Burden of anemia and intestinal parasites in farmers and family members and owned livestock in two geographic locations in Senegal before and during the rainy seasons

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ABSTRACT

Different environmental conditions can impact the burden of anemia and intestinal parasite infections in human and livestock populations. The objective of this study was to compare the prevalence of anemia and intestinal parasite infections in farmers, family members, and owned sheep in two geographic locations along the Senegal River in June (end of the dry season) and September (rainy season). In Diawara, the prevalence of anemia in humans was high in June (74%) and remained high in September (75%) (p = 0.91). The prevalence of intestinal parasite infections increased from 7% in June to 54% in September (p < 0.05). Anemia was associated with age (children) and sex (women) (p < 0.05); but not with a positive diagnosis of intestinal parasite infection (p = 0.73). In sheep, the prevalence of anemia increased from 43% in June to 73% in September (p < 0.05), and the prevalence of intestinal parasite infections increased from 75% in June to 100% in September (p < 0.05). A positive diagnosis of Haemonchus contortus was associated with anemia (p = 0.05) and loss of body weight (2.4 kg) (p = 0.08). In Mpal, similar anemia and parasite infection trends were observed in children and sheep. The persistent high prevalence of anemia, and the impact of the rainy season on the burden of intestinal parasite infections in farmers, family members, and owned sheep can justify a One Health approach, where Senegal’s ministries of health and of agriculture share resources for implementation and evaluation of government program efforts to reduce anemia in children and women, as well as morbidity and mortality in owned livestock; particularly in remote areas where public health services and veterinary services are very limited.

1. Introduction

In Senegal, the impact of different environmental conditions (i.e., dry season versus rainy season) on the burden of anemia and intestinal parasite infections in rural households including farmers, family members, and owned livestock is not well known. One explanation for this limitation is that published research studies have not targeted humans and livestock (together) sharing the same ecosystem or examined health changes in response to different environmental conditions [1–6]. In a previous study, we found that the prevalence of anemia in farmers and family members was high in two geographic locations along the Senegal River in June 2015 (end of the dry season): 74% in Diawara, near the Malian border, and 45% in Mpal, closer to Dakar, the capital city [7]. Furthermore, the prevalence of intestinal parasite infections (Giardia sp) was 7% at the two locations. Anemia was associated with geographic location (Diawara), age (children), or sex (women), but not with intestinal parasite infections. In owned sheep, the prevalence of anemia was 47% and 37% at the two locations, respectively. In addition, the
prevalence of *Haemonchus contortus* was 12% and 9%, respectively. Anemia in sheep was associated with a positive diagnosis of *H. contortus*, a highly pathogenic gastro-intestinal parasite that can cause anemia and death if affected animals are not treated [3,4,8]. Because warm temperature, moisture availability, and pasture conditions can influence free-living stages of soil-transmitted parasites in humans and livestock, we expected that the prevalence of intestinal parasite infections in farmers and family members, and the prevalence of intestinal parasite infections and anemia in owned sheep would be higher during the rainy season, compared to the dry season. The objective of this study was to compare the prevalence of anemia and intestinal parasite infections in farmers, family members, and owned sheep at the two locations along the Senegal River in June (end of the dry season) and September (rainy season).

2. Materials and methods

2.1. Ethical and permit approval

The University of Florida’s Institutional Review Board (protocol # 201400702) and the Institute of Animal Care and Use Committee (protocol # 201408239) approved this study protocol.

2.2. Approach

A one health approach was used to measure and compare the prevalence of anemia and intestinal parasite infections in farmers, family members, and owned sheep in two agro-ecological zones in Senegal in June (end of the dry season) and September (rainy season) in 2015.

2.3. Study sites

The study was conducted on two farms with sheep in Mpal and Diawara, along the Senegal River during 15–26 June 2015 and 1–11 September 2015. The two farms are part of a network of sentinel sites used by the Institut Senegalais de Recherches Agricoles (ISRA) for the early detection of Rift Valley Fever virus infections in animals and people [7]. Mpal is located in the Sant-Louis Region, about 250 km from the capital city of Dakar. The average annual rainfall is about 380 mm, and the rainy season is from late June to early October. Diawara is a remote location in Tambacounda Region, on the Senegal River Valley, near the Malian border; about 700 km from Dakar. The average annual rainfall is about 600 mm, and the rainy season is from early June to October.

2.4. Farmers, family members, and owned sheep

In Diawara, the study sample included 84 family members in June. In September, 63 of the original 84 individuals were tested for anemia. All 84 family members in June and 48 of 63 in September offered stool samples to intestinal parasites. In addition, 56 sheep examined for diagnosis of anemia in June and September were included in the study; 53 of 56 offered paired fecal samples for diagnosis of intestinal parasites.

In Mpal, the study sample included 29 family members in June. Twenty-four of the original 29 family members were tested for anemia in September. All 29 family members in June, and 13 of 29 in September offered stool samples to diagnose intestinal parasites. In addition, 41 sheep examined for diagnosis of anemia in June and September were included in the study; 36 of 41 offered paired fecal samples for diagnosis of intestinal parasites.

2.5. Diagnosis of anemia in humans and sheep

Procedures for diagnosis of anemia were previously reported [9]. In humans, blood samples were tested on-site for diagnosis of anemia as defined by World Health Organization (WHO) guidelines (normal: Hemoglobin (Hb) ≥ 12.0 g/dL; mild anemia: Hb 11.0–11.9 g/dL; moderate anemia: Hb 7.1–10.9 g/dL; severe anemia: Hb < 7.0 g/dL). In sheep, the FAMACHA© system was used to identify sheep affected with clinical anemia [7,10].

2.6. Diagnosis of intestinal parasites in humans and sheep

Procedures for diagnosis of intestinal parasites were previously reported [7]. Briefly, diagnosis of intestinal parasites in human stool samples was performed using the formalin-ethyl acetate sedimentation technique [11]. Two direct smears of fresh feces preserved with Zinc-PVA were prepared from each sample and stained following standard trichrome procedures to identify intestinal protozoa [10]. In sheep, fecal samples were evaluated by centrifugal flotation procedure using Sheather's solution [11]. Samples containing eggs of the family Trichostrongylidae with at least 100 eggs per gram of feces and two grams of remaining feces were further examined for identification of *H. contortus* eggs [12]. *Haemonchus* eggs were visualized by using a peanut agglutinin (PNA) conjugated to fluorescein isothiocyanate and fluorescent microscopy [12]. The PNA binds only *Haemonchus* eggs and not to other trichostrongyles [12]. The reported diagnostic specificity (true negatives) and sensitivity (true positives) of the test is 100% and up to 75–77%, respectively [12].

2.7. Data collection

In humans, the following data were collected from each study subject: study site, the month of testing (June, September), study number identification, age, sex, anemia, and diagnosis of intestinal parasites [7]. In sheep: site, month of testing, ear-tag number, age-class (lamb, adult), sex, body condition score (1.0 = thin to 5.0 = fat), body weight, FAMACHA© score (1–5), and diagnosis of intestinal parasites [7].

2.8. Data analysis

In humans, the prevalence of anemia and intestinal parasite infections in June vs. September were compared using a chi-square test. Body weight (kg) in June vs. September (paired-data) was compared using the Wilcoxon signed rank test. Logistic regression was used to estimate the odds of anemia, as a function of age, sex, and intestinal parasite infection. In sheep, the prevalence of anemia, intestinal parasite infections, and *H. contortus* infections in June was compared to that in September using a chi-square test. The association between anemia and a positive diagnosis of *H. contortus* was tested using a chi-square test. Among sheep that tested positive for *H. contortus* in June or September, body weight in June vs. September was compared using the Wilcoxon signed rank test. Values of $p < 0.05$ were considered significant.

3. Results

3.1. Diawara

3.1.1. Anemia and intestinal parasite infections in humans

The prevalence of anemia was high in June (62/84 or 74%) and remained high in September (47/63 or 75%) ($p = 0.91$) (Fig. 1). In June, cases of anemia were classified as mild (27/62) or moderate (35/62). In September, cases were mild (25/47) or moderate (22/47).

The prevalence of intestinal parasite infections increased from 6/84 (7%) in June to 26/48 (54%) in September ($p < 0.05$) (Fig. 1). *Giardia* sp. was the only intestinal parasite diagnosed in June (6/6), and *Entamoeba coli* was most frequently diagnosed in September (23/26; including three co-infections with *Giardia* sp., *Endolimax nana*, or *Blastocystis hominis*).
3.1.2. Anemia as a function of age, sex, and intestinal parasite infections

Using logistic regression, in June, the odds of anemia were six times higher in children than adults (adjusted OR 6.62; 95% CI = 21.6, 20.29; p < 0.01), after controlling for sex. In addition, the odds of anemia were three times higher in females than males, after controlling for age (aOR = 3.09; 95% CI = 1.00, 9.51; p = 0.04) (Table 1). In September, the odds of anemia remained higher in children than in adults (aOR = 6.19); but the association did not reach statistical significance (p = 0.08). In addition, the odds of anemia remained higher in females than males (aOR = 2.39); but the association was not significant (p = 0.18). Anemia was not associated with intestinal parasite infections in June (p = 0.58) or September (p = 0.73).

3.1.3. Intestinal parasite infections in sheep

The overall prevalence of intestinal parasite infections increased from 40/53 (75%) in June to 53/53 (100%) in September (p < 0.05) (Fig. 2). Mono-infections of *Eimeria* or co-infections of *Eimeria* and tri-chostrongyles were more frequently diagnosed in June (14/40 and 12/40, respectively), and co-infections of *Eimeria* and trichostrongyles were in September (27/53).

3.1.4. *Haemonchus contortus* and anemia in sheep

The frequency of sheep with a positive diagnosis of *H. contortus* increased from 5/53 (9%) in June to 14/53 (26%) in September (p < 0.05) (Fig. 2). In addition, the frequency of cases of anemia in sheep increased from 24/56 (43%) in June to 41/56 (73%) in September (p < 0.05).

The frequency of cases of clinical anemia was higher in sheep that tested positive for *H. contortus* (15/19 or 79%), compared to those that tested negative (48/87 or 55%) (p = 0.05). Among 17 sheep with a positive diagnosis of *H. contortus* in June or September, body weight was lower in September (median = 34.0 kg; first quartile = 29.6, third quartile = 36.8), compared to June (36.4 kg; 31.2, 42.6) (p = 0.08).

3.2. Mpal

3.2.1. Anemia and intestinal parasite infections in humans

The prevalence of anemia was high in June (13/29 or 45%) and in September (26/63). Twenty-one study subjects were excluded because they were not present in September: 17 with anemia (10 females, 7 males) and four without anemia (3 females, 1 male).

**Table 1**

Univariable and multivariable analyses of anemia as a function of age, sex, and intestinal parasite infections in farmers and family members in Diawara in June and September.

| Variable              | Category | n   | OR  | 95% CI | p    | aOR | 95% CI | p    |
|-----------------------|----------|-----|-----|--------|------|-----|--------|------|
| June (n = 84)         |          |     |     |        |      |     |        |      |
| Age (years)           | 20-60    | 26  | 1.00| –      | –    | –   | –      | –    |
|                       | 13-19    | 14  | 3.67| 0.83, 16.26 | 0.08 |
|                       | 5-12     | 29  | 4.80| 1.40, 16.46 | 0.01 |
|                       | 1-4      | 15  | 13.94| 1.72, 112.72 | 0.01 |
| Age (years)           | 20-60    | 26  | 1.00| –      | –    | –   | –      | –    |
|                       | 1-19     | 58  | 5.44| 1.91, 15.51 | < 0.01 |
|                       | 5-12     | 24  | 4.35| 1.15, 17.95 | 0.03 |
|                       | 1-4      | 10  | 8.18| 0.89, 75.26 | 0.06 |
| Sex                   | Male     | 30  | 1.00| –      | –    | –   | –      | –    |
|                       | Female   | 54  | 2.26| 0.84, 6.12 | 0.10 |
| Intestinal parasites  | No       | 78  | 1.00| –      | –    | –   | –      | –    |
|                       | Yes      | 6   | 1.84| 0.20, 16.70 | 0.58 |
| September (n = 63)*   |          |     |     |        |      |     |        |      |
| Age (years)           | 20-60    | 21  | 1.00| –      | –    | –   | –      | –    |
|                       | 13-19    | 8   | 6.36| 0.66, 60.97 | 0.10 |
|                       | 5-12     | 24  | 4.55| 1.15, 17.95 | 0.03 |
|                       | 1-4      | 10  | 8.18| 0.89, 75.26 | 0.06 |
| Age (years)           | 20-60    | 21  | 1.00| –      | –    | –   | –      | –    |
|                       | 1-19     | 42  | 5.45| 1.62, 18.41 | < 0.01 |
|                       | 5-12     | 24  | 4.55| 1.15, 17.95 | 0.03 |
|                       | 1-4      | 10  | 8.18| 0.89, 75.26 | 0.06 |
| Sex                   | Male     | 21  | 1.00| –      | –    | –   | –      | –    |
|                       | Female   | 42  | 1.83| 0.57, 5.90 | 0.30 |
| Intestinal parasites  | No       | 22  | 1.00| –      | –    | –   | –      | –    |
|                       | Yes      | 26  | 0.80| 0.21, 2.99 | 0.73 |

*p < 0.05.

**Anemia:** June, n = 84; September, n = 63.

***Intestinal parasite infections:** June, n = 84; September, n = 48.
remained high in September 12/24 (50%) \((p = 0.70)\) (Fig. 3). In June, cases of anemia were classified as mild \((8/13)\) or moderate \((5/13)\). In September, cases were mild \((5/12)\) or moderate \((7/12)\).

The prevalence of intestinal parasite infections increased from 2/29 \((7\%)\) in June to 33/36 \((92\%)\) in September; but the difference was not significant \((p = 0.16)\) (Fig. 3). *Giardia* sp. was the only intestinal parasite diagnosed in June \((2/2)\) and *E. coli* in September \((3/3)\).

3.2.2. Anemia as a function of age and sex

The odds of anemia were higher in children than in adults in June \((aOR = 3.61)\) and September \((aOR = 5.07)\), after controlling for sex; but these associations were not significant \((p = 0.15\) and \(p = 0.08\), respectively) (Table 2).

3.2.3. Intestinal parasite infections in sheep

The frequency of intestinal parasite infections in sheep increased from 28/36 \((78\%)\) in June to 33/36 \((92\%)\) in September; but the difference did not reach statistical significance \((p = 0.10)\) (Fig. 4). Overall, mono-infections of *Eimeria* or co-infections of *Eimeria* and trichostongyles were most frequently diagnosed in sheep in June \((9/28\) and \(12/28\), respectively) and September \((19/33\) and \(13/33\), respectively).

3.2.4. *Haemonchus contortus* and anemia in sheep

The frequency of sheep with a positive diagnosis of *H. contortus* decreased from 4/36 \((11\%)\) in June to 1/36 \((3\%)\) in September; but the difference was not significant \((p = 0.35)\) (Fig. 4). In addition, the frequency of anemia in sheep increased from 17/41 \((42\%)\) in June to 23/41 \((56\%)\) in September; but the difference was not significant \((p = 0.18)\).

A positive diagnosis of *H. contortus* was not associated with anemia; two of five \((40\%)\) sheep with a positive diagnosis of *H. contortus* were diagnosed with anemia, compared to 34/67 \((51\%)\) sheep with a negative diagnosis \((p = 0.64)\). Among five sheep with a positive diagnosis of *H. contortus* in June or September, body weight was not different \((p = 0.81)\) in June \((median = 31.8\ kg; 24.7, 48.8)\) and September \((32.7\ kg; 24.2, 48.2)\).

4. Discussion

This study provides new information on the burden of anemia and intestinal parasite infections in farmers, family members, and sheep in two agro-ecological zones before and during the rainy seasons in Senegal.

4.1. Diawara

The prevalence of anemia in humans was high in June, remained high in September, and more children and women were diagnosed with anemia, compared to adults and men, respectively. In a previous study, we reported that the most important cause of anemia in Senegal is iron deficiency associated with a diet poor in bioavailable iron, deficiencies of folate, vitamin B12, and vitamin A [1,7]. In addition, we explained that food allocation could be regulated within the family in favor of men and older age groups [7,9,13]. Furthermore, women are at risk of developing iron deficiency due to obligatory iron losses through menstruation [14]. The persistent high prevalence of anemia in June and September justifies assessing the effectiveness of government program efforts to reduce anemia in Diawara (e.g., prevention, access to and consumption of iron-rich foods, appropriate iron supplementation, malaria chemoprophylaxis) [1,15].

In humans, the prevalence of intestinal protozoan parasite infections increased from 7% in June to 54% in September. *Giardia* sp. and *E. coli* were most frequently diagnosed in June and September, respectively.
Giardia and E. coli are enteric protozoans commonly detected in human fecal samples in Senegal and other African countries [16,17]. Giardia sp. and E. coli are both causes of gastrointestinal disorders or diarrhea in humans [18]. Sources of infection include exposure to infected people or animals, or ingestion of water or food contaminated with feces [18,19]. In September, the higher burden of E. coli can be attributed to higher exposure to contaminated water or food during the rainy season. To our knowledge, the burden of intestinal parasite infections in humans has not been investigated and compared under different environmental conditions in Senegal (e.g., dry season vs. rainy season).

In sheep, the prevalence of intestinal parasite infections increased from 75% in June to 100% in September. Among infected sheep, mono-infections of Eimeria or co-infections of Eimeria and trichostrongyles were most frequently diagnosed in June and September. In Senegal, the rainy season offers more favorable environmental conditions that can support the development, survival, and transmission of intestinal parasite infections in sheep. In a recent study in Burkina Faso, the prevalence of intestinal parasite infections in sheep increased from 392/706 or 56% in the cold dry season to 565/682 or 83% during the rainy season; infections with Strongyles or Eimeria were most commonly diagnosed in sheep [19].

In this study, the prevalence of anemia in sheep was higher during the rainy season, and it was associated with a positive diagnosis of H. contortus. Warm temperature, moisture availability, and pasture conditions during the rainy season can play a significant modulating role in the success rate of and speed of development of the free-living phases of H. contortus [20]. In addition, in this study, a positive diagnosis of H. contortus was associated with body weight loss (2.4 kg) in September, compared to June. In another study, body weight gain was 2–7 kg lower in goats experimentally infected with H. contortus, compared to non-infected goats [21]; the authors explained that a significant amount of protein is redirected for the repair of damaged

### Table 2

Univariable and multivariable analyses of anemia as a function of age, sex, and intestinal parasite infections in farmers and family members in Mpal in June and September.

| Variable                | Category | n   | OR  | 95% CI  | p  | aOR  | 95% CI  | p  |
|-------------------------|----------|-----|-----|---------|----|------|---------|----|
| **June (n = 29)**       |          |     |     |         |    |      |         |    |
| Age (years)             | 20–60    | 13  | 1.00|         |    |      |         |    |
|                         | 13–19    | 3   | 1.67| 0.11, 25.40 | 0.71|      |         |    |
|                         | 5–12     | 7   | 4.44| 0.62, 32.05 | 0.13|      |         |    |
|                         | 1–4      | 6   | 16.67| 1.36, 203.92 | 0.02|      |         |    |
| Age (years)             | 20–60    | 13  | 1.00|         |    |      |         |    |
|                         | 13–19    | 16  | 5.56| 1.08, 28.61 | 0.04| 5.07 | 0.80, 32.02 | 0.15|
|                         | 5–12     | 14  | 1.00|         |    |      |         |    |
|                         | 1–4      | 15  | 0.20| 0.04, 0.98 | 0.04| 0.51 | 0.07, 3.48 | 0.20|
| Sex                     | Male     | 13  |     |         |    |      |         |    |
|                         | Female   | 16  |     |         |    |      |         |    |
| Intestinal parasites    | No       | 13  | 1.00|         |    |      |         |    |
|                         | Yes      | 2   |     |         |    |      |         |    |

| **September (n = 24)**  |          |     |     |         |    |      |         |    |
| Age (years)             | 20–60    | 11  | 1.00|         |    |      |         |    |
|                         | 13–19    | 3   | ND  |         |    |      |         |    |
|                         | 5–12     | 6   | ND  |         |    |      |         |    |
|                         | 1–4      | 4   | ND  |         |    |      |         |    |
| Age (years)             | 20–60    | 11  | 1.00|         |    |      |         |    |
|                         | 13–19    | 13  | 6.00| 1.02, 35.33 | 0.04| 5.07 | 0.80, 32.02 | 0.08|
|                         | 5–12     | 11  | 1.00|         |    |      |         |    |
|                         | 1–4      | 13  | 0.36| 0.07, 1.88 | 0.22| 0.56 | 0.09, 3.53 | 0.53|
| Sex                     | Male     | 11  |     |         |    |      |         |    |
|                         | Female   | 13  |     |         |    |      |         |    |
| Intestinal parasites    | No       | 10  | 1.00|         |    |      |         |    |
|                         | Yes      | 3   | ND  |         |    |      |         |    |

* Five study subjects were excluded because they were not present in September: Four with anemia (1 female, 3 males) and one without anemia (female).

** ND = Not determined. There were no study subjects in the age group 1–4 years old diagnosed without anemia.

*** ND. There were no study subjects diagnosed with anemia and intestinal parasite infection, and the number of study subjects who offered a stool sample = 13.

Fig. 4. Prevalence (%) of anemia and intestinal parasite infections in sheep in Mpal in June and September.

*Anemia; June and September, n = 41.

**Intestinal parasite infections and H. contortus infections: June and September, n = 36.

Giardia and E. coli are enteric protozoans commonly detected in human fecal samples in Senegal and other African countries [16,17]. Giardia sp. and E. coli are both causes of gastrointestinal disorders or diarrhea in humans [18]. Sources of infection include exposure to infected people or animals, or ingestion of water or food contaminated with feces [18,19]. In September, the higher burden of E. coli can be attributed to higher exposure to contaminated water or food during the rainy season. To our knowledge, the burden of intestinal parasite infections in humans has not been investigated and compared under different environmental conditions in Senegal (e.g., dry season vs. rainy season).

In sheep, the prevalence of intestinal parasite infections increased from 75% in June to 100% in September. Among infected sheep, mono-infections of Eimeria or co-infections of Eimeria and trichostrongyles were most frequently diagnosed in June and September. In Senegal, the rainy season offers more favorable environmental conditions that can support the development, survival, and transmission of intestinal parasite infections in sheep. In a recent study in Burkina Faso, the prevalence of intestinal parasite infections in sheep increased from 392/706 or 56% in the cold dry season to 565/682 or 83% during the rainy season; infections with Strongyles or Eimeria were most commonly diagnosed in sheep [19].

In this study, the prevalence of anemia in sheep was higher during the rainy season, and it was associated with a positive diagnosis of H. contortus. Warm temperature, moisture availability, and pasture conditions during the rainy season can play a significant modulating role in the success rate of and speed of development of the free-living phases of the lifecycle of H. contortus [20]. In addition, in this study, a positive diagnosis of H. contortus was associated with body weight loss (2.4 kg) in September, compared to June. In another study, body weight gain was 2–7 kg lower in goats experimentally infected with H. contortus, compared to non-infected goats [21]; the authors explained that a significant amount of protein is redirected for the repair of damaged
tissues, the synthesis and production of immunoglobulin and reducing the amount of protein deposition in the muscles, leading to body weight reduction.

4.2. Mpal

Similar trends of anemia and parasite infections observed in Diawara were observed in Mpal, except that women in Mpal were not at higher risk of anemia than men after controlling for age. In a previous study, we reported that socio-economic conditions in Mpal are more favorable [7]. The average annual income per household is 2–3 times higher in regions close to Dakar, the capital city, compared to those in more remote areas. Contributing factors that affect remote communities in Senegal include poor road infrastructure, difficult market access, and fewer opportunities for household income diversification outside farming.

4.3. Study limitations

Study results reported here apply to the two study sites in Diawara and Mpal, but they cannot be extrapolated to all farms in the two study regions: Tambacounda (Diawara) and Sant-Louis (Mpal). The study sample in Mpal was small, a situation that prevented higher frequencies of parasite infections in humans and sheep in September, compared to June, to be declared as statistically significant. Finally, funding limitations affected our capacity to examine the association between anemia and malaria in farmers and family members.

4.4. Conclusions

In humans, the prevalence of anemia was high in June (end of the dry season) and remained high in September (rainy season). In Diawara, the burden of anemia was higher in children and women than in adults and men, respectively. The prevalence of intestinal parasite infections was higher in September, compared to June. A positive diagnosis of intestinal parasite infection was not associated with anemia.

In sheep, the prevalence of anemia and intestinal parasite infections was higher in September, compared to June. In addition, anemia was associated with a positive diagnosis of *H. contortus*.

4.5. Policy options

These study results justify an assessment of the effectiveness of government program efforts to reduce anemia in children and women, and morbidity and mortality in owned sheep in rural households, with emphasis on control and prevention of *H. contortus* infections. Another option is to advocate for a One Health approach to improve the health of farmers, family members, and owned livestock in rural Senegal. For example, Senegal’s ministries of health and of agriculture can consider sharing resources for implementation and evaluation of government program efforts to reduce anemia in children and women, as well as morbidity and mortality in owned livestock in rural households; particularly in remote areas where public health services and veterinary services are very limited.

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CRediT authorship contribution statement

Heather D.S. Walden: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision. Modou Moustapha Lo: Investigation, Resources, Writing – review & editing, Supervision. Fiona P. Maunsell: Investigation, Methodology, Data curation, Writing – review & editing, Supervision. Khadija Fall Traore: Investigation, Methodology, Data curation, Resources, Supervision. Sarah Reuss: Investigation, Methodology, Writing – review & editing, Supervision. Alyson Young: Investigation, Methodology, Writing – review & editing. Jorge A. Hernandez: Conceptualization, Investigation, Methodology, Software, Validation, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare no competing interests.

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