated with this unusual outbreak | [70]       |

¹In veterinary students

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The works reporting infections by *Toxoplasma gondii* [55–59], vancomycin-resistant enterococci [42] and *Toxocara canis* [54] in veterinary students did not demonstrate any association between these infections and the contact with animals.

In the survey performed by de Rooij et al. [38] in the Veterinary Faculty of the University of Utrecht (the Netherlands), students acknowledged to have endured the following zoonotic diseases: Campylobacteriosis (1.5%), Ecthyma (1.3%), Giardiasis (0.1%), Cat scratch (0.4%), Listeriosis (0.3%), Salmonellosis (1.2%), Dermatophytosis (8.5%), other fungal infections (5.5%), *Staphylococcus* (0.7%) and *Verotoxigenic Escherichia coli* (0.3%). However, no cases of Brucellosis, Cryptosporidiosis, Leptospirosis, Psittacosis, Q fever, or Toxoplasmosis were communicated.

**Discussion**

The outcomes of the studies analyzed in the present review suggest that the cases of zoonotic diseases in veterinary students are underestimated in the available scientific literature. Most of the 62 selected articles describe outbreaks, clinical cases or serological studies, and only one article provides a survey about self-reported zoonoses in students, which was included in a study of Q fever [38]. This is probably due to the fact that common cases of disease or cases of little clinical importance without collective repercussions are not usually published in peer-reviewed journals, limiting the possibility to reach conclusions from a quantitative point of view. Nevertheless, regarding a qualitative approach, the search criteria applied allowed the identification of a representative number of zoonotic diseases reported in veterinary students. However, the fact that most of the selected works (64%) refer to European or North American countries should be taken into consideration, as the number of cases due to pathogens which appear more frequently in non-occidental countries might be underestimated.

Cryptosporidiosis is the most frequently reported zoonosis, as well as the disease which causes the greatest number of affected students in the associated outbreaks. Generally, the epidemiological characteristics of the cases or outbreaks of cryptosporidiosis are constant between the different studies [43–51], except for one work in which the outbreak was due to two infected foals [52] instead of calves. Insufficient hygienic practices, including inappropriate hand washing (as alcohol-based hand gels are unsuitable), eating inside the cars used to get to the farms and deficient washing temperature of the protective clothing are considered as a risk factor in all these cases [50]. In addition, the fact that oocysts are persistently eliminated in huge amounts to the environment by infected individuals, their great environmental resistance and the relatively low infective dose to human beings (≥10 oocysts) should be taken into account. All these aspects, together with the presence of student groups assisting diseased calves (at commercial or university farms) favor the presentation of outbreaks [43–51]. Not only veterinary students have been affected by cryptosporidiosis; this way, recurrent outbreaks were reported in consecutive semesters causing 31 and 37 cases, respectively, in students between 9th–12th grade from a high school and two middle schools which participated in an educational farm program [71]. In this work, the difficulty of implementing adequate hygienic measures among students is described. Despite the fact that no cases of cryptosporidiosis in veterinary students associated to small ruminants have been reported, preventive advice should also be considered when visiting farms with affected lambs [72].

The results obtained in the different works reporting brucellosis in veterinary students should be temporary and geographically contextualized. The articles relative to France and UK between the 1960s–1980s [12–14] refer to a time period in which animal brucellosis presented high prevalence values and eradication campaigns were being developed. Nowadays, UK is free of bovine and small ruminant brucellosis, whilst in France the whole country is free of bovine brucellosis, 64 departments are officially free of *B. melitensis* [73] and no clinical cases
of this disease have been reported in small ruminants since 2003. To the contrary, Mediterranean countries still present variable numbers of infected animals and thus, these areas gather the majority of human brucellosis cases in the EU [74]. However, no cases in veterinary students have been reported in these countries in the last years. On the other hand, human cases of brucellosis are currently anecdotic in most of the states of the USA [75]. In contrast, high prevalence values of animal brucellosis are reported in Central America, the Middle East and Asia, which means that veterinary students are at risk in those regions, as pointed out in the articles on this subject [17–19].

The articles reporting Q fever are mainly focused in USA, Europe and Iran. All of them emphasize the occupational risk associated to veterinary students [8, 35–40]. Moreover, these works describe an increase in seroprevalence values when comparing first-year students with students in the last years of their degree. Contact with animals (especially ruminants), contact with people working with animals [35], academic orientation towards large animal specialties, having endured a zoonosis during their degree and having lived at a farm housing ruminants [38]. The Dutch experience clearly demonstrates the link between the impact of Q fever in veterinary students and the situation of the animals regarding this disease. Hence, before the outbreaks in 2007–2009, the mean seroprevalence value in students was 18.7% [38]. This value increased to 30% in 2009 [39]. Additionally, the fact that most of the infections were not notified as they cursed asymptomatically or with mild flulike symptoms must be taken into consideration. Notwithstanding, the negative impact the infection by *Coxiella burnetti* may have, especially on pregnant women and risk groups [76], make it necessary to monitor these collectives precisely. In general, a correct hygiene and utilization of the personal protective equipment (PPE) have been identified as protective factors against infections by *C. burnetti* [35]. Nonetheless, those measures may not be sufficient to protect students. After the culling campaign carried out in the Netherlands as a control strategy against Q fever in caprine farms, 17.5% of the workers seroconverted despite their experience using PPE, which promoted the vaccination of this risk group [77]. In this context, serological surveillance of students at risk, and especially those which display compatible symptoms, has been considered [35, 37]. Vaccination with the Australian vaccine is contraindicated in seropositive people [78], although it could be a possibility for seronegative students at the beginning of their degree [39], with special regard to those whose medical history presents a risk of developing chronic forms of Q fever [37]. In any case, doctors looking after veterinary students should take infections by *C. burnetti* into consideration in order to realize an early diagnosis and thus avoid the developing of chronic forms of this disease [38, 39].

Fungal infections are the main cause of zoonoses in veterinarians, reaching frequencies which fluctuate between 45.5% [1] and 54.1% [4] of the reported cases of zoonoses. In a survey performed in Canada, 7.6% of the veterinarians declared having endured a mycosis within a 5 year time period [3]. Similarly, dermatophytosis and other fungal infections were the main self-reported zoonoses by veterinary students of the Veterinary Faculty of the University of Utrecht, with a total of 94 cases among the 960 students surveyed [38]. Nevertheless, in the present systematic review only 2 articles reporting dermatomycosis in veterinary students were found, suggesting that the only published cases of fungal infections are those which are etiological, epidemiological or clinical exceptions [69, 70].

The occupational risk associated to veterinary students has also been addressed and reported by works describing infections by methicillin-resistant staphylococci (MRS) [29–31]. Apart from the association of these infections to visiting infected porcine farms [30], the presence of MRS in the clothing worn by hospital personnel in a veterinary teaching hospital has also been demonstrated. Therefore, changing clothes and using disposable equipment when working with carrier animals are recommended [79]. On the contrary, the detection of
vancomycin-resistant enterococci in veterinary students has not been associated to contact with livestock but to factors such as age and previous hospitalization [42]. Regarding the works which assess seropositivity against *Leptospira* spp., four articles suggest a zoonotic origin [23–26], whereas only one study states that veterinary students can be defined as a low risk group though their great exposure to animal urine [27] and other of them did not detect any positive over the 4-year period studied [8].

Despite the first evidences associating a greater reactivity of students against toxoplasmas due to their contact with livestock or its environment [55], there is no actual evidence that these veterinary students present a higher risk of infection by *Toxoplasma gondii* than other collectives. Hence, other sources of infection such as food are discussed [55–59]. Likewise, the higher seroprevalence values observed in veterinary students against *Toxocara canis* [54] do not allow to categorically determining the occupational character of those outcomes. Concerning the risk factors associated to this pathogen, errors in hygienic practices and food contamination have been suggested [53].

The consulted literature only described one case of zoonosis in veterinary students originated in a microbiology laboratory [21] and another in a necropsy room [68]. These findings suggest that biosafety protocols are easier to develop in academic facilities than in external farms. The results of the present systematic review highlight the need of including training in zoonotic diseases since the first years of Veterinary Science degrees, or at least before starting with clinical subjects. This training should especially focus on preventive measures, as a way of protecting students. Thus, providing information concerning biosafety regulations and preventive measures is essential to reduce the risk of emergency or re-emergency of zoonoses [80]. In this sense, the Biosecurity Working Group of the Veterinary Faculty of the University of Liège has developed a thorough manual about Biosecurity Standard Operating Procedures, under the direction of Professor Saegerman [81]. This manual describes general biosafety protocols and specific procedures concerning work with different animal species, food science, field practices, experimental farm practices, anatomy department and diagnostic laboratory, including necropsy area and diagnostic imaging. Moreover, all this information is displayed on an adaptive website according to different user profiles (e.g. students, handicapped students, veterinarians, visitors, staff) in the form of an illustrated manual of biosecurity procedures [82]. In the same way, the development and publication of summaries about protective actions, PPE, occupational health and/or control measures against environmental diseases, such as the document recently put to date by the National Association of State Public Health Veterinarians [83], are of special interest. Likewise, campaigns promoting hand hygiene before eating food (based on video displaying, posters and the promotion of hand disinfectants) have proved to be effective between veterinary students, as these campaigns achieved a lasting improvement on their hand hygiene [84]. This training in zoonoses ought to consider special recommendations concerning immunosuppressed students or students with specific medical conditions (e.g. pregnant students). For this, recommendations on the management of animals by immunosuppressed patients [85, 86], may be very useful, as the risk of infection of veterinary students will always be greater than the risk of the owners with the same medical condition. At the same time, Veterinary schools should apply surveillance and monitoring programs so as to advice affected students or students suspicious of enduring zoonoses, allowing the detection and investigation of these cases in order to prevent their further transmission.

**Supporting Information**

S1 File. PRISMA 2009 checklist. (DOC)
Author Contributions
Conceptualization: AS AC.
Formal analysis: AS MPvH JTD AP CdlF AGM JCC AC.
Investigation: AS MPvH JTD AP CdlF AGM JCC AC.
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