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# Serosurveillance and Risk Factors of Peste des Petits Ruminants in Sheep and Goats in Giza Governorate, Egypt

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**Abstract**

PESTE DES PETITS Ruminants (PPR) remains a major threat to small ruminants health and productivity in Egypt. A cross-sectional serological survey was conducted in Giza Governorate from May 2014 to July 2015 to estimate PPR prevalence and assess the associated risk factors. A total of 316 randomly selected animals (200 sheep, 116 goats) were sampled and tested using virus neutralization test (VNT) and competitive ELISA (c-ELISA). The overall seroprevalence was 67.4% (95% CI: 62.2–69.9) by VNT and 65.3% (95% CI: 62.6–68.0) by c-ELISA. Prevalence was higher in sheep than goats, though differences were not statistically significant. Risk factor analysis, based on structured questionnaires, was performed using Chi-square tests followed by multivariate logistic regression. Two factors were significantly associated with seropositivity: regular introduction of new animals without quarantine ($p = 0.041$) and animal migration ($p = 0.004$). These findings indicate high PPR exposure in small ruminant populations in Giza, likely due to ongoing or past circulation of the virus. Strengthened biosecurity measures, including a minimum two-week quarantine for newly introduced animals, are recommended to reduce transmission risk.

**Keywords:** PPR seroprevalence, small ruminants, VNT, c- ELISA, risk factors.

## Introduction

Peste des petits ruminants (PPR) is a notifiable, Class A transboundary viral disease with high mortality, primarily affecting sheep and goats. It causes substantial socioeconomic losses and poses a significant threat to the global food security. The etiological agent, PPR virus (PPRV), is a member of the genus Morbillivirus within the family Paramyxoviridae and is genetically classified into four distinct lineages (I–IV), which are immunologically identical [1]. The Food and Agriculture Organization of the United Nations (FAO) and the World Organisation for Animal Health (WOAH) have designated PPR as a target for global eradication by 2030 [2]. Under the Global Framework for the Progressive Control of Transboundary Animal Diseases (GF-TADs), the Global Control and Eradication Strategy (GCES) was adopted for a stepwise eradication protocol. This stepwise approach uses the PPR Monitoring and Assessment Tool (PMAT) to classify countries into progressive control stages (below Stage 1, Stages 1–4, and WOAH-free status) based on key criteria, including diagnostic capacity, surveillance systems, legal frameworks, and stakeholder engagement [3]. Effective control of PPR relies on accurate and timely diagnosis, alongside mass vaccination strategies using live attenuated vaccines such as Nigeria 75/1 and Sungri 96, both of which confer lifelong immunity against all currently known strains.[3].

Surveillance policies typically employ serological monitoring via competitive enzyme-linked immunosorbent assay (cELISA) and virus neutralization test (VNT) [4]. A competitive screening ELISA kit ID Screen® PPR kit (ID vet Innovative Diagnostics) is produced from the CIRAD reference labs and validated with high sensitivity and specificity [5], [6]. This competitive ELISA protocol is based on the immobilization of a highly purified PPR antigen on the ELISA plate. ID screen® PPR competition kit uses N protein coated

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ELISA plates to determine the antibody response in immune animals while other commercially available kits use H protein for the same purpose [7].

PPR was first reported in Egypt in 1987, and inadequate vaccination coverage has since allowed recurrent outbreaks, particularly in rural sheep and goat populations [8]. Genetic characterization of the circulating virus revealed that it belongs to lineage IV with close relationship to other viruses circulating in Asia and the Middle East [9] [10]. All Egyptian PPR GenBank submissions are closely related to those from Eritrea, Ethiopia, Sudan and Tunisia [11]. The prevalence of PPR was 53% as estimated in [12]. A locally produced vaccine is available in Egypt [13]. There are several risk factors associated with PPR infection on animal and herd basis that include animal`s age (3-18 months), sex, climatic condition, species and the management system. These factors are critical in terms of feasible control and eradication progressive strategies implementation [14], [15].

The present study aims to perform both descriptive and analytical cross-sectional investigations to determine the period seroprevalence of PPR in sheep and goats in Giza Governorate (May 2014–July 2015) and to identify animal- and management-related risk factors associated with infection.

## Material and Methods

*Study area description*

The study was carried out in Giza governorate. Giza is in the latitude of 30.013056, and the longitude of 31.208853. The total area of the governorate is 1579.75 km2, representing about 1.3% of Egypt. The governorate is divided into 18 cities and 13 counties and neighborhoods. The total population of small ruminant in Giza governorate is about 98217 heads according to the report of the Egyptian general organization of Veterinary services for the year 2013.

*Study animals*

These animals were subdivided according to their species, age and sex as shown in table (1) and according to their location in Giza governorate as shown in table (2).

*Study design*

A group included 316 apparently healthy animals (200 sheep and 116 goats) were subjected to a seroprevalence cross sectional study of PPR in Giza governorate. The study had 2 flavours: descriptive and analytical as described by [16].

*Sampling size determination*

The target population in this study was all sheep and goats in Giza governorate with this inclusion criteria; age: more than 5 months old and not vaccinated against PPR.

Animals that fulfill these criteria were sampled and referred to as 'The study population' with the following sample size calculation scheme. Sample size calculation formula for stratified sampling method was used as reported in [16].

$$n = \frac{Z^2 \cdot P(1-P)}{d^2}$$

As; n = required sample size, P (exp) = expected prevalence, d = desired absolute precision and 3.8 is the multiplier for a confidence level 95 %.

By choosing 95% confidence level, 5 % desired absolute precision and 29% expected prevalence which obtained from the results of PPR serosurveillance in Egypt which was carried out by Egyptian general organization of veterinary services (https://www.egy-vet-synd.org/en/general-authority-for-veterinary-services).

A stratified random sampling approach was employed as in [16] by dividing the study population into mutually exclusive subgroups (strata), followed by random selection of sampling units from each stratum. The number of units selected per stratum was determined using proportional allocation, whereby the sampling fraction reflects the proportion of the population within each stratum. In this study, geographical stratification was applied by dividing Giza Governorate into ten main geographic strata. The sample size was calculated separately for each stratum. The overall sampling fraction was determined by dividing the total sample size by the estimated population of sheep and goats in Giza Governorate, as reported by the Egyptian General Organization of Veterinary Services.Then the sampling fraction was multiplied by the estimated sheep and goats count in each stratum individually as shown in table (3)

The sample size for each stratum was equally distributed among the main areas and their respective villages, as illustrated in Figure 1b. Within each main area or village, a sampling frame consisting of the available sampling units (shepherds) was constructed. Subsequently, sampling units were selected from the frame using a simple random sampling method. Finally, one animal was selected from each participating shepherd.

Auwseem center (required sample size; 16 samples) was divided into 5 main villages and areas which including; Auwseem village (4 samples), El-Kom EL- Ahmr (3 samples), Bortos (3 samples), Baragel (3 samples) and Bashtel (3 samples).

In case of only one sample to be obtained from an area, the first shepherd that was seen at the entrance

of this area was selected to be included in the sampling.

*Questionnaire*

Data related to owners (name and telephone number if possible), animals (locality, species, sex and age) and management factors (flock size, rearing mixed species in the flock, migratory or fixed flock, vaccination and veterinary supervision, introduction of new animals and quarantine) were obtained and recorded in a closed format questionnaire as recommended by [16].

*Sampling process*

Blood samples were collected from jugular veins on plain tubes (5mL) then kept overnight in +4°C for serum separation. The tubes were then centrifuged at 3000 rpm for 10 minutes. Serum was collected, kept at -20°C then used for cELISA and VNT testing afterwords.

*Laboratory testing*

*Competitive ELISA (ID vet PPR competition kit).*

It was carried out for detection of PPRV antibodies in serum samples according to [14]**.** Briefly**,** all reagents stored in the refrigerator were first equilibrated to room temperature (15–21 °C). Each well of the microplate was then filled with 25 µL of dilution buffer 13 solution. Following the designated plate layout, 25 µL of the positive control, negative control, and serum samples were added to their corresponding wells. The microplate was sealed with an adhesive cover and incubated at 37 °C for 45 minutes. After incubation, the wells were washed using 300 µL of wash solution and dried by tapping onto a towel. Subsequently, 100 µL of conjugate solution was dispensed into each well, and the plate was incubated at 21 °C for 30 minutes, followed by a second wash step. After washing, 100 µL of substrate solution was added to each well, and the plate was incubated at room temperature for 15 minutes. The enzymatic reaction was then terminated by the addition of a stop solution. The optical density (OD) of each sample was measured at 450 nm using an ELx800 Absorbance Microplate Reader (BioTek® Instruments, Inc., USA). The sample-to-negative control competition percentage (S/N%) was automatically calculated using Gen 5™ 3.04 software. Samples with an S/N% $\leq$ 50% were interpreted as positive, those with an S/N% > 60% as negative, and values between 50% and 60% were considered doubtful.

*Virus neutralization test (VNT)*

The procedure was conducted according to [17].

Serum samples were heat-inactivated in a water bath at 56 °C for 30 minutes to eliminate nonspecific viral inhibitors. In a microtiter plate, Two-fold serial serum dilutions were prepared up to a 1:8 dilutions. One column was kept as a virus control, and another as a cell control.

Twenty-five microliters of PPRV at 100 $TCID_{50}$/mL (Nigerian strain 75/1) were added to each well. The serum-virus mixtures were incubated at 37 °C in a $CO_2$ incubator for 1 hour. After incubation, 150 µL of growth medium containing $1\times10^5$ cells/mL were added to all wells.

The test included appropriate positive serum, virus, and cell controls. The plates were incubated at 37 °C in a 5% $CO_2$ incubator and observed daily under an inverted tissue culture microscope for 7–10 days to monitor cytopathic effect (CPE). The antibody titer was determined as the reciprocal of the highest serum dilution that completely neutralized 100 $TCID_{50}$ of PPRV, as evidenced by the absence of CPE.

*Statistical analysis of the data*

Data on potential risk factors were collected using a structured, closed-format questionnaire through direct interviews with flock owners. Responses were entered into SPSS software (version 11.5; IBM Corp., Armonk, NY, USA) for analysis. The association between PPR seropositivity and individual risk factors was first assessed using univariate Chi-square tests. Variables showing a p-value $\leq 0.20$ in univariate analysis were subsequently entered into a multivariate logistic regression model to control for potential confounding effects. Odds ratios (OR) and 95% confidence intervals (CI) were calculated. A p-value $\leq 0.05$ was considered statistically significant. The analytical approach followed the methodology recommended by [7].

*Ethical approval*

No experimental infections were performed in this study. All samples were collected from naturally exposed animals as part of the routine governmental PPR surveillance program conducted in Giza Governorate, Egypt. In accordance with national veterinary guidelines, such surveillance activities do not require separate institutional ethical approval. Animal handling and sample collection were performed by authorized veterinary staff following standard welfare protocols to minimize stress and discomfort. The purpose of sampling was explained to the flock owners, and oral informed consent was obtained prior to sample collection.

## Results

The overall seroprevalence of PPRV as determined by c- ELISA and VNT in shown in table (4) where the seroprevalence shown in cELISA is 62% and 67.4% in VNT test.

*Correction of the estimated PPR seroprevalence*

The c-ELISA is considered an imperfect test (sensitivity 94.5% and specificity 99.4% as

compared with the gold standard VNT) so that, the estimated prevalence could be corrected by the equation given by [16] as follow:

$$\text{True Prevalence} = \frac{\textit{estimatedPrevalence} + \textit{specificity};100}{\text{sensitivity} + \text{specificity};100}$$

True prevalence = 62+99.4;100/ (94.5+99.4;100) = 65.3 % (95% CI, 62.6%-68%).

The results of titration of serum samples for PPRV specific neutralizing antibodies (quantitative VNT) as shown in table (5). The age susceptibility is shown in table (6) in comparison between sheep and goats.

*Results of the analytical study were shown in tables (9,10)*

*Univariate analysis*

It is shown that locality, species, sex , age , flock type and regular introduction of new animals make statistically significant difference in PPR susceptibility as shown in Table (9).

*Multivariate analysis*

Table (10) presents the results of the multivariate logistic regression analysis used to identify significant risk factors associated with PPR seropositivity at the individual animal level. Flock type and regular introduction of new animals showed statistically significant associations.

## Discussion

PPR in endemic in domestic and causes recurrent outbreaks in wild small ruminants in the Middle East region [18]. This study revealed a high seroprevalence of peste des petits ruminants virus (PPRV) antibodies in sheep and goats in Giza Governorate during 2014–2015, with comparable results between virus neutralization test (VNT) and competitive ELISA (cELISA). Migratory flock type and regular introduction of new animals without quarantine emerged as significant risk factors. Other factors—species, sex, age, flock size, flock composition, and veterinary supervision—were not statistically associated with seropositivity.

Our results revealed that the overall prevalence of PPR antibodies in both species were 67.4 % (95% CI, 62.2%-69.9%) and 65.3 % (95% CI, 62.6%-68%) as determined by VNT and cELISA, respectively, these results agree with the results obtained by [14] who concluded that the higher level of PPR seroprevalence obtained in these studies may be attributed to lack of quarantine, communal grazing and misdiagnosis.

In our study, the study population was defined as sheep and goats in Giza governorate that were older than 5 months to avoid confusion with maternal antibodies which last for 4 to 5 months of age as suggested by [14].

VNT is the gold standard test for detection of PPR antibodies as reported in [19, 20] while cELISA has good correlation with VNT (R=0.94), the specificity and sensitivity are 99.4% and 94.5%, respectively, when compared with VNT as concluded by [21], [22, 23]. As the cELISA can overcome the disadvantages of VNT and in the same time has a good correlation with the gold standard, many researchers recommended substitution of VNT by cELISA in epidemiological studies.

An analytical study for testing a hypothesis about association between seropositivity and risk factor, Another goal of our survey was to study a causal association between individual animal`s PPR seropositivity and some selected risk factors related to the animal (species, sex and age) and those related to management (flock size, species composition of flocks, migratory or fixed flocks, the practice of regular introduction of new animals and veterinary supervision).

Cross sectional studies are not efficient as cohort studies in such causal association studies due to the problem of time consequence (the Cause must precedes the risk) which is one of the Hill's criteria for causal association as in cross sectional studies the disease and risk factors are investigated at the same time without confirmation which of them occurred firstly as given by [16]

The problem of time consequence in cross sectional studies was discussed by [24] who noted that this problem could be overcame by selecting a time independent risk factors (factors are not changed with time such as species, breed and sex of animal and some fixed and regular management factors), This approach was used in our study.

In our study, data regarding the risk factors investigated were obtained in the field by personal interviewing questionnaire (closed format). Personal interviewing when compared with self-completed questionnaire showing that the most important advantage of personal interviewing questionnaire is overcoming the illiteracy of most of the respondents over. Closed format questionnaire have the advantages of saving time and the easy by which the data can be collected and processed over the opened format questionnaire as stated by [16]

The causal association in our study was tested by two levels of statistical analysis, the first one was the univariate analysis by chi square test and all risk factors with significant effect (P-value less than 0.05) were introduced to the second level which was the

multivariate analysis by logistic regression technique so that the confounders could be excluded.

Studying the species susceptibility to PPRV infection, our results showed that the species-wise seroprevalences were 71 % and 68 % in sheep as determined by VNT and cELISA, respectively, while they were 61% and 51.7% in goats as determined by VNT and cELISA, respectively which indicated a higher infection rate in sheep than in goats but upon statistical analysis this difference was found to be non-significant (p value< 0.05) and so that this difference was obtained by chance, these results disagree with the results obtained by [25] who concluded that sheep have higher seropositivity than goats which explained by that sheep take the mild form of the disease and have a higher survival rate than goats so that can be easily catched by these surveys, also our results disagree with the results obtained by [26] who concluded that goats have higher seropositivity than sheep which explained by that goats are more susceptible to PPR than sheep; however, all these studies not mentioned information about the statistical analysis of such data except for [26] therefore this comparison may be unequivocal.

Studying the sex susceptibility to PPR infection in sheep and goats, our obtained results showed that the sex-wise seroprevalences in sheep were 71.6% and 70.6 % in males and females, respectively, as determined by VNT and 67.7 % and 68.2 % in males and females, respectively, as determined by c-ELISA, while, the sex-wise seroprevalence in goats were 84.2 % and 56.7 % in males and females, respectively, as determined by VNT and 72.2% and 51% in males and females, respectively, as determined by c-ELISA but the differences between males and females of sheep and goats obtained by our survey was found to be statistically non-significant, these results disagree with the results obtained by [27] who found that females were at higher risk than males for PPR seropositivity which may be attributed to the longer period for keeping females in flock than males as they are sold at younger age for meat. [28]mentioned that there is no biological plausibility for this difference. Our results agrees with the results obtained by [26] who concluded that sex has statistically non- significant effect on PPR seropositivity in goats in Tanzania.

Studying the age susceptibility to PPR infection in sheep and goats, Our results showed that the age-wise seroprevalences in sheep were 70.2%, 85.5%, 64.2%, 100% and 65.3 % in age groups (age in months) ≤15, <15 to ≤ 21, <21 to ≤ 27, <27 to ≤ 33 and <33, respectively, as determined by VNT and 63.5%, 68.5%, 71.4%, 100% and 70.6% in age groups (age in months) ≤15, <15 to ≤ 21, <21 to ≤ 27, <27 to ≤ 33 and <33, respectively, as determined by c-ELISA, while, the age-wise seroprevalences in goats were 61.3%, 80%, 33.3%, a and 61.1% in age groups (age in months) ≤15, <15 to ≤ 21, <21 to ≤ 27, <27 to ≤ 33 and <33, respectively, as determined by VNT and 53.8%, 40%, 83%, 100% and 48.8% in age groups (age in months) ≤15, <15 to ≤ 21, <21 to ≤ 27, <27 to ≤ 33 and <33, respectively, as determined by c-ELISA also the effect of age on PPR seropositivity was found to be statistically non-significant, testing a hypothesis about the association between age as a risk factor and PPR seropositivity as a risk in serological surveys is not logically because of the long duration of PPR specific antibodies following the natural infection (solid immunity) as mentioned by [12] so that we cannot determine whether these positive results were due to recent natural infection (related to the season during which these samples were collected) or due to old natural infection (not related to the season during which these samples were collected). This problem was previously discussed by [27].

Studying the effect of animals' species composition of flocks on PPRV infection in sheep and goats, our results showed that the flock composition had statistically non-significant effect on PPR seropositivity, these results disagree with the results obtained by [29] who concluded that Mixed raising of sheep and goats was identified as a risk factor for PPR seropositivity in sheep flocks in Jordan which attributed to that goats are known to be more sensitive to PPRV and therefore having goats in a sheep farm setting increase the PPR transmission possibility from goats to sheep.

Studying the effect of flock size on PPRV infection in sheep and goats, our results showed that flock size had statistically non-significant effect on PPR seropositivity, these results disagree with who found that large flock size has a significant effect on PPR seropositivity for both sheep and goats, their finding could be explained by the contagious nature of PPRV which required a close contact between animals for efficient transmission and this is facilitated by keeping large number of animals in one flock. Also there was a difference in designing the questionnaire between our study in view of the classification of sheep flocks according to their size as in our study the flocks were categorized by the following orders (less than 25 head, 25 to 51 heads, 51 to 100 heads and more than 100 heads) while [29] categorized the sheep flock sizes in their questionnaire in the following orders (50-100 heads, 101-200 heads and more than 200 heads) this difference may affected the comparing and interpretation of these results.

Studying the effect of absence of veterinary supervision on PPRV infection in sheep and goats, our results showed that the effect of absence of regular veterinary services on PPR seropositivity was statistically non-significant, these results agree with [27] who concluded that absence of regular veterinary supervision not included as a risk factor for PPR seropositivity. Our results disagree with the

results obtained by [29] who concluded that lacking of proper veterinary services and adequate infrastructure in the local live animal markets in Jordan may facilitate disease transmission.

Studying the effect of flock type on PPRV infection in sheep and goats, our results revealed that flock type (migratory versus non migratory) was identified by multivariate analysis as a risk factor for PPR seropositivity with P- value=0.0037 and OR 2.173 as shown in **table (10)** which meant that migratory flock were 2 times more at risk of acquiring PPR than fixed flock and this is attributed to many factors such as the migratory flocks have a higher chance for contact with other flocks which may carry the infection and contaminate the pasture during communal grazing or feeding on garbage, also migratory flocks are usually exposed to stress due to movement for long distances searching for feed, These results agree with the results obtained by [29] who concluded that migration of sheep and goats increased their susceptibility to PPR infection. Studying the effect of regular introduction of new animals on PPRV infection in sheep and goats, our results showed that regular introduction of new animals was also identified as a factor (statistically significant with P- value= 0.04 and OR 1.78) as introduction of new animals without quarantine is considered as a major way through which many diseases could be introduced to the susceptible healthy flocks by those animals which are in the incubation period (incubatory carrier was confirmed in PPR by several researchers [17],[30].

## Conclusion

The seropositivity of PPRV was found to be high in sheep and goats in Giza governorate in the period from May 2014 to July 2015 (period prevalence) but this finding was obtained by indirect method (serology) and for more appropriate conclusion, an active surveillance should be conducted and maintained by veterinary authorities to detect if this high seroprevalence due to old infection or due to recent activities of the virus in this area.

We recommended that the regular introduction of new animals into any stock should be preceded by at least 2 weeks period of quarantine and the veterinary authorities should take appropriate step in raising the awareness among farmers and shepherds about the risk of feeding their animals on garbage and contact with other flocks even if they appeared healthy.

It was found that the period just before or after Al-Adha festival is a suitable time for the spreading of many diseases among animals including PPR (descriptive epidemiology) so that such field observations should be tested by other analytical studies for confirmation of this hypothesis and we recommended that the veterinary authorities should control the animals‟ movement and animals markets during this period to reduce the incidence of many diseases. Finally, we recommend the presence of continuous disease-information systems such as surveillance and surveys, Application of an effective control system and eeffective use of living attenuated vaccines.

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*Declaration of Conflict of Interest*

The authors declare that there is no conflict of interest.

*Ethical of approval*

Not applied.

**TABLE 1. Subdivision of animals according to species, sex and age.**

| Species | Sex | Age in months | | | | |
|---|---|---|---|---|---|---|
| | | **<15** | **<15 to <21** | **<21 to<27** | **<27 to <33** | **> 33** |
| **Sheep n=200** | Males (n=74) | n=37 | n=24 | n=4 | n=0 | n=9 |
| | Females(n=126) | n=37 | n=11 | n=10 | n=2 | n=66 |
| **Goats n=116** | Males (n=19) | n= 7 | n=2 | n=1 | n=0 | n=9 |
| | Females (n=97) | n= 9 | n=3 | n=5 | n=2 | n=78 |

**TABLE 2. Subdivision of animals according to their location in Giza governorate, Egypt.**

| Locality | Species | Age in months | | | | |
|---|---|---|---|---|---|---|
| | | **<15** | **<15-<21** | **<21-<27** | **<27-<33** | **> 33** |
| **Werdan n= 26** | Sheep (n= 26) | n=3 | n=18 | n=3 | n=0 | n=2 |
| | Goats (n= 0) | n=0 | n=0 | n=0 | n=0 | n=0 |
| **El-Mansoria n= 25** | Sheep (n= 20) | n=5 | n=3 | n=0 | n=0 | n=12 |
| | Goats (n= 5) | n=3 | n=1 | n=1 | n=0 | n=0 |
| **Auseem n=16** | Sheep (n= 15) | n=5 | n=1 | n=0 | n=0 | n=9 |
| | Goats (n= 1) | n=0 | n=0 | n=1 | n=0 | n=0 |
| **Kerdasa n=20** | Sheep (n= 20) | n=12 | n=2 | n=2 | n=1 | n=3 |
| | Goats (n= 0) | n=0 | n=0 | n=0 | n=0 | n=0 |
| **Giza n=26** | Sheep (n= 20) | n=13 | n=2 | n=0 | n=0 | n=5 |
| | Goats (n= 6) | n=2 | n=1 | n=1 | n=0 | n=2 |
| **Abo Nomros n=15** | Sheep (n= 14) | n=5 | n=0 | n=2 | n=0 | n=7 |
| | Goats (n= 1) | n=1 | n=0 | n=0 | n=0 | n=0 |
| **Badrashen n=57** | Sheep (n= 29) | n=8 | n=4 | n=4 | n=0 | n=13 |
| | Goats (n= 28) | n=8 | n=0 | n=0 | n=0 | n=20 |
| **Ayaat n=77** | Sheep (n= 33) | n=15 | n=4 | n=3 | n=1 | n=10 |
| | Goats (n= 44) | n=0 | n=2 | n=2 | n=2 | n=38 |
| **El Saff n=31** | Sheep (n= 4) | n=0 | n=0 | n=0 | n=0 | n=4 |
| | Goats (n= 27) | n=2 | n=0 | n=0 | n=0 | n=25 |
| **Atfeeh n=23** | Sheep (n= 19) | n=8 | n=1 | n=0 | n=0 | n=10 |
| | Goats (n= 4) | n=0 | n=1 | n=1 | n=0 | n=2 |

**TABLE 3. Sample size calculation for each geographic stratum in Giza governorate.**

| Location | Stratum Population * sampling fraction | Sample size |
|---|---|---|
| **Werdan** | 7900 X 0.0032172 | 26 |
| **Al-Mansoryia** | 7181 X 0.0032172 | 24 |
| **Kerdasa** | 6170 X 0.0032172 | 20 |
| **Auwseem** | 4750 X 0.0032172 | 16 |
| **Abo El Nomros** | 4210 X 0.0032172 | 15 |
| **Al Badrashen** | 18500 X 0.0032172 | 59 |
| **Atfeh** | 7400 X 0.0032172 | 23 |
| **Al Saf** | 9900 X 0.0032172 | 31 |
| **Ayaat** | 24700 X 0.0032172 | 77 |
| **Giza districts** | 8201 X 0.0032172 | 28 |
| **Total** | 98217 | 316 |

Total number of samples obtained from each geographical stratum was shown in figure (1:a).

**TABLE 4. Overall seroprevalence of PPRV as determined by c- ELISA and VNT.**

| **cELISA** | | | | **VNT** | | | |
|---|---|---|---|---|---|---|---|
| Total number of Examined serum samples | Number of Positive samples | Number of Negative samples | Overall seroprevalence | Total number of examined serum samples | Number of Positive samples | Number of Negative samples | Overall seroprevalence |
| 316 | 196 | 120 | 62 % | 316 | 213 | 103 | 67.40 % |

**TABLE 5. Subdivision of positive serum samples as determined by VNT according to neutralizing antibodies titer of PPRV.**

| | Titer of PPR antibodies | | | |
|---|---|---|---|---|
| | **undiluted** | **2** | **4** | **8** |
| **Number of samples** | 25 | 57 | 52 | 79 |
| **Percentage to total positive** | 11.73 % | 26.76 % | 24.41 % | 37.08 % |

**TABLE 6. Age susceptibility to PPRV infection in sheep and goats as determined by competitive ELISA and VNT.**

| | **cELISA** | | | | | **VNT** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Age groups (in months)** | **Positive** | **Negative** | **Total** | **Estimated age wise prevalence** | **Positive** | **Negative** | **Total** | **Age wise seroprevalence** |
| **Sheep** | ≤15 | 47 | 24 | 74 | 63.5 % | 52 | 22 | 74 | 70.2 % |
| | <15 to ≤ 21 | 24 | 11 | 35 | 68.5 % | 30 | 5 | 35 | 85.5 % |
| | <21 to ≤ 27 | 10 | 4 | 14 | 71.4 % | 9 | 5 | 14 | 64.2 % |
| | <27 to ≤ 33 | 2 | 0 | 2 | 100 % | 2 | 0 | 2 | 100 % |
| | <33 | 53 | 22 | 75 | 70.6 % | 49 | 26 | 75 | 65.3 % |
| **goats** | ≤15 | 7 | 6 | 13 | 53.8 % | 8 | 5 | 13 | 61.3 % |
| | <15 to ≤ 21 | 2 | 3 | 5 | 40 % | 4 | 1 | 5 | 80 % |
| | <21 to ≤ 27 | 5 | 1 | 6 | 83 % | 2 | 4 | 6 | 33.3 % |
| | <27 to ≤ 33 | 2 | 0 | 2 | 100 % | 2 | 0 | 2 | 100 % |
| | <33 | 44 | 46 | 90 | 48.8 % | 55 | 35 | 90 | 61.1 % |

**TABLE 7. Sex susceptibility to PPRV infection in sheep and goats as determined by competitive ELISA and VNT.**

| | | **cELISA** | | | | **VNT** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Species** | Sex | **Positive** | **Negative** | **Total** | **Estimated Sex wise seroprevalence** | **Positive** | **Negative** | **Total** | **Sex wise seroprevalence** |
| **Sheep** | males | 50 | 24 | 74 | 67.7 % | 53 | 21 | 74 | 71.62 % |
| | female | 86 | 40 | 126 | 68.2 % | 89 | 37 | 126 | 70.63 % |
| **goats** | male | 13 | 6 | 19 | 68.4 % | 16 | 3 | 19 | 84.21 % |
| | female | 47 | 50 | 97 | 48.5 % | 55 | 42 | 97 | 56.70 % |

**TABLE 8. Species susceptibility to PPRV infection in sheep and goats as determined by c-ELISA and VNT.**

| | **cELISA** | | | | **VNT** | | | |
|---|---|---|---|---|---|---|---|---|
| **Species** | **Positive** | **Negative** | **total** | **Estimated Species wise seroprevalence** | **Positive** | **Negative** | **total** | **Species wise seroprevalence** |
| **Sheep** | 136 | 51 | 200 | 68 % | 142 | 58 | 200 | 71 % |
| **Goats** | 60 | 59 | 116 | 51.7 % | 71 | 45 | 116 | 61.20 % |
| **Total** | 196 | 120 | 316 | | 213 | 103 | 316 | |

**TABLE 9. Results of a univariate model for the association between some selected potential risk factors and seropositivity.**

| Risk factors | Overall P |
|---|---|
| **Locality** | 0.0005 |
| **Species** | <.0001 |
| **Sex** | 0.0185 |
| **Age** | 0.0125 |
| **Flock size** | 0.1306 |
| **Flock composition (species)** | 0.4835 |
| **Flock type** | 0.0001 |
| **Regular veterinary supervision** | 0.1539 |
| **Regular introduction of new animals** | 0.0008 |

P: P-value, OR: odd ratio, CI: confidence interval, flock type (migratory or fixed)

**TABLE 10. Results of multivariate model for the association between selected potential risk factors and individual animal seropositivity.**

| Risk factor | Categories | Multivariate analysis | | |
|---|---|---|---|---|
| | | Overall P | OR | 95% CI |
| **Flock type** | Migratory | 0.0037 | 2.173 | 1.286-3.672 |
| | Fixed | -------- | ------- | ---------- |
| **Regular introduction of new animals** | Yes | 0.0409 | 1.781 | 1.024-3.097 |
| | No | -------- | ------- | ---------- |

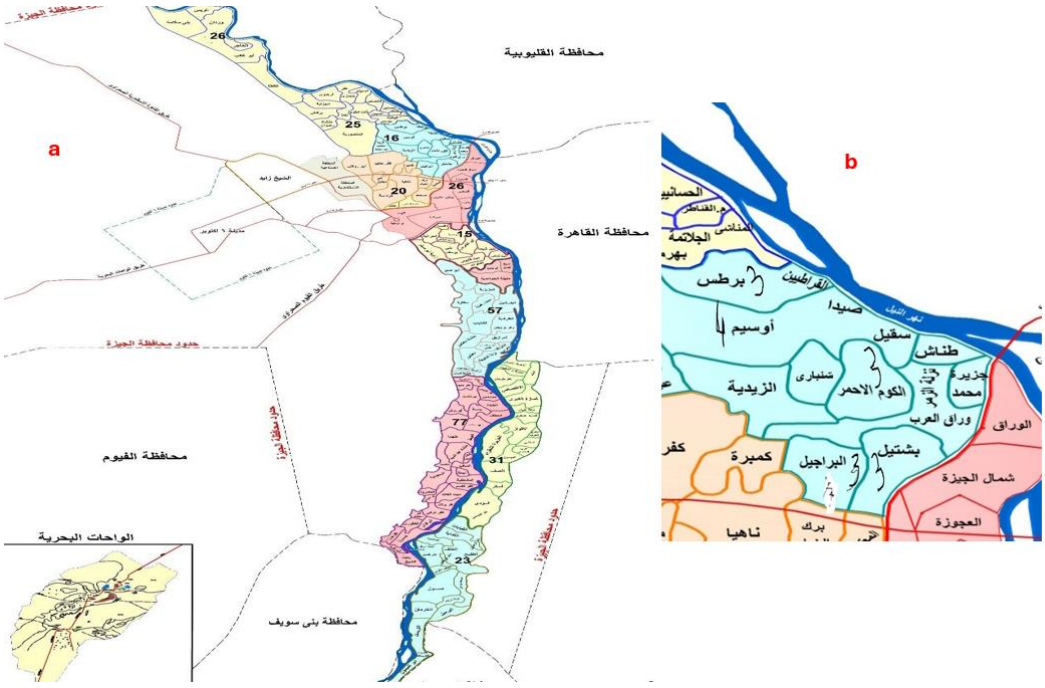


**Fig. 1. The total number of samples obtained from each geographical stratum and their classification. a, Stratification of the study area (Giza governorate) into 10 main geographical strata with proportional sampling from each stratum. b, The total required sample size for each stratum was none proportionally (equally) divided on its main areas or villages.**

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## المراقبة المصلية وعوامل الخطورة لمرض طاعون المجترات الصغيرة في الأغنام والماعز بمحافظة الجيزة، مصر

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**الملخص**

يُعَدّ طاعون المجترات الصغيرة (PPR) تهديدًا رئيسيًا لصحة وإنتاجية المجترات الصغيرة في مصر. أُجري مسح مصلي مقطعي في محافظة الجيزة خلال الفترة من مايو 2014 إلى يوليو 2015 بهدف تقدير معدل انتشار المرض وتقييم عوامل الخطورة المرتبطة به. جُمعت عينات من إجمالي 316 حيوانًا تم اختيارها عشوائيًا (200 من الأغنام و116 من الماعز)، وفُحصت باستخدام اختبار التعادل الفيروسي (VNT) واختبار الإليزا التنافسي (c-ELISA). بلغت النسبة المصلية العامة 67.4% (95% CI: 62.2–69.9) وفق اختبار VNT، و65.3% (95% CI: 62.6–68.0) وفق اختبار c-ELISA. كان معدل الانتشار أعلى في الأغنام مقارنة بالماعز، إلا أن الفروق لم تكن ذات دلالة إحصائية. أُجري تحليل لعوامل الخطورة اعتمادًا على استبيانات مُهيكلة، باستخدام اختبار كاي-تربيع متبوعًا بالانحدار اللوجستي المتعدد. وُجد أن عاملين ارتبطا معنويًا بالإيجابية المصلية، هما: الإدخال المنتظم لحيوانات جديدة دون حجر صحي ($p = 0.041$)، والتنقّل أو الترحال الحيواني ($p = 0.004$). تشير هذه النتائج إلى ارتفاع مستوى التعرّض لفيروس طاعون المجترات الصغيرة في تجمعات الأغنام والماعز بمحافظة الجيزة، وهو ما يُرجَّح أن يكون نتيجة لانتشار نشط أو سابق للفيروس. وعليه، يُوصى بتعزيز تدابير الأمن الحيوي، بما في ذلك تطبيق حجر صحي لا يقل عن أسبوعين على الحيوانات المُدخلة حديثًا، للحد من مخاطر انتقال العدوى.

**الكلمات الدالة:** طاعون المجترات الصغيرة، المجترات الصغيرة، اختبار التعادل الفيروسي(VNT) ، الإليزا التنافسي-c) ELISA)، عوامل الخطورة.