Research Article

Global Prevalence and Associated Risk Factors of Peste des Petits Ruminants (PPR) Virus in Sheep and Goats: A Meta-Analysis

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Abstract | Peste des petits ruminants (PPR), a prevalent viral disease of sheep and goats that impacts productivity and international animal trade globally. Meta-analysis serves as the most suitable approach for obtaining pooled data from individual studies. This study aimed at using a random-effects model of meta-analysis to compile the estimates of the global prevalence and potential risk factors of PPR among sheep and goats. Based on the selection criteria and quality assessment score, 40 peer-reviewed publications were included in the final database for the meta-analysis. The prevalence was determined in a forest plot using R studio software with a 95% confidence interval (CI). In addition, the significance of the study publications was shown through a funnel plot. The estimated pooled prevalence of PPR was 39.16 % from 2000-2021 with significant heterogeneity ($P < 0.01$) among the studies. A subgroup analysis was also performed for species, age, sex, study duration, and sample size for the assessment of the potential risk factors. The prevalence rate was found highest in sheep at 42.91%, female individuals at 32.32%, 500 or below sample size at 43.63%, in the period of 2000–2010 at 42.05% and aged animals at 41.23% non-significantly. This is the meta-analysis of PPR worldwide that offers a comprehensive picture of the prevalence of PPR in small ruminants with possible risk factors. Thus, this study will be useful in raising awareness and advocating engaging in initiatives PPR control and prevention.

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Introduction

Peste des petits ruminants (PPR) also known as sheep and goat plagues, one of the most serious fast-spreading and economically significant viral diseases characterized by the fever (40-42°C), mucopurulent nasal and ocular discharge, lack of appetite, necrotizing and erosivestomatitis, enteritis, pneumonia, sudden onset of depression, foul smelling diarrhea and death caused by Peste des petits ruminants virus (PPRV). PPRV is a ribonucleic acid virus belonging to the genus Morbillivirus and family Paramyxoviridae which affecting both domestic and wild small ruminants (Abd El-Rahim *et al*., 2010; Albayrak and Alkan, 2009; Fentahun and Woldie, 2012; Gibbs *et al*., 1979; Intisar *et al*., 2017; Singh *et al*., 2004).

PPRV is closely related to the rinderpest virus of cattle, morbilli viruses of marine animals, and human measles virus (Khalafalla *et al*., 2010). In 1940s, Ivory Coast in west Africa firstly reported the PPRV where it was known as Kata, pseudo-rinderpest, pneumo-enteritis complex and stomatitis pneumo-enteritis complex (World Organisation for Animal Health, 2013). Then it has spread across the Sub-Saharan Africa, Morocco, Arabian Peninsula, Middle East, and Indian subcontinent (Gari *et al*., 2017; Shaila *et al*., 1996; Taylor, 1984). PPR is reported in various parts of Asia and Africa (Dhar *et al*., 2002).

Among small ruminants including sheep and goats, it can show up to 50–80% mortality and around 90% morbidity. Sheep only show mild symptoms of the sickness, but goats experience severe symptoms (Khan *et al*., 2008). According to Gebre (2020) age (3-18 months), recovered animals, climatic condition, species, breeds and sex are major risk factors those are responsible for highly affecting the sheep and goats.

Currently PPR is considered as one of the devastating transboundary and notifiable disease that constitutes an emerging or re-emerging threat in many countries of the world. After eradicating Rinderpest, the World Organization for Animal Health (WOAH) and the Food and Agriculture Organization (FAO) of the United Nations, In March 2015 launched an initiative to eradicate PPR by 2030. PPRV is sensitive to abiotic environmental factors and outside of a host it cannot survive long. The virus is highly contagious and easily transmitted by aerosol and by close contact between infected and vulnerable animals (Baloch *et al*., 2021; Fournié *et al*., 2018; Hailegebreal, 2019; Khan *et al*., 2008).

Diagnosis protocols of PPR in sheep and goats range from symptomatic diagnosis to virus isolation whereas virus isolation is the gold-standard for the diagnosis of PPR (Banyard *et al*., 2010; Gebre, 2020). The effectiveness of PPR controls depends heavily on the prompt discovery of affected animals. Serological monitoring can be used to diagnose PPRV infection in sub-clinically infected animals, whereas clinical surveillance and the detection of antigen in clinical samples can rapidly identify severe instances in which animals exhibit clinical indications in the field (Abubakar *et al*., 2009). To control PPR, strategy of mass scale vaccination is required. However, losses can be minimized by taking preventative actions, for which understanding the pathophysiology and disease's causation is essential. Live attenuated vaccines are in use in endemic areas that provide long term immunity in sheep and goats (Khan *et al*., 2018).

Although many scholar reviews and analyses the geographical distribution, risk factor, diagnostic manual, serological tests etc. of PPR (Abd El-Rahim *et al*., 2010; Albayrak and Alkan, 2008; Dhar *et al*., 2002; Fentahun and Woldie, 2012; Hailegebreal, 2019; Singh *et al*., 2004) but there have no comprehensive meta-analysis on prevalence estimation of PPR up to recent years in global perspectives. The main reasons of the prevalence estimation is to gather better idea about the endemic situation in different geographical area of the world alongside sample used in better diagnosis, age, sex, breed, year of affecting. Therefore, this study aimed to evaluate through a meta-analytic approach to estimate prevalence and identifying the specific risk factors in different region of sheep and goat.

Materials and Methods

The study protocol and literature search strategy

A systematic literature search was conducted using electronic data-bases, including Google Scholar (n=8790), ScienceDirect (n=668), PubMed (n=261), BioMed (n=59) and Scopus (n=23) to retrieve the related studies for the last 21 years. Three following combinations of keywords were used: for population (sheep and goat); interventions (virus: PPR and associated risk factors); outcomes (prevalence

globally). Besides, additional studies were gathered by manually searching the cross-references or bibliographies section of eligible studies. However, the search criterion was limited to English- language studies. Finally, the eligible studies were extracted by two reviewers to eliminate the bias. The PRISMA protocols were followed for searching and scrutinizing procedures (Moher *et al.*, 2015).

Quality assessment of the study

The grading of recommendations assessment, development, and evaluation (GRADE) approach was used to assess the overall quality of evidence (Atkins *et al.*, 2004; Tegen *et al.*, 2020). The quality of each study was declared using the three major assessment tools (methodological quality, comparability and outcome, and statistical analysis of the study). Two points were given to each criterion. Publications with a total score of 5–6 points were considered high, 3–4 points to moderate, and less than 3 points to be considered low quality and excluded (Tegen *et al.*, 2020).

Study selection and data extraction

For conducting the methodical review and meta-analysis, we used four criteria as a standard for choosing the studies: (1) state of the case confined to sheep and goat species (2) prevalence including epidemiological studies written and published in the English language within the global territory; (3) diagnosis based on Enzyme-Linked Immuno Sorbent Assay (ELISA) and Reverse Transcription Polymerase Chain Reaction (RT-PCR); (4) studies published between 2000 to 2021. After designing the study, the title and abstract of the papers were scrutinized by two reviewers independently, and pertinent papers were retrieved. The retrieved documents were then rechecked thoroughly and deleted the duplicate and low-quality assessed articles. For conducting the meta-analysis, we processed the necessary data in Microsoft Excel with the first author's name and published year; study duration; location; species; animal's age and sex; diagnostic method; the number of samples; case positives; and percentage of prevalence were accumulated for each separate study.

Assessment of bias, data preparation, and analysis

The prevalence was shown in a forest plot using R studio software with a 95% confidence interval (CI). Finally, we graphically showed the funnel plot for clearing the significance of study (Figure 1). Due to high heterogenicity among the studies, we separately analyzed subgroup parameters (categorical covariates), including age (young and old), sex (male and female), sample size (500 or below 500 and >500), and study duration (2000–2010 and 2011–2021) of the studies. We conducted a LRT test and Walt test among the categorized variables in each subgroup parameter. The random effect model was considered for estimating the pooled prevalence and we considered the statistical test for showing the heterogeneity variation between studies and among the studies by considering low (I^2 25%), moderate (I^2 50%), and high (I^2>75%) heterogeneity (Mia *et al.*, 2021). All analysis was performed using software R studio (Version 4.3.1).

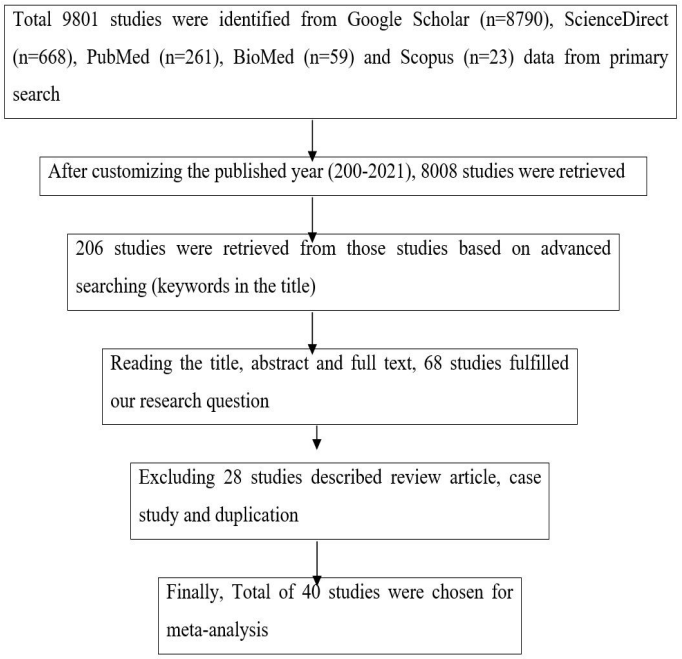

Figure 1: *The assortment method of entitled studies for calculable scrutiny via flow diagram.*

Results and Discussion

Study selection

In this step, we visualized a flow diagram that contains the selection process of choosing articles in Figure 2. By searching the keywords in five databases, we found 9801 records, and then we customized results based on the published year range between 2000 and 2021 and found 8008 records. After advance searching, we retrieved 206 records that contained mentioned keywords in the title. Then, reading the title, abstract and full text, we got 68 studies that answered our research question. Next, we have finalized 40 studies for conducting the meta-analysis based on exclusion and inclusion criteria.

Table 1: *Characteristic of 40 included studies.*

Study	Location	Duration	Technique	Species	No. of sample	Positive case	Quality assessment score
Mbyuzi *et al.*, 2014	Tanzania	2007-2009	ELISA	Goat	434	125	4
				Sheep	70	25	
Intisar *et al.*, 2017	Sudan	2008-2012	ELISA	Goat	1568	726	3
				Sheep	8036	5071	
Singh *et al.*, 2004	India	2001-2003	ELISA	Goat	2907	943	3
				Sheep	1500	545	
Abd El-Rahim *et al.*, 2010	Egypt	2006	ELISA	Goat	40	30	3
				Sheep	243	154	
Albayrak and Alkan, 2009	Turkey	2008	ELISA	Goat	892	133	3
Gelana *et al.*, 2020	Ethiopia	2018	ELISA	Goat	806	124	6
Saeed *et al.*, 2018	Sudan	2015	ELISA	Sheep	546	372	6
				Goat	372	162	
Gari *et al.*, 2017	Ethiopia	2014-2015	ELISA	Goat	700	339	4
Khan *et al.*, 2008	Pakistan	2005-2006	ELISA	Sheep	338	192	3
				Goat	595	287	
Waret-Szkuta *et al.*, 2008	Ethiopia	2001-2003	ELISA	Goat	13651	892	3
Abubakar *et al.*, 2009	Pakistan	2005-2007	ELISA	Goat	616	272	3
				Sheep	440	238	
Almeshay *et al.*, 2017	Libya	2013	ELISA	Goat	120	71	4
				Sheep	601	266	
Abubakar *et al.*, 2011	Pakistan	2009-2010	ELISA	Goat	522	294	3
				Sheep	101	50	
Mahmoud *et al.*, 2017	Egypt	2016	ELISA	Goat	110	50	3
				Sheep	190	126	
Gebre, 2020	Ethiopia	2016-2017	ELISA	Goat	968	20	3
Khan *et al.*, 2018	Pakistan	2016-2017	ELISA	Goat	1264	615	3
				Sheep	1219	596	
Gari *et al.*, 2015	Ethiopia	2012	ELISA	Goat	258	217	3
				Sheep	242	171	
Hailegebreal, 2019	Ethiopia	2014-2015	ELISA	Goat	200	68	3
				Sheep	190	46	
Faris *et al.*, 2012	Ethiopia	2006-2007	ELISA	Goat	726	494	3
				Sheep	370	176	
Baloch *et al.*, 2021	Pakistan	2021	ELISA	Goat	4900	1386	3
				Sheep	800	201	
Afera *et al.*, 2014	Ethiopia	2011-2012	ELISA	Goat	240	114	3
Nigusua and Fentie, 2012	Ethiopia	2008-2009	ELISA	Sheep	384	101	3
Hassan, 2012	Bangladesh	2011-2012	ELISA	Goat	282	193	3
				Sheep	123	98	
Namtimba, 2015	Tanzania	2014-2015	ELISA	Goat	252	147	3
Salih, 2015	Sudan	2012	ELISA	Goat	219	105	4
				Sheep	261	114	
Osman *et al.*, 2009	Sudan	2001-2003	ELISA	Goat	519	307	3
Saeed *et al.*, 2010	Sudan	2008	ELISA	Goat	306	170	3
				Sheep	500	336	

Table continued on next page.....

Study	Location	Duration	Technique	Species	No. of sample	Positive case	Quality assessment score
Rudra, 2019	Bangladesh	2018-2019	ELISA	Goat	400	61	5
Hailegebreal, 2018	Ethiopia	2014-2015	ELISA	Goat	200	68	4
				Sheep	190	46	
Gizaw *et al.*, 2018	Ethiopia	2015-2016	ELISA	Goat	135	53	3
				Sheep	94	39	
Nkangaga, 2014	Tanzania	2011-2012	ELISA	Goat	415	20	6
				Sheep	35	3	
Shuaib *et al.*, 2014	Sudan	2011	ELISA	Goat	820	576	5
Durrani *et al.*, 2010	Pakistan	2006-2007	RT-PCR	Goat	252	39	3
				Sheep	252	46	
Abubakar and Munir, 2014	Pakistan	2011-2012	RT-PCR	Goat	330	103	3
				Sheep	35	13	
Nizamani *et al.*, 2015	Pakistan	2012-2013	ELISA	Goat	5787	2013	3
				Sheep	1309	487	
Mpenda and Buza, 2014	Tanzania	2010-2011	ELISA	Sheep	191	0	3
				Goat	192	21	
Wifag, 2009	Sudan	2007-2008	ELISA	Goat	232	178	3
Eltahir, 2020	Sudan	2018-2019	RT-PCR	Sheep	337	324	3
				Goat	146	146	
Luther *et al.*, 2005	Nigeria	2003-2004	ELISA	Goat	227	56	3
Woma, 2015	Nigeria	2012-2013	ELISA	Goat	3489	774	3
				Sheep	1089	244	

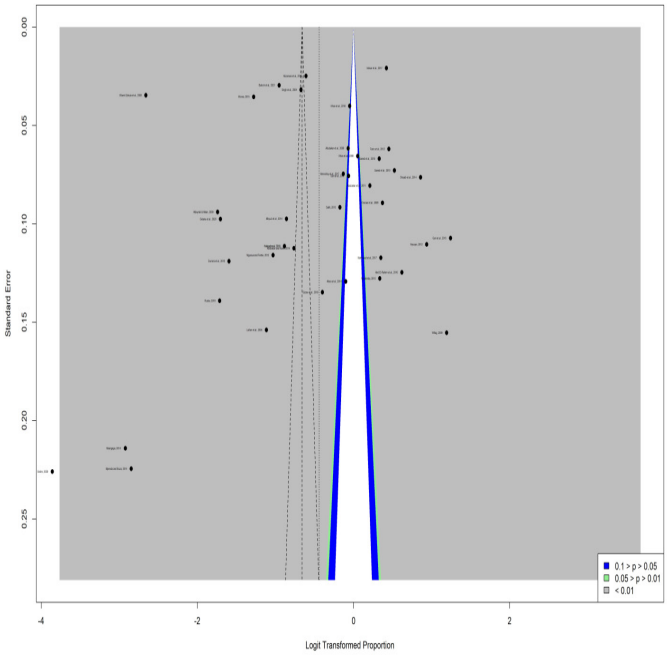

Figure 2: *Funnel plot for perceiving the significance of the study publications.*

Characteristic of included studies

We visualized all the characteristics of each study in Table 1. In addition, the significance of the study publications was shown through a funnel plot. The *P*-value of blue, green and gray colored surrounded studies was 0.1> *P* >0.05; 0.05> *P* >0.01; and *P* <0.01 (Figure 2).

Prevalence of PPR in animal population

Showing the result in Table 1 and Figure 3, the estimated prevalence of overall PPR was 39.16 % (95% CI: 30.00-49.16) from 2000-2021. Moreover, we found considerable heterogeneity (I^2 = 100 %, tau^2 = 1.7099 and *P* < 0.01) among the studies.

Prevalence of PPR stratified by country

According to study location the prevalence of PPR were 40.41 % (Bangladesh); 61.78 % (Egypt); 28.96 % (Ethiopia); 33.76 % (India); 46.74 % (Libya); 21.90 % (Nigeria); 38.50 % (Pakistan); 70.54 % (Sudan); 17.20 % (Tanzania); and 14.91 % (Turkey). The highest prevalence rate (70.54 %) was shown in Sudan (95% CI: 53.52-83.87) and lowest prevalence rate (14.91%) was found in Turkey (95% CI: 12.72-17.40). However, the *P*-value for the test of subgroup difference among the countries was < 0.01 (Figure 4). In addition, the prevalence of PPR according to study location is illustrated in Figure 5.

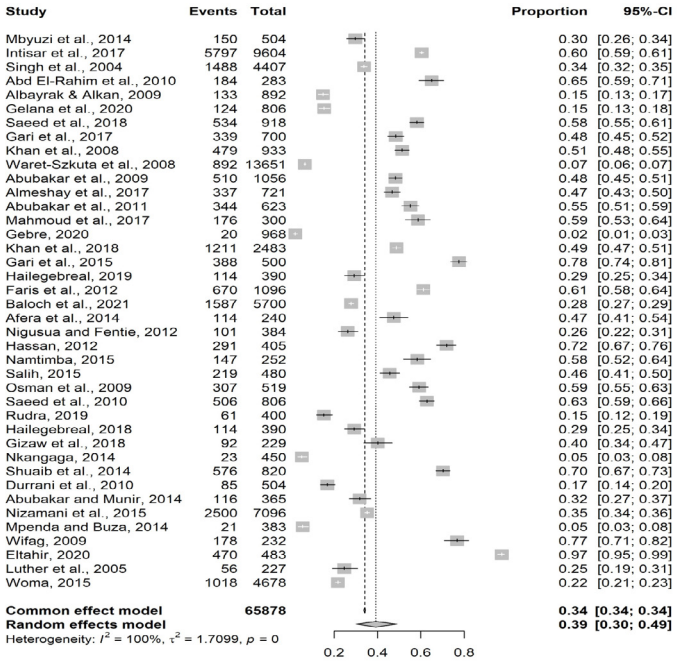

Figure 3: *The forest plot demonstrates the prevalence of PPR.*

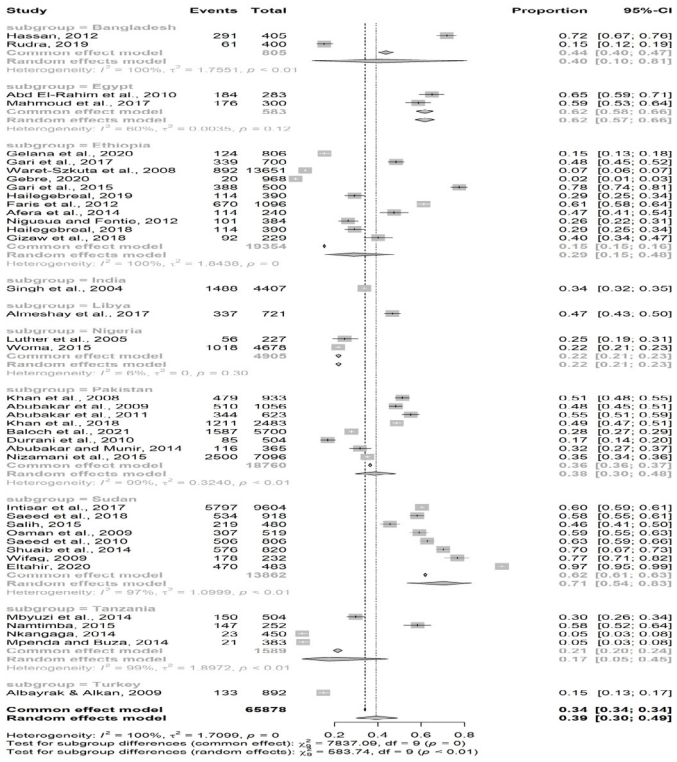

Figure 4: *The forest plot demonstrates the prevalence of PPR stratified by country.*

Prevalence of PPR stratified by study period

Inside the overall prevalence, we categorized subgroup analysis: study period, species, sex, age and sample size. Firstly, in the periodic analysis 40 studies mention the duration period, and the overall prevalence was 42.05% (95% CI: 30.06-55.06) in the period of 2000–2010, and 37.44% (95% CI: 25.28-51.43) in the period of 2011 to 2021 but the *P*-value for the subgroup differences between the periods was 0.63 (Table 2). In addition, the heterogeneity of 2000–2010 period is, I^2 = 100%, tau^2 = 1.0634, Q=6951.38 and P < 0.01; and 2011-2021 period is, I^2 = 99%, tau^2 = 2.1002, Q=2854.94 and P < 0.01. However, we found considerable heterogeneity (I^2 = 100%, tau^2 = 1.7099 and P < 0.001) between the two study periods (Figure 6).

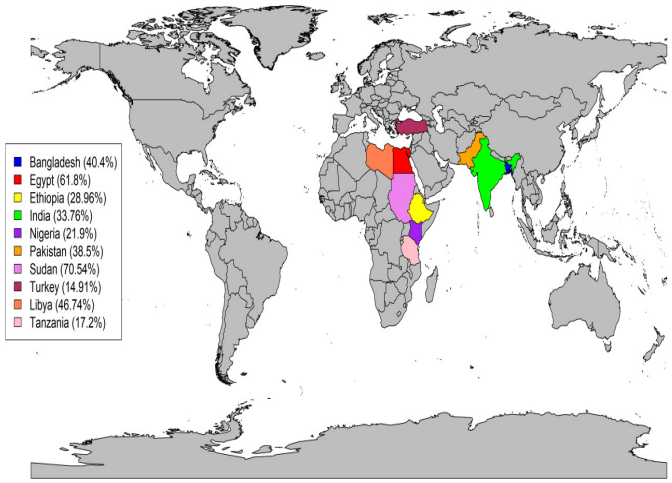

Figure 5: *The prevalence of PPR according to study location.*

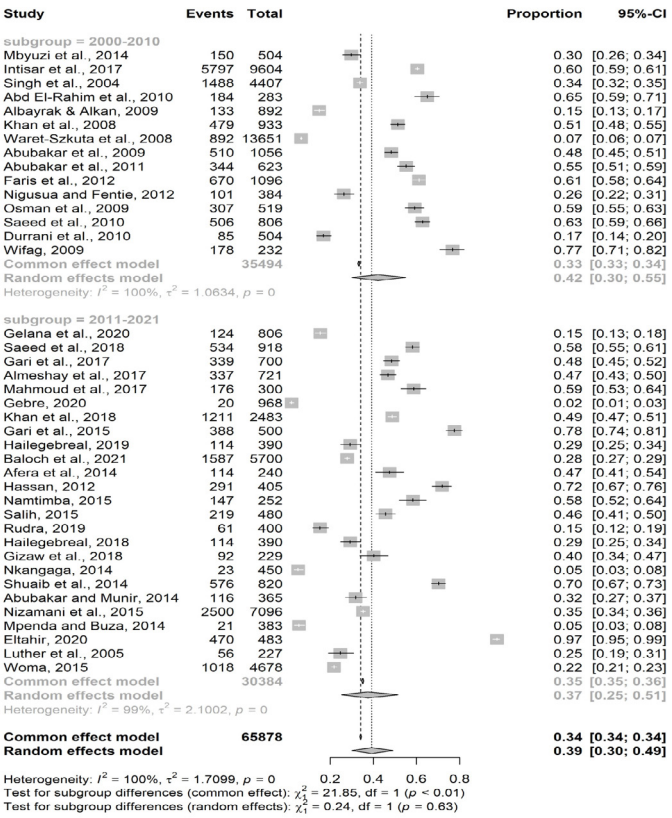

Figure 6: *The forest plot demonstrates the prevalence of PPR according to study period.*

Prevalence of PPR stratified by species

In the case of species, we found the maximum number of studies (39) from goat with the prevalence rate was 40.11% (95% CI: 30.24-50.85). In contrast, the highest prevalence rate was found at 42.91% (95% CI:

31.47-55.17) for sheep. However, the *P*-value for the test of subgroup difference between goat and sheep was 0.73. Moreover, the summary of the statistics was (I^2=99%, tau^2=1.8900, Q=6215.91 and $P < 0.01$) for goat, (I^2=99%, tau^2=1.7202, Q=1849.95 and $P < 0.01$) for sheep. However, we found considerable heterogeneity (I^2 = 99%, tau^2 = 1.8302 and $P < 0.01$) between the species (Figure 7).

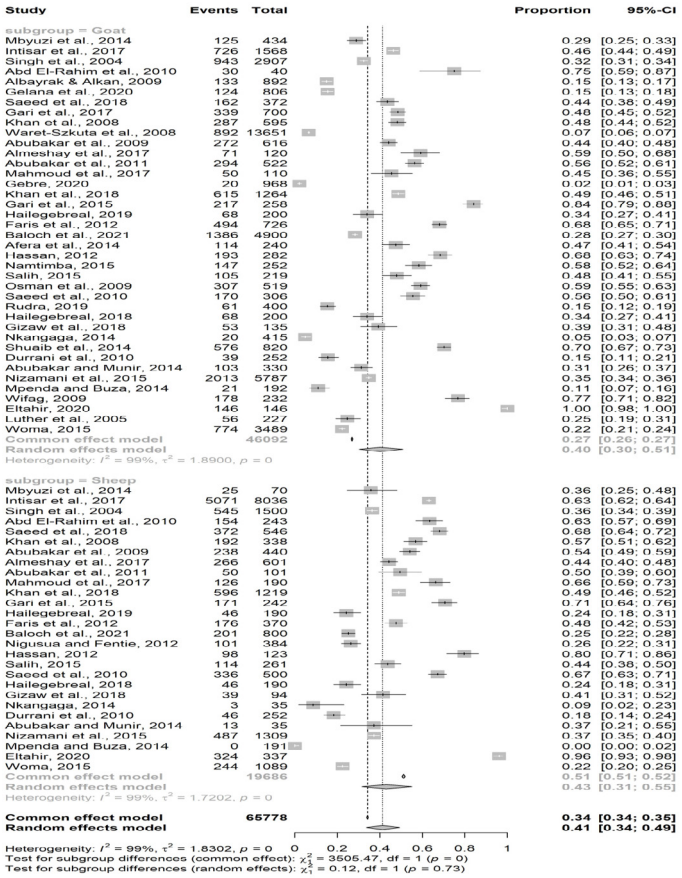

Figure 7: *The forest plot demonstrates the prevalence of PPR stratified by species.*

Prevalence of PPR stratified by different diagnostic test methods

In addition to the risk factors, we also categorized the test procedure into two distinct groups, including ELISA and RT-PCR. In the ELISA test, the prevalence rate was 37.63% (95% CI: 29.19-46.89); in contrast, 60.02% (95% CI: 10.19-95.21) prevalence rate was found in RT-PCR technique. However, the *P*-value for the test of subgroup difference between ELISA and RT-PCR was 0.49. In addition, the heterogeneity of ELISA technique was, I^2 = 100%, tau^2 = 1.3847, Q=9651.52 and $P < 0.01$; and RT-PCR technique was, I^2 = 99%, tau^2 = 5.1739, Q=288.31 and $P < 0.01$. However, we found considerable heterogeneity (I^2 = 100%, tau^2 = 1.7099 and $P < 0.01$) between the ELISA and RT-PCR (Figure 8).

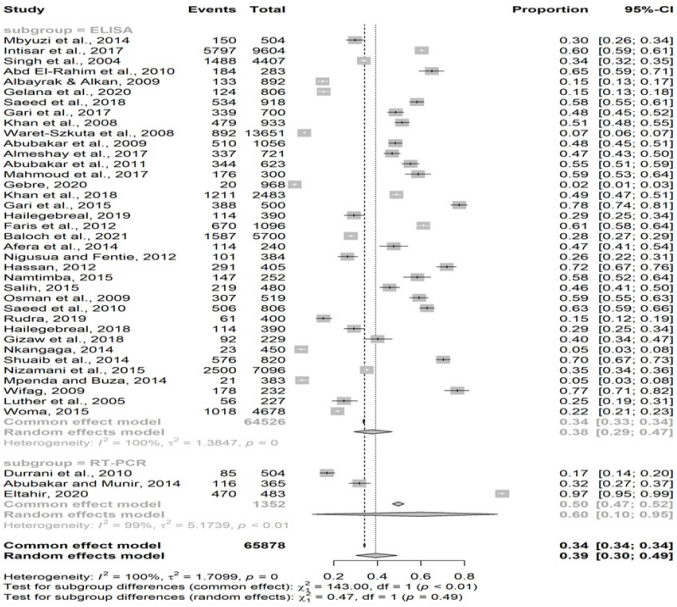

Figure 8: *The forest plot demonstrates the prevalence of PPR according to different diagnostic test methods.*

Table 2: *Potential risk factors of PPR in sheep and goat.*

Variable	Sub group	No. of studies	Sample size	Prevalence (95% CI)	P value	Heterogeneity		LRT test (P value)	Walt test (P value)
						Q-value	I^2 (%)		
Study period	2000-2010	15	35494	42.05 (30.06-55.06)	0.63	6951.38	100%	<0.01	<0.01
	2011-2021	25	30384	37.44 (25.28-51.43)		2854.94	99%		
Species	Goat	39	46092	40.11 (30.24-50.85)	0.73	6215.91	99%	<0.01	<0.01
	Sheep	28	19686	42.91 (31.47-55.17)		1849.95	99%		
Sex	Male	19	6732	28.61 (20.59-38.26)	0.64	401.02	96%	<0.01	<0.01
	Female	19	15713	32.32 (21.12-45.99)		1777.05	99%		
Age	Young	21	8695	24.74 (14.01-39.88)	0.08	1063.90	98%	<0.01	<0.01
	Old	21	19402	41.23 (30.38-53.01)		1933.71	99%		
Sample size	500 or below	18	6393	43.63 (27.99-60.65)	0.44	1241.18	99%	<0.01	<0.01
	Above 500	22	59485	35.70 (25.72-47.10)		8631.58	100%		

Besides, between the male and female, we got the higher prevalence rate in female individuals i.e. 32.32% (95% CI: 21.12-45.99). In contrast, the incidence rate was 28.61% (95% CI: 20.59-38.26) in male individuals. However, the *P*-value for the test of subgroup difference between male and female was 0.64. Moreover, the summary of the statistics was (I^2=99%, Q=1777.05 and $P < 0.01$) for female, (I^2=96%, Q=401.02 and $P < 0.01$) for male (Table 2).

Furthermore, we categorized young and old animals under the age group, where the prevalence rate was 24.74% (95% CI: 14.01-39.88) in young animal. Likewise, 41.23% prevalence rate was identified within old animals (95% CI: 30.38-53.01). However, the *P*-value for the test of subgroup difference between young and old was 0.08. Moreover, the summary of the statistics was (I^2=98%, Q=1063.90 and $P < 0.01$) for young, (I^2=99%, Q=1933.71and $P < 0.01$) for old (Table 2).

Next, we categorized the sample size into two groups, including 500 or below 500 samples and above 500 samples. For the sample size below or equal 500, we got the 43.63% (95% CI: 27.99-60.65) prevalence rate, meanwhile, 35.70% prevalence rate was found within the subgroup limited to above 500 samples (95% CI: 25.72-47.10). However, the *P*-value for the test of subgroup difference between 500 or below 500 samples and above 500 samples was 0.44. Moreover, the summary of the statistics was (I^2=100%, Q=1241.18 and $P < 0.01$) for 500 or below 500 samples size, (I^2=99%, Q=8631.58 and $P < 0.01$) for above 500 samples size (Table 2).

Peste des petits ruminants (PPR) remain a persistent menace, leading to significant mortality rates among sheep and goat species. This highly contagious viral disease poses an ongoing challenge to the livelihood of small-scale farmers throughout many regions in Africa, the Middle East, and Asia (Yizengaw *et al.*, 2021). Having access to comprehensive and aggregated data on a particular disease and its associated risk factors is of utmost importance when formulating effective mitigation strategies for policymakers. Meta-analysis serves as the most suitable approach for obtaining pooled data from individual studies (Mia *et al.*, 2021). Relevant meta-analysis findings hold significance in the treatment and control of infectious diseases like PPR, as they provide insights that are impossible to determine just from individual investigations (Dohoo *et al.*, 2009). Therefore, the current study evaluates the global prevalence of PPR and its potential risk factors. According to the best of the author's knowledge, this is the first quantitative meta-analysis on the sero-prevalence as well as risk factors of PPR in sheep and goats worldwide from 2000 to 2021.

Our findings noted that 39.16% (95% CI: 30.00-49.16) of the sheep and goat populations are affected by PPR worldwide. In addition, among the countries there is a significant difference. In contrast, Sowjanya *et al.* (2021) reported that the overall pooled prevalence of PPR is 24% (95% CI: 15-33), with 30% in Asia (95% CI: 14-49) and 20% in Africa (95% CI: 11-30) in large ruminants (bovine and camel) and wildlife. However, Yizengaw *et al.* (2021) reported that the sero-prevalence of PPR in small ruminant was 27.71% (95 % CI: 21.46 - 33.96) in Ethiopia. This heterogeneity is due to the location of PPRV, methods used to identify the disease, sample origin, sampling approach, stage of infection, research duration, animal species, and sample size. The variation in sero-prevalence may be ascribed to ecological attributes of a particular region, including factors such as climate, settlement patterns, sanitary conditions, and socio-economic activities (Yizengaw *et al.*, 2021).

African countries showed a greater disease prevalence than Asian countries, with an approximated pooled prevalence of 39.46% (95% CI: 37.23%-41.69%) for PPR in sheep and goats, as reported by Ahaduzzaman (2020). PPR has historically been recorded more frequently in nations in Africa and Asia, however it has lately been observed in European ruminant populations (Parida *et al.*, 2016). The high prevalence of PPR in sheep and goats can be attributed to several factors. These include the transboundary movement of infected animals without sufficient quarantine measures, the existence of hot and humid climatic conditions that facilitate disease transmission, inadequate vaccination coverage and monitoring, limited awareness about PPR among small-scale farmers, and insufficient funding for disease control programs in developing or underdeveloped nations (Ahaduzzaman, 2020).

In the subgroup analysis, we analyzed our findings based on the studies year and found 42.05% prevalence rate in between 2000–2010, which is higher than the year 2011 to 2021 (37.44%). Showing the results in the case of study period, it states that the pooled

prevalence decreased 5% on non-significantly in the last 10 years (2011–2021). This may be due to the PPR vaccine as a control measure in recent days.

Our current study analyzed the species-wise prevalence and found that 40.11% in the goat population and 42.91% in the sheep population (Table 2). The estimated pooled sero-prevalence indicated that PPR varies significantly between species and higher in sheep than goats. This report is similar with other several studies (Abubakar *et al*., 2009; El-Yuguda *et al*., 2009; Enan *et al*., 2013; Gelana *et al*., 2020) and disagreed with reports that indicated PPR is more prevalent in goat than sheep (Fentie *et al*., 2018; Faris *et al*., 2012). Although sheep and goats have biological differences, increased sero-prevalence in one species than other may be caused by sampling procedures, animal abundance or distribution in a given area, management techniques, and viral strains, among other things (Yizengaw *et al*., 2021). PPRV may also preferentially infect goats over sheep, or vice versa, depending on the environment, and illness severity may differ between species (Truong *et al*., 2014).

In sex-wise subgroups, we found a non-significant higher prevalence rate in female individuals (32.32%) than male (28.61%). This could be because breeding females are used for flock reproductive maintenance for a longer period than males. Other contributing factors could include a larger density of females in flocks than males, or physiological differences between females and males (e.g. females endure some stress because of production as well as reproduction (Ahaduzzaman, 2020). This study's findings correspond with previous studies (El-Yuguda *et al*., 2013; Farougou *et al*., 2013; Mahamat *et al*., 2018). This research strongly contradicts Rony *et al*. (2017), who suggested a higher prevalence of the condition in males. They attributed this disparity to a potential overrepresentation of male animals in a flock, particularly among those aged less than two years. The increased demand for male animals for meat production has led to their frequent presence in markets, resulting in a higher infection rate compared to female animals that are primarily kept at home for breeding purposes. This discrepancy in infection rates can also be attributed to genetic variations among the animals (Rony *et al*., 2017).

In age groups, the present study declared that old have higher prevalence than young but there is no significant difference between young and old individuals. We found a 24.74% prevalence rate among young animals and 41.23% amongst old animals. In contrast, Yizengaw *et al*. (2021) mentioned that PPR was significantly higher in young animals (36.53%) than in adults (23.12%) and old (8.08%). According to Bari *et al*. (2018) and Kihu *et al*. (2015), the higher prevalence of the disease in young animals compared to older animals may be attributable to malnutrition, a less developed immune system, and inadequate husbandry techniques. Our finding agrees with the results of many studies (Ahaduzzaman, 2020; Abubakar *et al*., 2009, 2011, 2017; Acharya *et al*., 2018; Gari *et al*., 2017), where based on estimated pooled prevalence PPR was higher in adult animals than in young animals. The greater prevalence in adults may be brought about by elements including the increased risk of older animals contracting PPRV due to virus circulation, adult animals' propensity to age, and the deterioration of maternally produced antibodies in older animals. According to reports, PPRV is highly immunogenic and persists in animals' bodies for a long time, especially in areas where it is endemic (Acharya *et al*., 2018). In the case of sample size, we found a higher prevalence rate (43.63%) for 500 or below 500 sample size than above 500 sample sizes (35.70%). However, there is no significant difference between 500 or below 500 samples and above 500 samples.

Finally, we categorized the different test procedures for analyzing the prevalence rate and we found a higher prevalence rate in RT-PCR (60.02%) than ELISA technique (37.63%). Because PCR is more sensitive than other approaches, the prevalence is typically significantly greater where the PCR-based method is employed for detection (Ahaduzzaman, 2020).

The prevalence statistics in this report varied depending on where the sample came from and how long the study was. The disease was more common in animals that came from slaughterhouses and fields and in animals that stayed in mixed flocks. This could be because there are more sick animals in abattoirs (because lots of farmers sell animals for slaughter during outbreaks) or because animals in abattoirs come from different areas and farms. It could also be because serology was used in most mixed flock and farm-based studies (Rashid *et al*., 2008). Another possible cause is the spread of PPRV from sheep

to goats, or the virus's survival in mixed flocks (Gari *et al*., 2017). Studies that lasted less than six months revealed a higher prevalence, which may be attributable to a different study design. A substantial proof of publication bias was found in Egger's tests utilizing a linear regression method and funnel plots asymmetry. However, real heterogeneity, location, data irregularity, and artifacts, or even chance, may all contribute to the origin of funnel plot asymmetry (Egger *et al*., 1997).

Study limitations

There are a few limitations to consider in this study. There is a lack of reports on the prevalence of PPR in sheep and goats outside of Africa and Asia in the search range. Therefore, no prevalence data could be obtained from these regions. Furthermore, the article eliminated non-English literature, unpublished articles, retrospective perspectives, technique validation articles, experimental trial findings, and case studies. Furthermore, the genotype/sequencing data utilized for identifying countries with endemic PPR or PPR outbreaks have revealed the widespread prevalence of PPRV in numerous countries worldwide. However, due to the absence of prevalence data, it was not feasible to incorporate them into this study. Finally, heterogeneity in models was significant, suggesting that other factors that were not considered might have had substantial effects.

Conclusions and Recommendations

To summarize, we found a 39.16 % prevalence rate of PPR in small ruminants. The pooled prevalence rate of PPR is high even though a higher degree of variability was observed among studies, among countries, and associated risk factors. The disease is more prevalent in sheep than goats whereas susceptibility is higher in old animals than young. In addition, we found a non-significant higher prevalence rate in female individuals than male. Besides, the occurrence of PPR is mainly in the Asia and African region but the pooled prevalence is decreased 5% on non-significantly in the last 10 years (2011–2021). Furthermore, in the case of diagnosis of PPR we found a higher prevalence rate in RT-PCR than ELISA technique. Based on these results, it is recommended that in areas where PPR is prevalent, screening tests for the disease be performed routinely on sheep and goat flocks. This would help stop the spread of the disease and make the animals more productive.

Novelty Statement

PPR is a prevalent viral disease of small ruminants worldwide. Although some scholar reviews of PPR, there has been no comprehensive meta-analysis on prevalence estimation of PPR up to recent years in global perspectives. In this paper, we evaluate through a meta-analytic approach to estimate prevalence and identify the specific risk factors of PPR of sheep and goat up to recent years in global perspectives.

Author's Contribution

Apurbo Kumar Mondal, Md Rabiul Auwul, Md. Sodrul Islam: Conceptualized the study, formulated the methodology, analyzed, and interpreted the data, wrote the manuscript.
Md. Momotaj Hossen: Extracted the data and wrote the manuscript.
Narayan Paudyal, Md. Shahidul Islam, Kazi Khalid Ibne Khalil: Added additional information and involved in revision. All authors approved the final version of manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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